PROGRAM 2 **SESSION**

Richard Doyle, Soil CRC Program Leader	Program 2 Overview
Marcus Hardie University of Tasmania	'Smart' soil sensors
Peter Dahlhaus Federation University	Visualising Australasia's Soils
Pauline Mele Agriculture Victoria	Bioindicators of high performing soils: A design and validation framework for in-field applications
Caroline Mohammed University of Tasmania	Smelling soil
Pierre Roudier Landcare Research New Zealand	Novel sensor technology to measure and map soil nutrients, water and hydraulic characteristics
Liang Wang University of Newcastle	Affordable approaches to rapid field test soil chemical properties

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PROGRAM 2
SOIL METRICS

DOYLE

Performance through collaboration

Hi PERFORMANCE SOIL ?

- Profitable
- Resilient
- Adsorbing
- Transforming
- Staying-put

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KEY SOIL FUNCTIONS

- Habitat and biodiversity
- Water movement and availability
- Filtering and buffering
- Nutrient cycling
- Physical stability and support
- Long-term C stabilization

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PROGRAM 2

PERFORMANCE METRICS

- Define key indicators
- Develop useful metric and sensors
- Undertake smart data analytics
- Visualise outputs/responses for farmers
- Education + training → next generation farm innovators

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SO FAR…………….

SCOPING

1. Indicators of HPS (Dahlhaus)

2. Smart sensor options for HPS (Hardie/Bennett)

Further summation and formal publication; on-going

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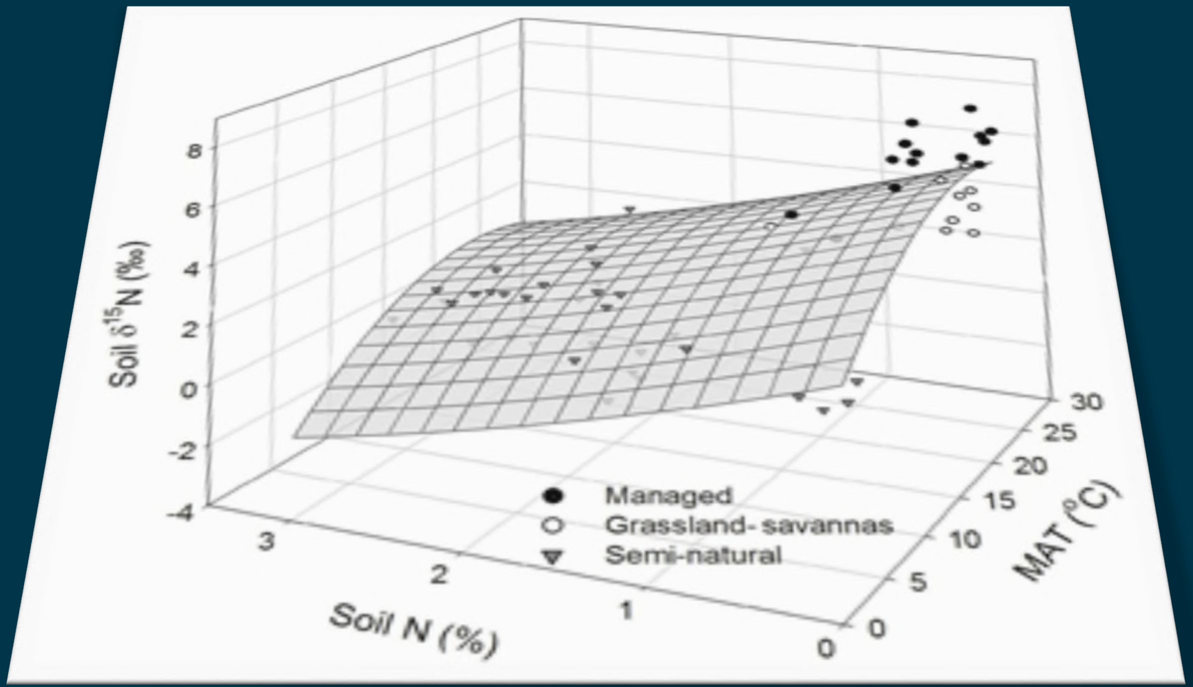
KEY MESSAGES FROM SCOPING

- The usefulness of any *indicator*, or suite of indicators, can only be truly evaluated within the context of the business operation and the impacts of management decisions.
  - Horses for courses..........

- Range of potentials sensor technologies is immense; but in the order physical – chemical – biological
  - We must carefully decide, deliver and ensure adoption

RAAP

1. C and N isotopes measures to track SOM function (Wells)
2. N15 tracked climate more strongly while C13 tracked human soil management more strongly



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PROGRAM 2 - NEW PROJECTS

1. Indicators & sensor nexus (Mele + scoping studies)

2. New sensors
   1. Water (Hardie)
   2. Wet chemistry (Lobsey, Wang)
   3. Gas chemistry (Powell)

3. Data analytics
   1. Water (~Hardie)
   2. Biology + chemistry (Mele)

4. Data visualisation (Dahlhaus)

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SMART SOIL SENSORS

- Smart shovel – moisture mapper
- Self-learning moisture sensors
- Below ground sensor communication

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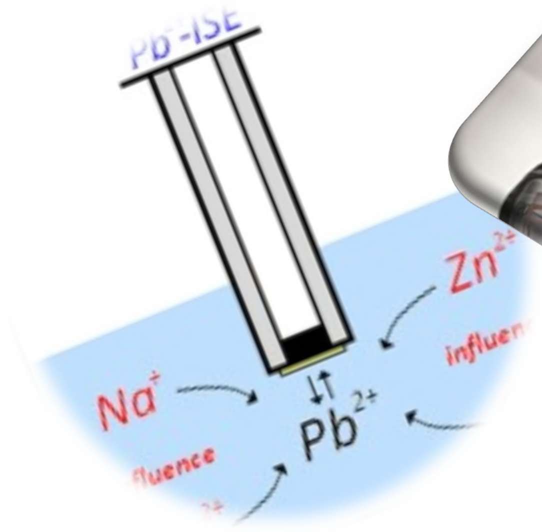
FIELD CHEMICAL SENSORS

- Ion selective electrodes – taking them to the field
- Correlations to other field technologies -- EM



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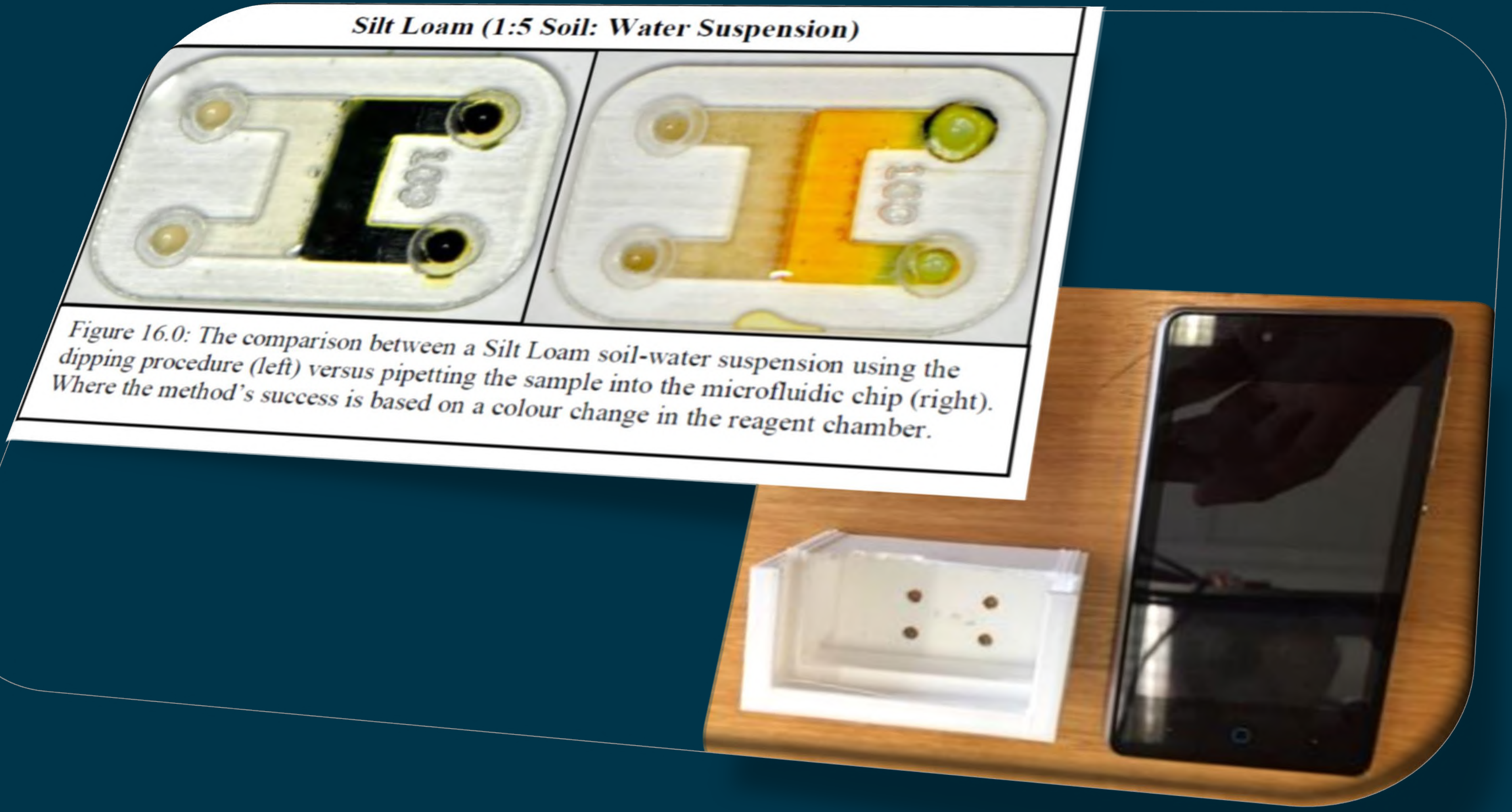
(SOIL) LAB ON A CHIP



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SMELLING SOIL

- Test existing sensors in heathy to poor soils
- Link data to DNA analysis of soils

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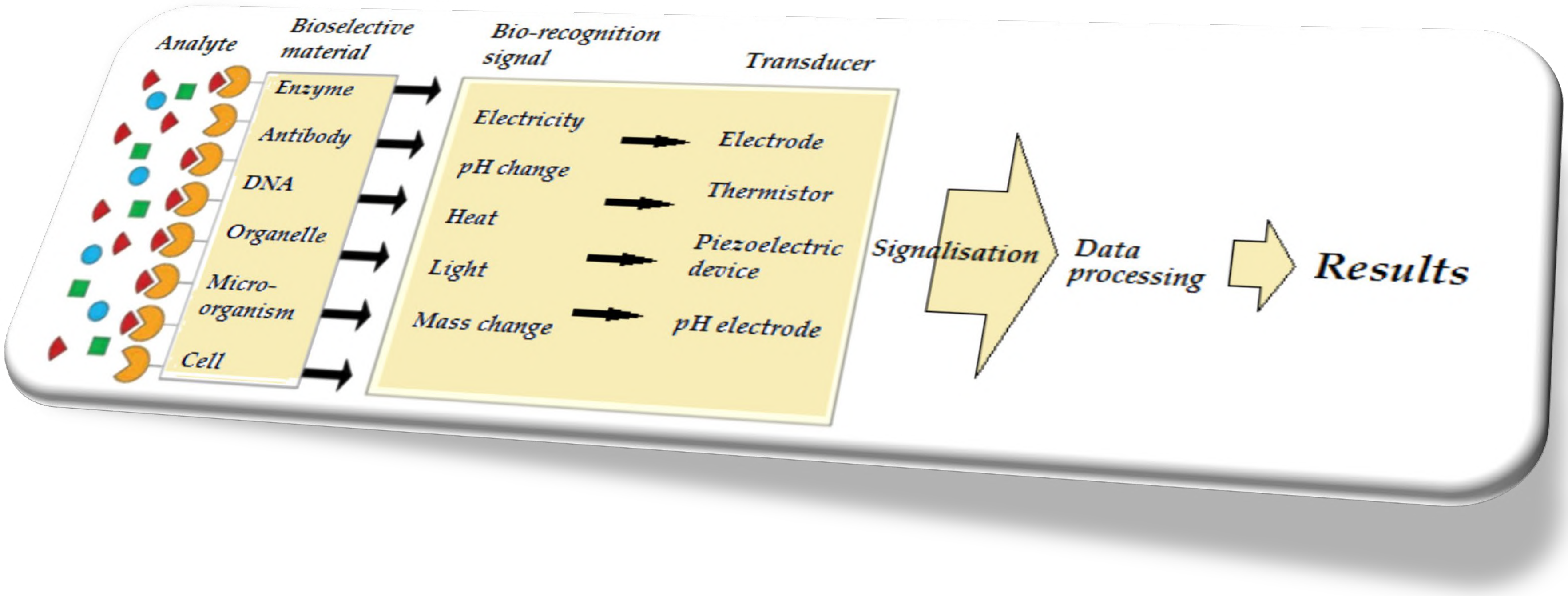
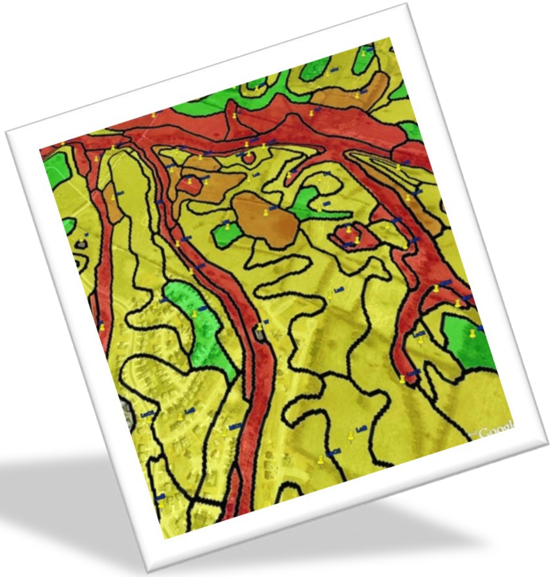
SOIL MICROBE FUNCTIONALITY

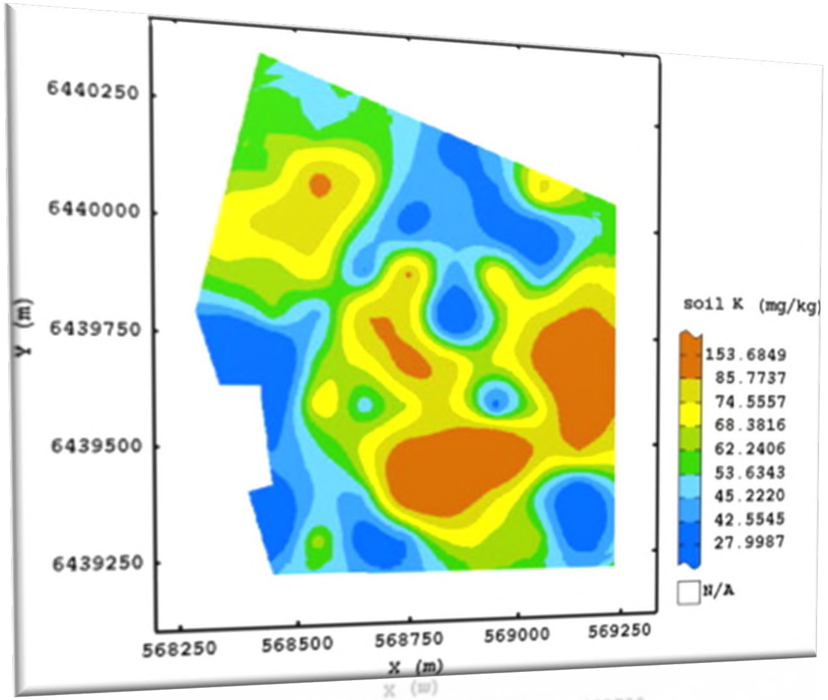
Chemical and physical data
DNA analysis of microbes
MIR calibrations



DATA VISUALIZATION

- Visualising Australian Soils (Dahlhaus)
  - Data access portal





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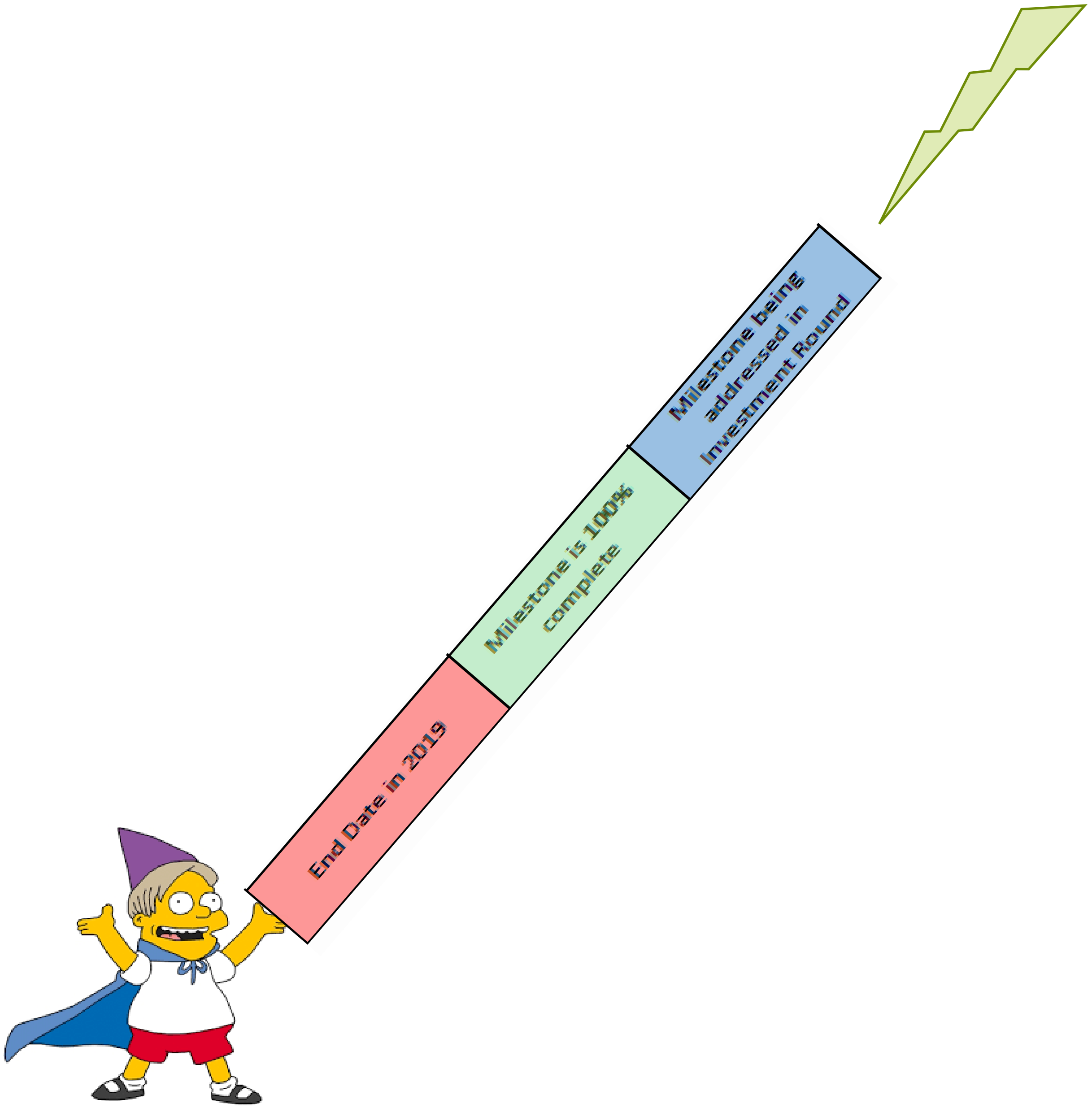

PROGRAM 2

Milestone	Title	Start Date	End Date	% Complete Q1 2019	17-1	18-1	18-2	18-3
2.1.1	Establish steering committee	1/07/2017	30/12/2017	100%				
2.1.2	Review and develop soil health and function indicators	1/01/2018	30/06/2019	90%				
2.1.3	Soil health and function indicator metrics	1/01/2018	30/12/2020	55%				
2.1.4	Soil indicator relationships and interdependencies	1/01/2018	30/06/2022	11%				
2.1.5	Novel soil assessment methods and metrics	1/01/2018	30/12/2025	11%				
2.1.6	Rapid testing field based tool kit	1/01/2020	30/12/2026					
2.1.7	Key indicator targets & guidelines in a framework for use	1/01/2020	30/03/2027					
2.2.1	Establish steering committee	1/07/2017	30/12/2017	100%				
2.2.2	Review and scope proximal & remote sensing technologies	1/01/2018	30/12/2018	100%				
2.2.3	Proximal sensor development or enhancement	1/01/2018	30/12/2025	9%				
2.2.4	Lab on a chip	1/01/2018	30/12/2025	10%				
2.2.5	Mapping Sensors	1/01/2019	30/12/2020					
2.2.6	Novel sensor mapping technologies	1/01/2020	30/12/2022					
2.2.7	Commercialisation approaches	1/01/2025	30/03/2027					
2.3.1	Establish steering committee	1/07/2017	30/12/2017	100%				
2.3.2	Workshop soil sensory data	1/10/2017	30/06/2018	100%				
2.3.3	Storage and access sensed data capacity	1/01/2018	30/12/2020	13%				
2.3.4	New approaches for server based analysis of sensed data	1/01/2018	30/12/2025	6%				
2.3.5	Analysis of HPS data for soil metrics	1/01/2022	30/03/2027					
2.3.6	Visualisation of soil metric data	1/01/2022	30/03/2027					
2.4.1	Establish steering committee	1/07/2017	30/06/2018	100%				
2.4.2	Human interface technology preferences	1/01/2018	30/12/2020	6%				
2.4.3	Configuring/enabling existing soil-crop models and codes	1/01/2018	30/12/2025	5%				
2.4.4	Machine learning approaches developed and tested	1/01/2018	30/12/2025	4%				
2.4.5	Grower focussed mobile tools using server based data	1/01/2018	30/12/2025	4%				
2.4.6	Grower feedback	1/01/2020	30/03/2027					

KEY FUTURE PROJECT NEEDS?

- New/more sensors……………?
- Deeper farmer/group engagement – whys, whats and hows
- Smart data analytics; using soil reliable data streams…..machine/environmental learning?
- Credible visualisation to enable wise decision making – trusted voice!

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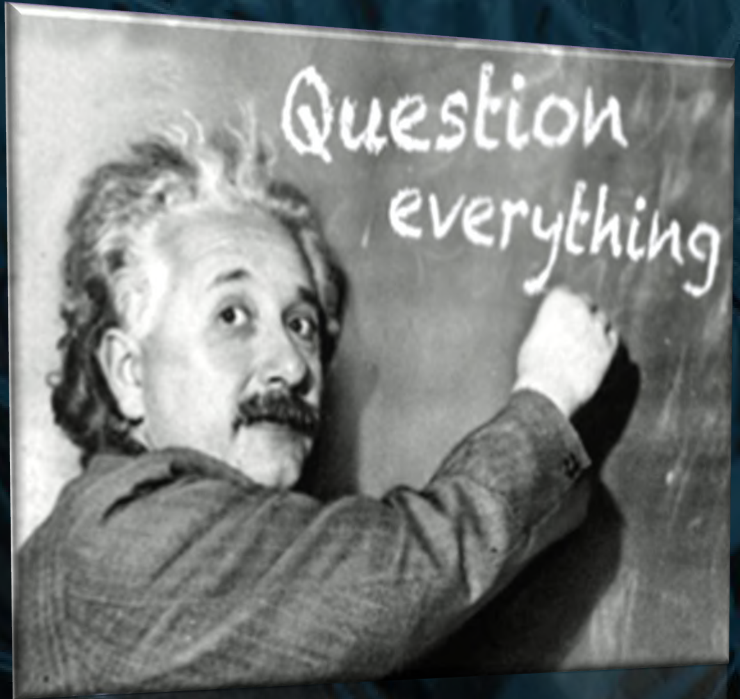

………well…………time for 2 (two)

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SMART SOIL SENSORS
MARCUS HARDIE
UTAS / TIA / SENSE-T

3 April 2019

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PROJECT TEAM

Marcus Hardie	Soil Physics	UTAS Tasmanian Institute of Agriculture
Caroline Mohammed	Systems Research	UTAS Tasmanian Institute of Agriculture
Stephen Cahoon	Director Sense T	UTAS Tasmanian Institute of Agriculture
Simeon Edwards	Research Engineer	UTAS / Sense T
Warrick Gillespie	Research Engineer	UTAS / Sense T
Mike Manion	Research Engineer	UTAS / Sense T
Post Doc	Research Engineer	UTAS / Sense T
Post Doc	Research Engineer	UTAS / Sense T
Byeong Kang	AI and ML	UTAS ICT
John Bennet	Soil Physics	USQ
Roy Anderson	Spatial analysis	USQ
Joarder Kamruzzaman	Sensor Networks	Federation
PHD (Darren West)	Machine Learning	UTAS
PHD	Wireless Comms.	Federation

BACKGROUND

- The 'Smart' Shovel: Grower have told us they have gone back to walking the paddock with a shovel. We will build them a better shovel, with soil moisture, and salinity sensors, with data mapped and visualized through smart phones whilst in the paddock.
- Below Ground Sensor Data Transmission. Growers are frustrated with the hassle of in-field sensors. We will develop the ability to send sensor data wirelessly through soil, without risk of damage from stock, pests or machinery.
- Self-learning moisture sensors. We will develop algorithms that use existing soil moisture sensors to learn soil properties needed for use with models such as APSIM, and enable growers to relate moisture content to crop stress.

Prototype buried sensor system

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PROJECT ACTIVITIES

- Smart Shovel
- Buried Data Comms.
- Self learning moisture probes

Grower Meeting 1
- What
- How
- Why

Prototypes developed

Grower Meeting 2
- Validate
- Est. field trials

Refine Prototypes & Software

Grower Meeting 3
- Report field trials

Refine Prototypes & Software

Pre commercialisation prototype

Project 2 Commercialisation

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ENGAGEMENT AND COLLABORATION

Grower Groups

- Burdekin Productivity Services
- Southern Farming Systems
- FarmLink
- Landmark
- Riverine Plains
- (Birchip Cropping Group)

VISUALISING AUSTRALASIA'S SOILS

PETER DAHLHAUS
FEDERATION UNIVERSITY AUSTRALIA

3 April 2019

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PROJECT TEAM

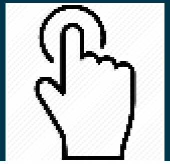
- FedUni: Dahlhaus, MacLeod, Robinson, Simons, Thompson, Wills, Wong
- MWLR: Medyckyj-Scott, Ritchie
- USQ: Bennett, Pembleton
- UTAS: Cahoon, Doyle, Gillespie

- 15 partners from Soil CRC participants

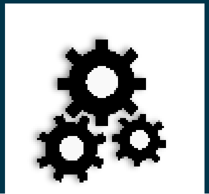
BACKGROUND

Project Aim: Establish a **soil research data federation**, based on agreed data stewardship and governance frameworks, that allows Australasian soils data from all sources (private and public), to be discoverable to all Soil CRC participants through an intuitive-to-use internet portal.

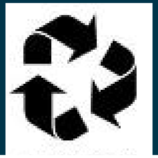
Findable



Accessible



Interoperable



Reusable

= FAIR data

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PROJECT ACTIVITIES

Focus on a clear case to make this a fundamental foundation activity in the Soil CRC, i.e.

- A working portal with farmer group / industry group data across Australia (& New Zealand)
- Groups advocating use of the portal because there is an obvious benefit
- Case studies / examples of the value proposition to farmers / advisors / catchment managers / researchers
- Value add to data, for example by showing trends

- Kick-off meeting ✓
- Establish Steering Committee ✓
- Project Governance and Data Stewardship frameworks ✓
- Establish pilot portal with open data from Australia and New Zealand ✓
- Engage with early adoption project partners to share soil data in the federation ✓

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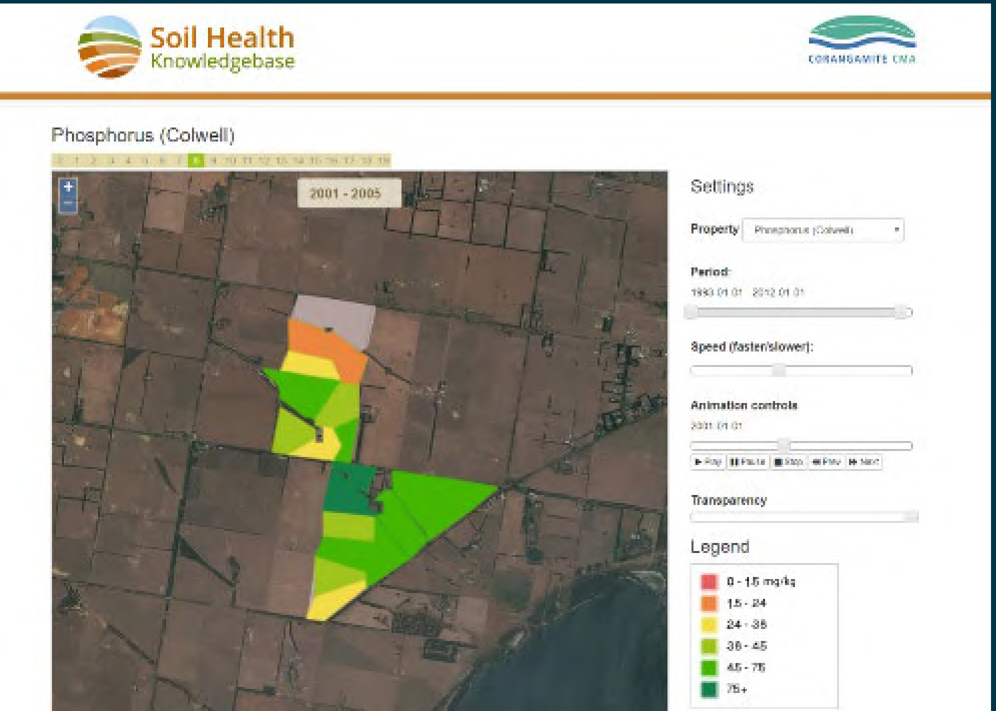
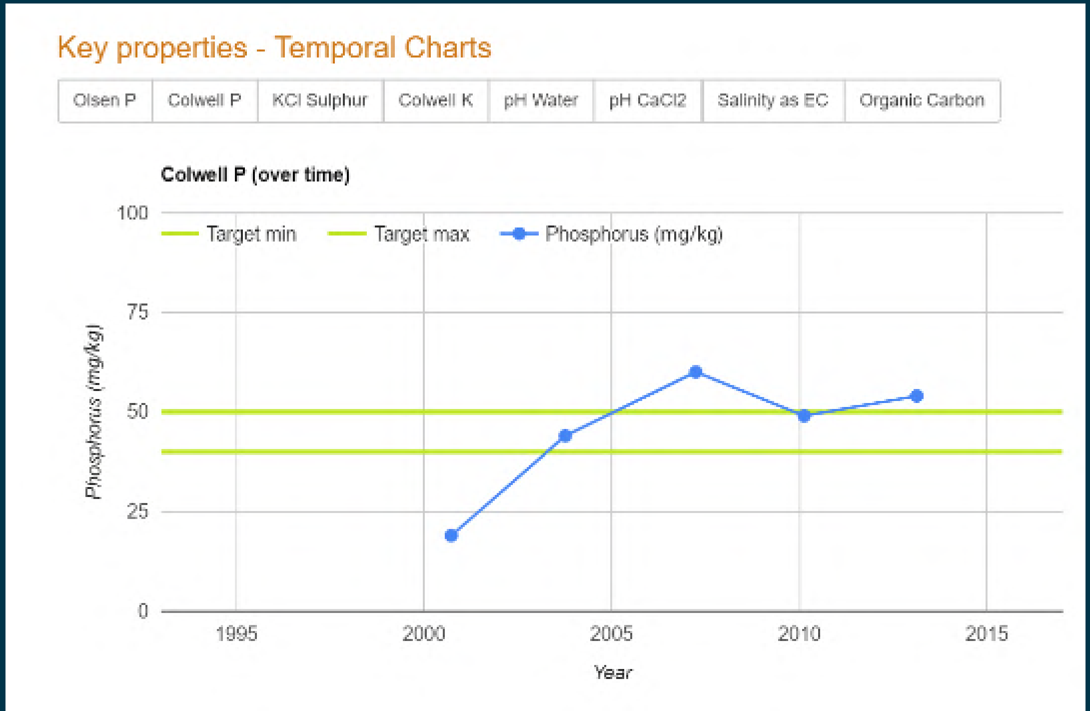
ENGAGEMENT AND COLLABORATION

- Do you have a clear need to access soil data?
- Do your group members want to see the soil data for their location?
- Does your organisation have soils data that could be visualised?
- Are you leading a Soil CRC project that is collecting data?
- Are you involved in a Soil CRC project that needs to access data in particular formats?





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BIOINDICATORS OF HIGH PERFORMING SOILS: A DESIGN & VALIDATION FRAMEWORK FOR IN-FIELD APPLICATIONS (JULY 2019-JUNE 2022)

PROJECT LEADER: PAULINE MELE

AGRICULTURE VICTORIA

CALL 18-3

2018 MAJOR INVESTMENT ROUND 2

3 April 2019

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PROJECT TEAM

Partner groups:

Southern Farming Systems (SFS)- Lisa Miller & Jon Midwood

North Central CMA (NCCMC)- Felicity Harrop

Birchip Cropping Group (BCG)- Cam Taylor

Wimmera CMA (WCMA)- Joel Boyd

Other groups:

Glenelg Hopkins CMA (GHCMA)- Richard Murphy

Perennial Pasture Systems (PPS)- Rob Shea

Research :

Federation University (18.3.2.1)- A/Prof Peter Dahlhaus, Kathy Gamble, Scott Limmer, Andrew Macleod, A/Prof Helen Thompson, Dr Nathan Robinson, Bruce Simons, A/Prof Peter Vamplew, Dr Benjamin Wills, Dr Megan Wong & PhD candidate (tba)

Agriculture Victoria (18.3.2.6)- Melissa Cann/Rebecca Mitchell, Dr Helen Hayden, Mark Imhof, Matt Kitching/Bruce Shelley, A/Prof Pauline Mele,

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ENGAGEMENT AND COLLABORATION

- Soil CRC & land holder partners **to develop & implement communication plan**
- Soil CRC landholder & research representatives from relevant Farmer Groups, CMAs and key CRC-Soil Programs/projects **to establish project advisory group**
- Nicon Rural & Cameron Nicholson (strong linkage to SFS & NLP2 projects) **to explore access to instrumented sites**
- Soil CRC project 'Carbon functionality & Regenerative Agriculture: a co-innovation approach appraising soil performance and multi- outcome farming systems' (Dr Gwen Grelet, Manaaki Whenua Landcare Research, PIRSA, Soils for Life and Wheatbelt NRM)
- Soil CRC project 'Smelling Soil: Novel electronic noses for mobile in-field determination of microbial health, diversity and function.' (UTas, Shane Powell)
- Soil CRC project 18.2.1 'Visualising Australasia's Soils: A Soil CRC interoperable spatial knowledge system' (Federation university, A/Prof Peter Dahlhaus)
- Producer groups, producers, consultants, service providers and advisers in the agriculture value chain, particularly those involved in the grains industry
- Potential investors such as RDCs, agribusiness & commercial partners particularly those associated with soil measurement
- Bioplatforms Australia (Australian microbiomes); The Australian biodiversity sensor network (ABSNET; Michael Lidell, JCU)
- PhD candidates
- Modellers & Policy makers (ie SOE)

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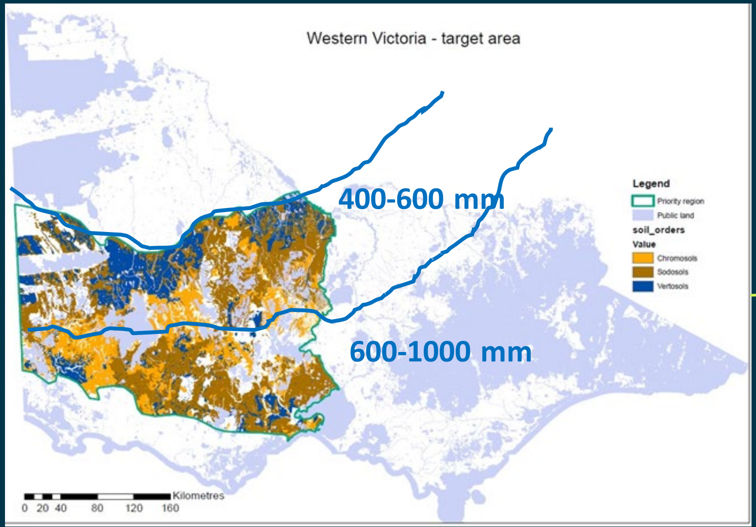
BACKGROUND

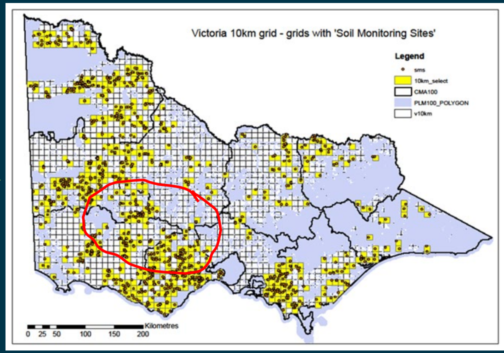
- Addressing soil-based limitations to plant performance can achieve an 80% improvement in productivity (Sale et al. 2016) yet…
- Only a quarter of Australian farmers conduct soil testing, with a strong focus on macro-nutrients (N and P) and pH (Lobry de Bruyn & Andrews 2016)
- Biological functions including nutrient (N & C) cycling, disease suppression, structural maintenance <u>underwrite</u> soil performance and are <u>central</u> in soil monitoring for performance improvements. These features may provide a vital metric to guide improvement of low performing soils and to maintain high performing soils yet……
- Biological functions are not routinely measured (considered tier 2 &3 by Soil Health Institute) & are usually defined by their physico-chemical and biological microenvironment
- This proposal addresses 2 priorities; it defines thresholds for a limited subset of existing & emerging soil health indicators and it identifies biological metrics that 'meet the needs of users and are defined in the context in which they are applied' (Dahlhaus et al. 2018); the important context is…..
- Cropping regions in western Victoria have been targeted because they have the largest yield potential gap in Australia (1.6 and 3.0 t/ha for wheat; http://yieldgapaustralia.com.au).

PROJECT ACTIVITIES

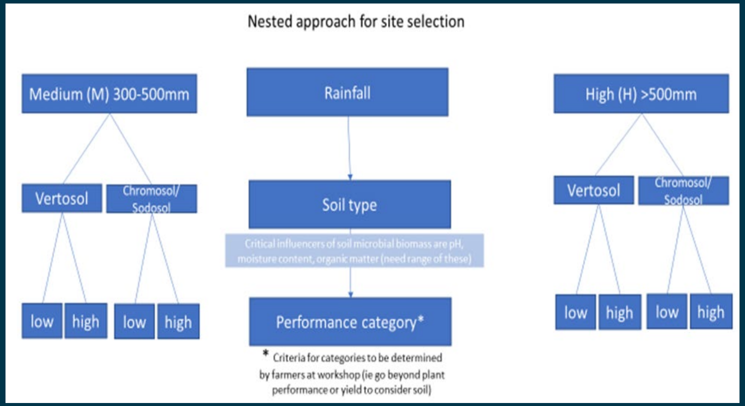
- Sites[1] selected in defined target area based on rainfall/soil geomorphology/instrumentation

[1] defined by partners as low and high production sites





data grid (10 x 10 km)



- Biological[2] (existing*, emerging, novel), spectral[2] (MIR/NIR) and sensor[2] (temperature, moisture) collected at defined scale; * incl. commercial kits

[2] selected to align with other CRC projects (Grelet, Powell, Dahlhaus)

- Integration of biological, spectral and sensor data for developing algorithms for models & maps

  (PhD student focus)

- Develop thresholds & models (for simulator) using existing (mainly chemical & physical) & new data (biology & real-time physical) data

  (PhD student focus)

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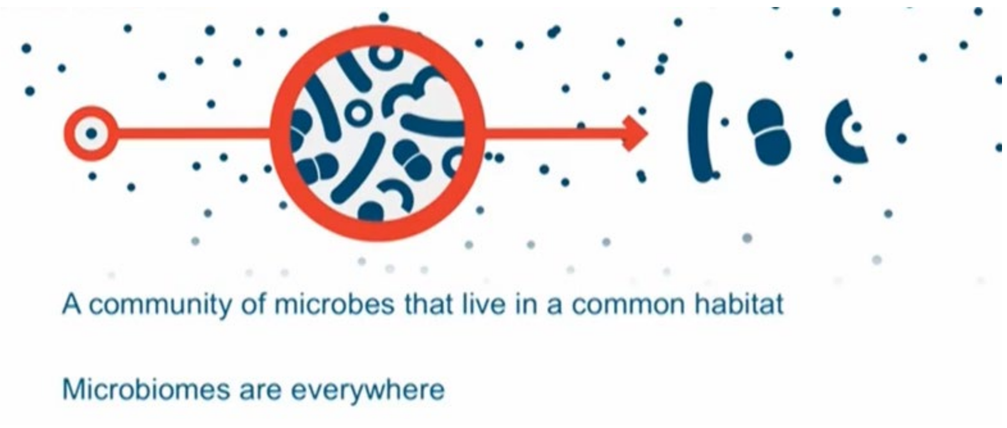
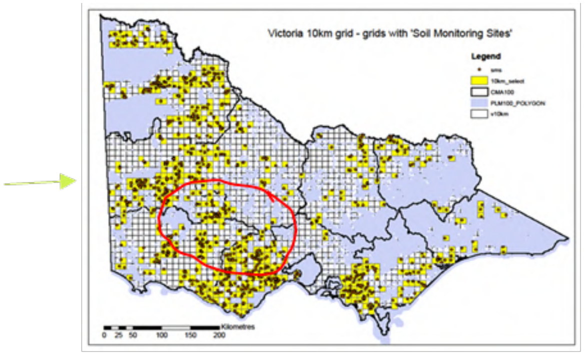
What is a (micro)biome?



We define our habitat by soil type, annual av rainfall & production



data grid (10 x 10 km)

We choose our bioindicators from the biome that live in this 'habitat'

Measure (biology)	Method*	Measure metadata	Field applied sensors & MIR platforms*
Microbial Biomass	Commercial: Biolog & microresp	Chemistry- pH, N, C, P, K, redox potential	Temperature & moisture
Earthworm & nematode species abundance	NGS- genotyping	Structure- particle size, porosity, aggregate stability, bulk density	MIR spectra (hand held) & predicted physico-chemical properties
Microbial Community structure, diversity	NGS- genotyping (16S/ITS rRNA; WGS) qPCR groups	Ecology/pedology- moisture, temperature, ground cover, soil characterisation	NIR spectra (hand-held)
Microbial community function, diversity	NGS- WGS Metametabolomics	Management-cropping regime, plant performance	

* What is used now? What emerging technology is available? (workshop after July 2019)

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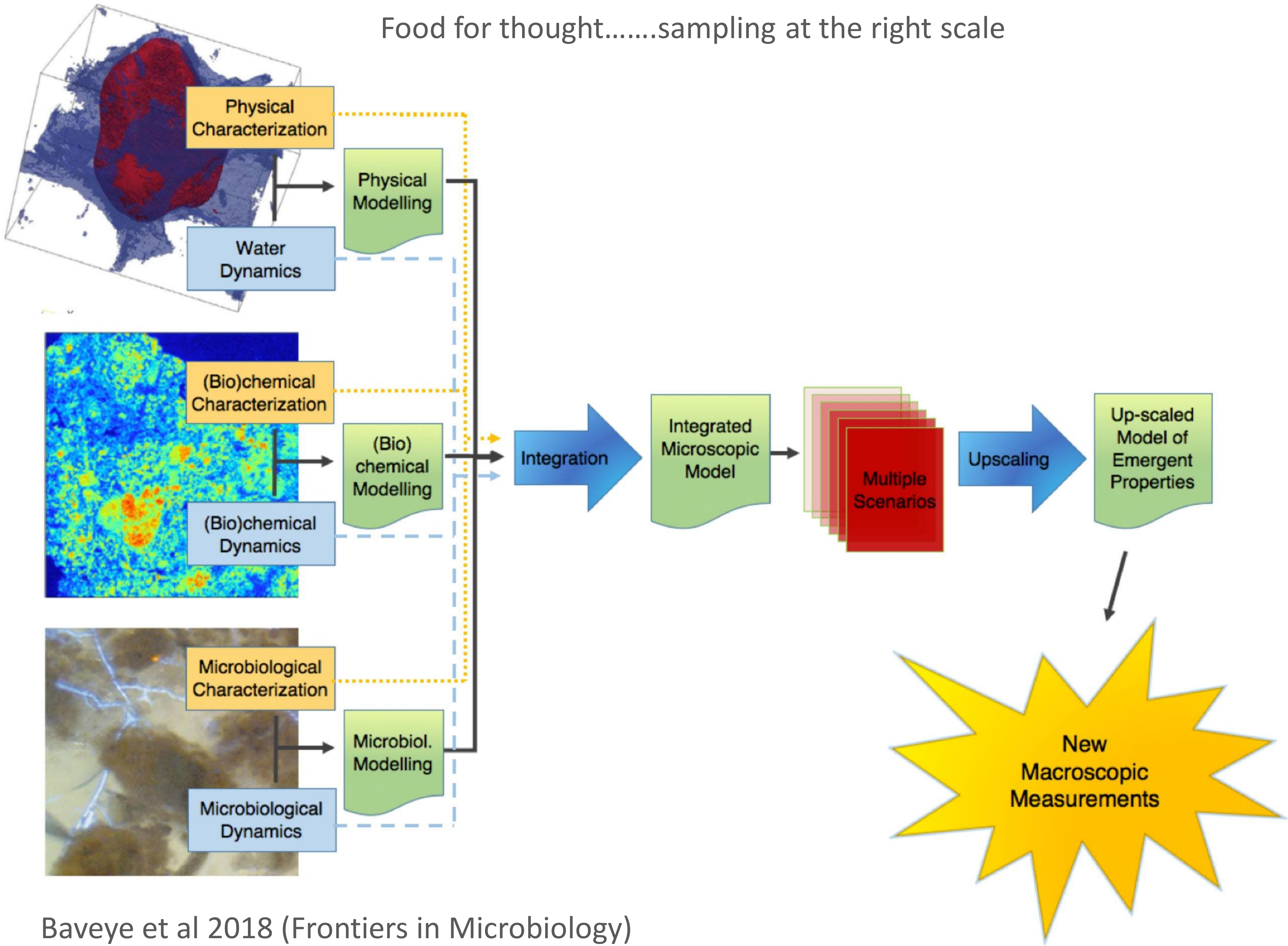
Food for thought.......sampling at the right scale



Baveye et al 2018 (Frontiers in Microbiology)

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SMELLING SOIL: NOVEL ELECTRONIC NOSES FOR MOBILE IN FIELD DETERMINING MICROBIAL HEALTH, DIVERSITY AND RESILIENCE

SHANE POWELL
UNIVERSITY OF TASMANIA
KATHERINE EVANS, MARCUS HARDIE, JOHN BOWMAN, ROSS CORKREY, CAROLINE MOHAMMED

SOUTHERN FARMING SYSTEMS
FARMLINK RESEARCH LIMITED
BIRCHIP CROPPING GROUP INC
SOILS FOR LIFE

3 April 2019

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BACKGROUND

"Proof of life" for an eNose which can measure, monitor and evaluate soil microbial health

- The use of an electronic nose (E-nose) is potentially one of the most feasible technologies to provide a quantitative, in-field and low cost system to distinguish soil health using gases produced by soil bacteria (aroma).

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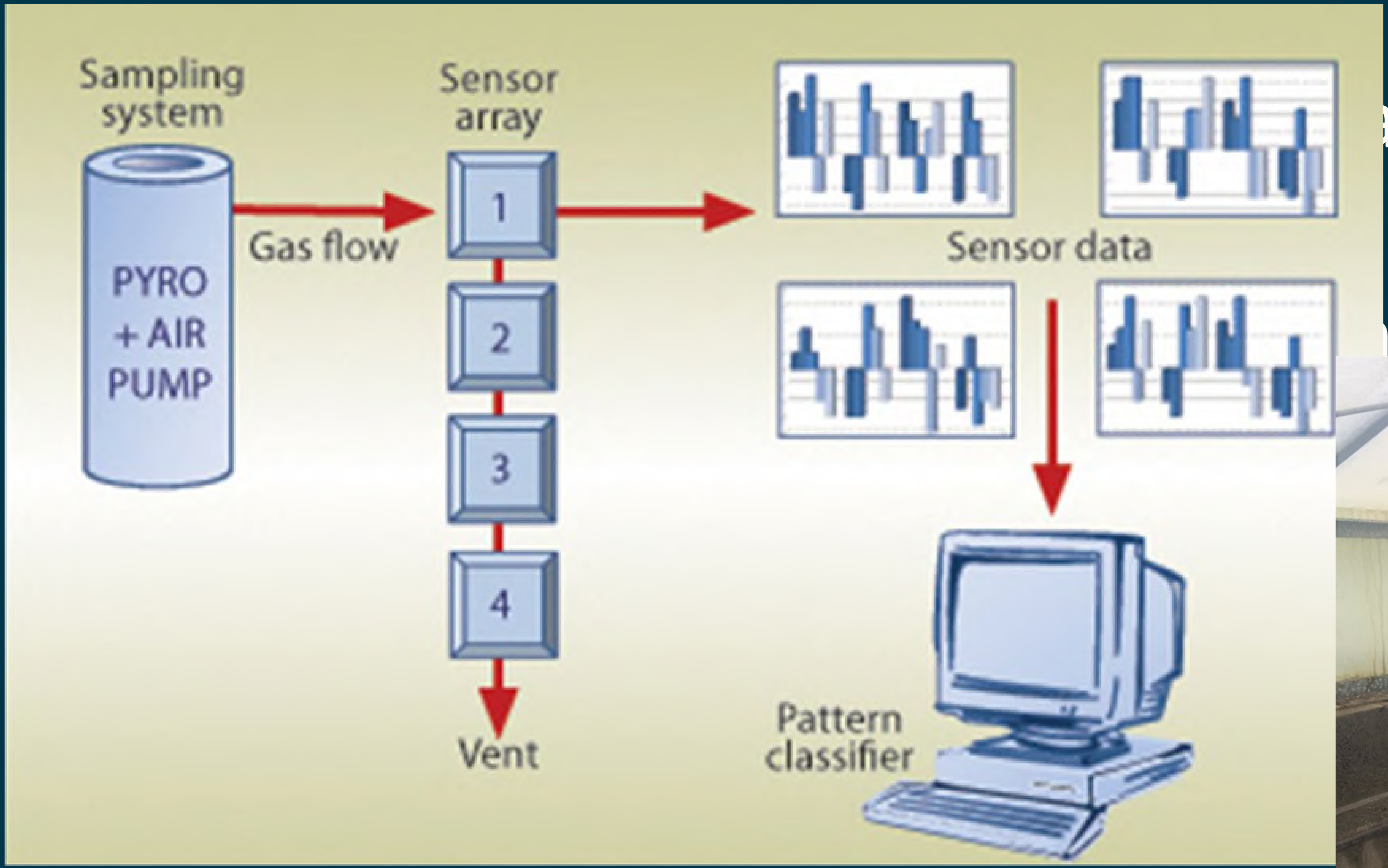
BACKGROUND



(Source: National Research Council Canada, 2014)

an measure, monitor

nose) is potentially

PROTOTYPE DEVELOPMENT

- Existing sensors we plan to use include; carbon monoxide, carbon dioxide, sulphur dioxide, hydrocarbons, ammonia, organic solvents, nitrogen dioxide, ethylene, and nitric oxide. These sensors range in cost from $40-$400 and are all currently available
- We aim to exploit the cross sensitivity of these sensors to create a signature of soil aromas. The tool will also include basic environmental monitoring capability (soil moisture, pH and temperature; air temperature and humidity)

ENGAGEMENT AND COLLABORATION

Approach

- **Industry and next-user** guided
- **Systems & outcome focus,** rather than a product approach
- Problem focused or **Pull technology**
- **De-risk** technology deployment

Systems PULL Approach

What Decision ? → Information → Data → Select Technology → Domain knowledge

Clarity of purpose: *"what problem are we trying to solve"*

tia TASMANIAN INSTITUTE OF AGRICULTURE

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ACTIVITIES SUMMARY

- Find out what end and next users require from an eNose
- Develop prototype eNose that uses a low-cost sensor array and can detect aromas emitted from soils
- Correlate eNose response with specific gas emissions and microbial activity
- Field test using the prototype eNose

NOVEL SENSOR TECHNOLOGY TO MEASURE AND MAP SOIL NUTRIENTS

CRAIG LOBSEY
USQ

3 April 2019

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PROJECT TEAM

- Craig Lobsey (University of Southern Queensland)
- **Pierre Roudier (Manaaki Whenua Landcare Research)**
- John Bennett (University of Southern Queensland)
- Carolyn Hedley (Manaaki Whenua Landcare Research)
- Ravinesh Deo (University of Southern Queensland)
- Yingcan Zhu (University of Southern Queensland)
- Jaye Hill (PhD Student, University of Southern Queensland)
- Lawrence Di Bella (Herbert Cane Productivity Services)
- Rob Milla (Burdekin Productivity Services)
- Michael Sefton (Burdekin Productivity Services)
- David West (University of Southern Queensland)

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BACKGROUND

- It is difficult to monitor soil nutrients (e.g. nitrogen) due to their high spatio-temporal variability (in three dimensions).
- It is difficult to manage these nutrients due to their mobility (or lack thereof) through the soil profile.
- Nutrient management requires understanding not just current nutrient status but also soil nutrient supply and dynamics under different rainfall and irrigation scenarios.
- Soil sensor technology can provide this understanding and enable greater confidence in nutrient management and optimisation.
- In this project we aim to develop the enabling sensor technology that will provide;
    i. Low cost, rapid and in-field assessment of soil chemical and nutrient status.
    ii. More efficient measurement and mapping of soil water and hydraulic properties that determine nutrient mobility through the soil profile.

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PROJECT ACTIVITIES

- Develop and evaluate integrated electrochemical sensing technology that will enable low cost and rapid assessment of soil chemical properties (e.g. nitrate, potassium, phosphate, sodium and pH).
- Develop the algorithms and techniques combining spatio-temporal electromagnetic induction (EMI) surveys, inversion modelling and open access remote sensing to improve estimates and mapping of soil water and hydraulic properties.
- Develop automated sensor based measurement of soil water retention curves enabling more efficient, accurate and high throughput sample characterisation in the laboratory.

ENGAGEMENT AND COLLABORATION

- Sensor development and evaluation will occur in the Herbert and Burdekin cane regions (QLD) and NZ.
- This is supported by project collaborators Herbert Cane Productivity Services Limited (HCPSL) and Burdekin Productivity Services (BPS).
- We will be developing datasets (EMI) and laboratory instrumentation for soil hydraulic characterisation.
- We will be developing sensors, algorithms and data that can support model development, parameterisation and application.

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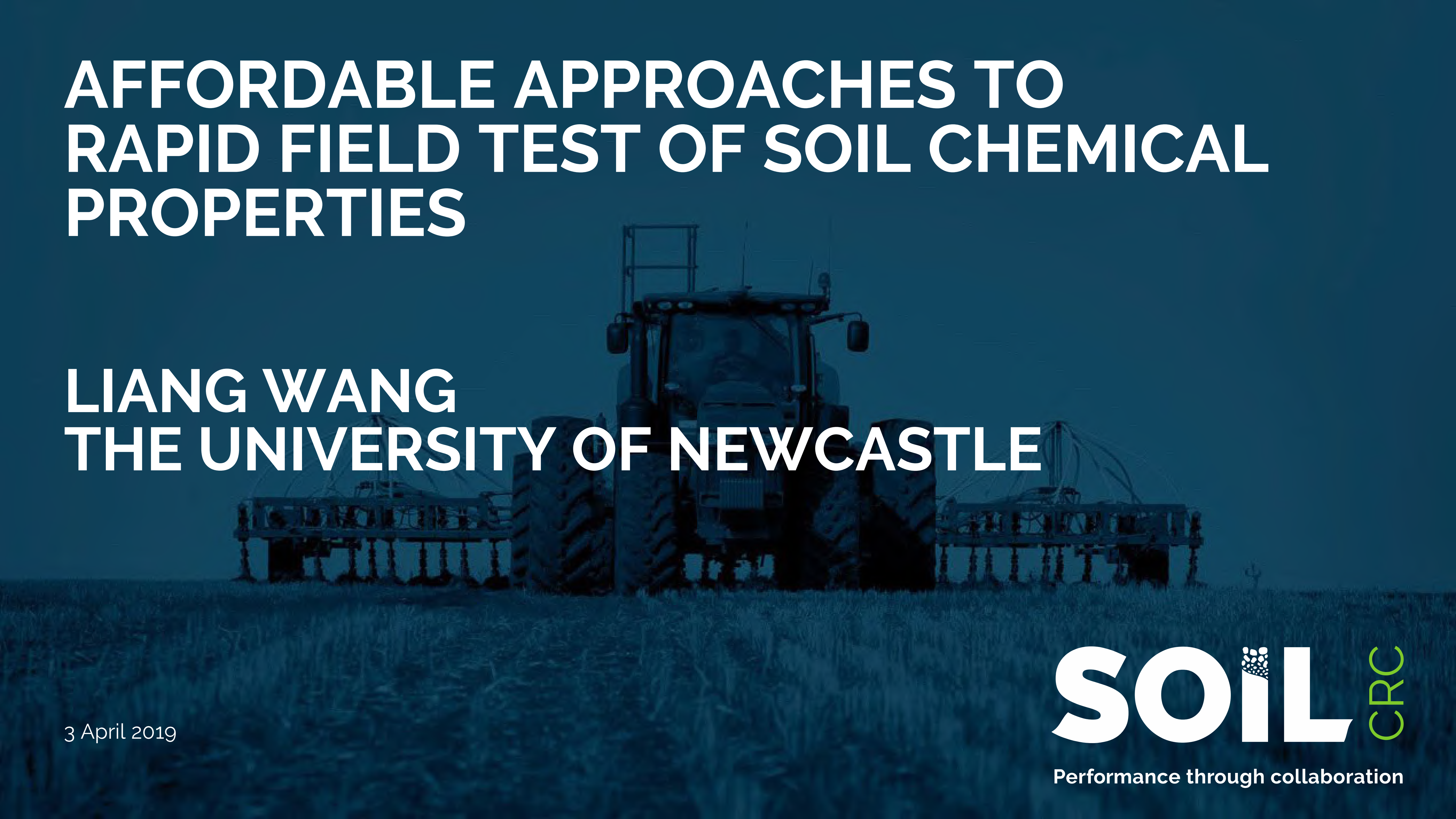
AFFORDABLE APPROACHES TO RAPID FIELD TEST OF SOIL CHEMICAL PROPERTIES



LIANG WANG
THE UNIVERSITY OF NEWCASTLE

3 April 2019

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PROJECT TEAM

- Prof. Michael Breadmore, University of Tasmania
- Prof. Ravi Naidu, The University of Newcastle
- Mr. Lawrence Di Bella, Herbert Cane Productivity Services Ltd
- Mr. Rob Milla, Burdekin Productivity Services Ltd
- Dr. Fernando Maya Alejandro, University of Tasmania
- Dr. Ying Cheng, The University of Newcastle
- Dr. Feng Li, University of Tasmania

BACKGROUND

Traditional soil sampling and chemical analysis:

- Costly;
- Time consuming;
- Sophisticated.

Precision agriculture

The widespread interest in the development of :

- Rapid soil sensing systems;
- Simple and affordable solutions to farmers.

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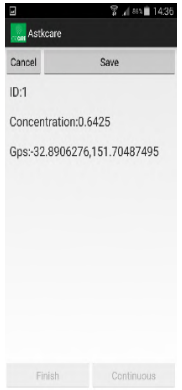
PROJECT ACTIVITIES

- This project aims to develop solutions for farmers to determine soil chemical properties.
  1. Simple;
  2. Affordable;
  3. Rapid;
  4. Field-based.



- To develop colorimetric method and device;
- To develop the chemometric method and mobile applications.

SOIL CRC

Performance through collaboration

ENGAGEMENT AND COLLABORATION

- End users feedback:

We will provide our free trial toolkits to all the farmer groups participated in CRC Soil;

- Commercialization:

We will promote our prototypes in CRC Soil community to target business partners for commercialization.