Creating DSM to apply

SIX-EASY-STEPS ameliorant and nutrient guidelines

Maryem Arshad, Nan Li,

Michael Sefton, Lawrence Di Bella, Rod Nielson, John Trianatfilis

Problem definition:
SIX-EASY-STEPS

Digital Soil Mapping
DSM

Case Studies:
CEC, ESP and Exch. Ca + Exch. Mg

DSM
SIX-EASY-STEPS

Introduction

Australian Sugarcane

Sugarcane (*Saccharum officinarum* L.) occupies ~545,000 ha

70% cultivation in alluvial-estuarine areas, however there are problems because soil

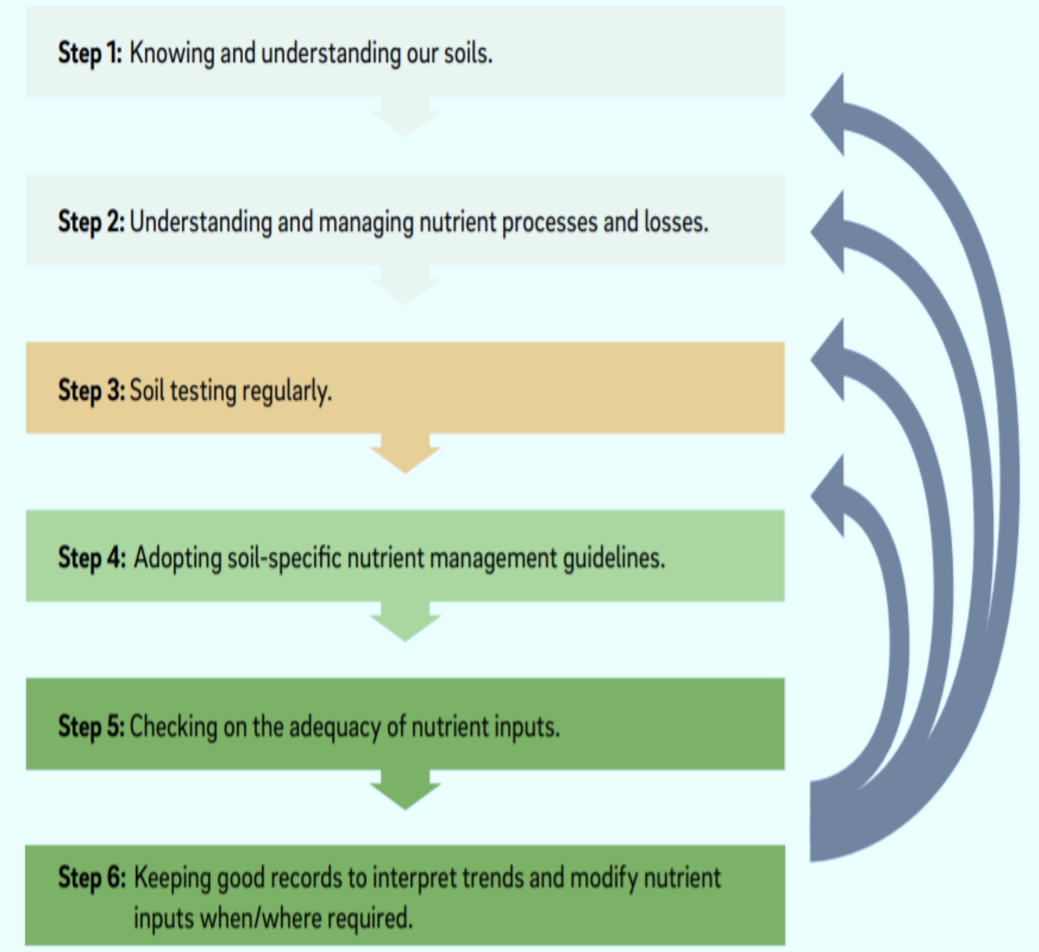
- infertile (sandy > 60 %),
- Acidic (pH < 5.5) and
- sodic (ESP > 15 %)

Implications with regard to;

- Cation Exchange Capacity (CEC)
- Nutrients (**Exch. Ca** + **Exch. Mg**)
- Unstable (i.e. ESP)

Introduction – An industry "Soil"ution?

Six-Easy-Steps
Nutrient management guidelines



Six-Easy-Steps

Soil Ameilorants

Lime

Gypsum

Soil Nutrients

- Calcium (Ca)
- Magnesium (Mg)
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Sulphur
- Micronutrients

Introduction – An industry “Soil”ution?

Six-Easy-Steps
Nutrient management guidelines

Table 1 - Lime guidelines based on exchangeable soil calcium (Ca)

Soil calcium (meq/100g)	Lime application (tonnes/ha)
<0.2	3
0.2 – 0.4	2.5
0.4 – 0.6	2
0.6 – 0.8	1.5
0.8 – 1.1	1
1.1 – 1.5	0.5

Table 3 - Gypsum guidelines for sodic soils

ESP (%)	Gypsum rate (tonnes/ha)
<5	0
5 - 10	5
10 - 15	7.5
>15	10

Six-Easy-Steps (Burdekin Valley)

Ameliorants

Lime

Infertility
CEC (cmol(+)/kg)
Apply

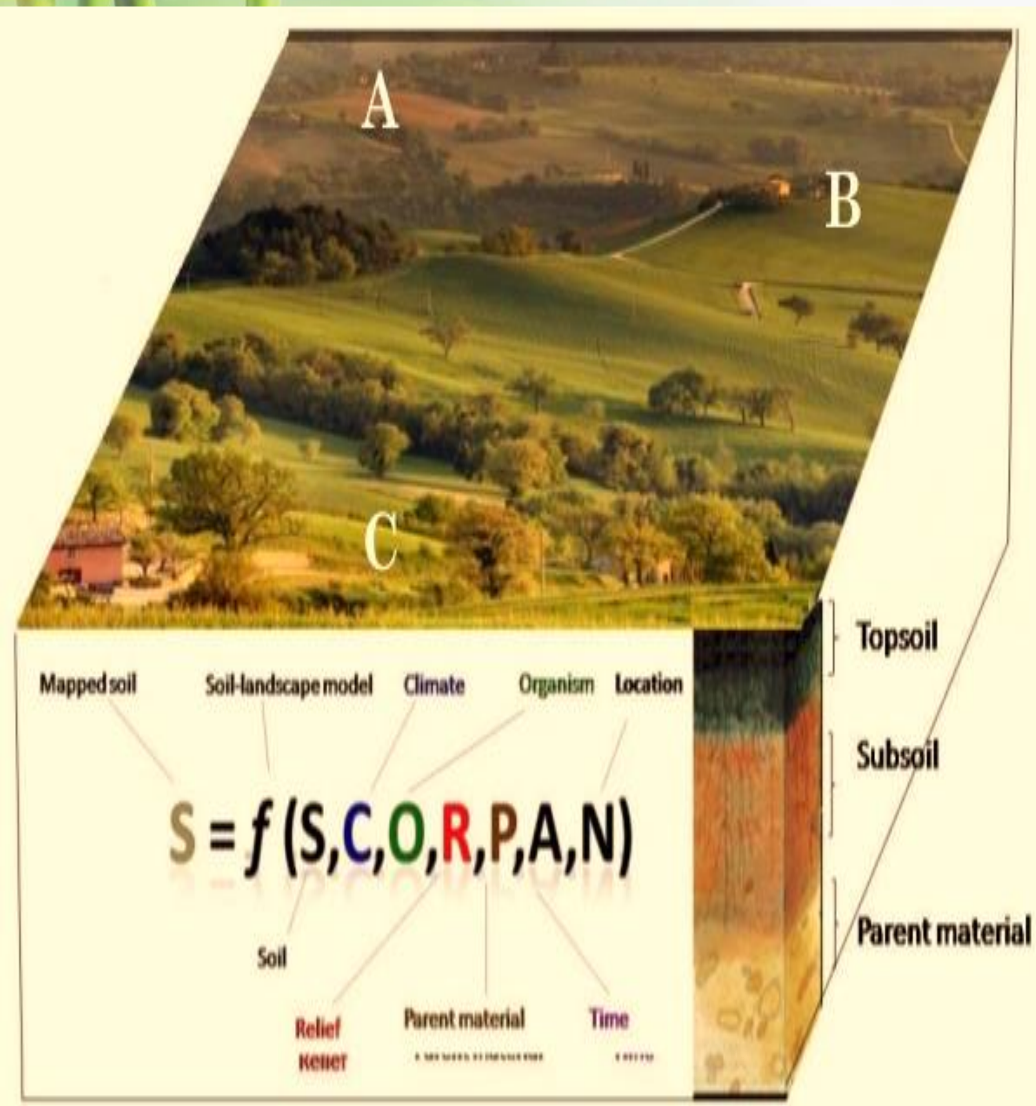
Gypsum

Sodictiy
ESP (%)
Apply

Introduction – An industry problem?

Six-Easy-Steps (Soil data not so cheap)

DSM – An innovative “Soil”ution?



Digital Soil Mapping

Creation and population of spatial information using

Soil and

Digital data

coupled with **Models** either

Spatial or

Non-spatial inference

Three components:

Soil and

Digital data

Models

Digital data

Table 1. IAEA recommended windows for conventional 3-channel airborne gamma-ray spectrometry (IAEA 1991).

Element analysed	*Isotope used*	*Gamma ray energy MeV*	*Energy window MeV*
Potassium	^{40}K	1.46	1.370–1.570
Uranium	^{214}Bi	1.76	1.660–1.860
Thorium	^{208}Tl	2.61	2.410–2.810

Gamma-ray spectrometer- RS700

Passive proximal sensor which detects gamma-rays from radioactive isotopes

Measures:

K

U

Th

TC

Depth of measurement

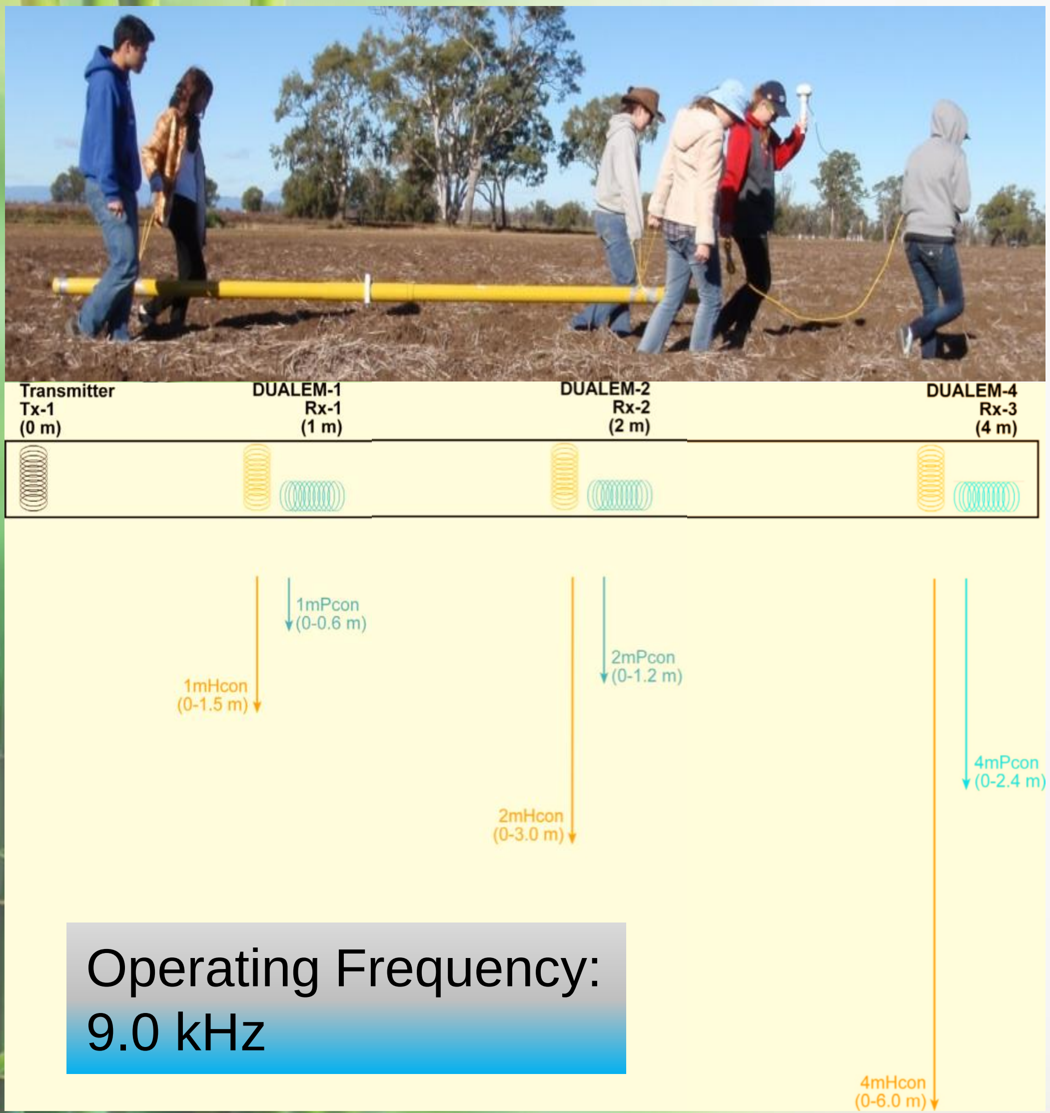
0-0.45 m

Related:

clay

mineralogy

Digital data



Operating Frequency:
9.0 kHz

Electromagnetic induction: DUALEM-421

Single frequency multi-coil array electromagnetic (EM) instrument

Measures:

Apparent electrical conductivity (**ECa** –mS/m)

Perpendicular (Pcon) and

Horizontal coplanar (Hcon)

Depth of measurement

1mPcon (0-0.5 m) 1mHCon (0-1.5)

2mPcon (0-1 m) 2mPcon (0-3)

Related:

moisture, *salinity*,

clay and mineralogy

Comparing management zone maps to address infertility and sodicity in sugarcane fields

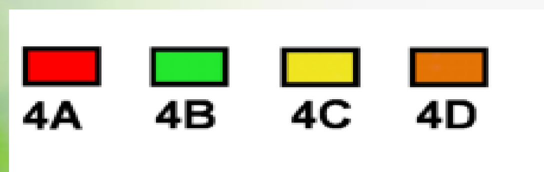
Maryem Arshad,

Nan Li, Sam Lamari, Michael Sefton, John Triantafilis

Problem

Digital Soil Mapping
DSM

Clustering



Management Zones

DSM – An innovative “Soil”ution?

DSM

Step 1: Meeting

Step 2: Measurement

Step 3: Modelling

Step 4: Mapping

Step 5: Management

Step 6: Monitoring

Herbert - HCPSL

Soil: **CEC**
ESP

Digital: **Digital Elevation Model**
γ-ray spectrometry
Electromagnetic EM

Model: **Clustering Digital data**

Comparison: **DSM**
Traditional soil texture map
Field delineations

Infertility
CEC (cmol(+)/kg)
Apply

Sodictiy
ESP (%)
Apply

Introduction – An industry "Soil"ution?

Six-Easy-Steps
Nutrient management guidelines

Table 1 – Lime guidelines for acid soils (when pH water < 5.5)

CEC (meq/100g)	Lime application (tonnes/ha)
< 3.0	2.25
3.0 – 6.0	4
> 6.1	5

Table 4 – Gypsum guidelines for sodic soils

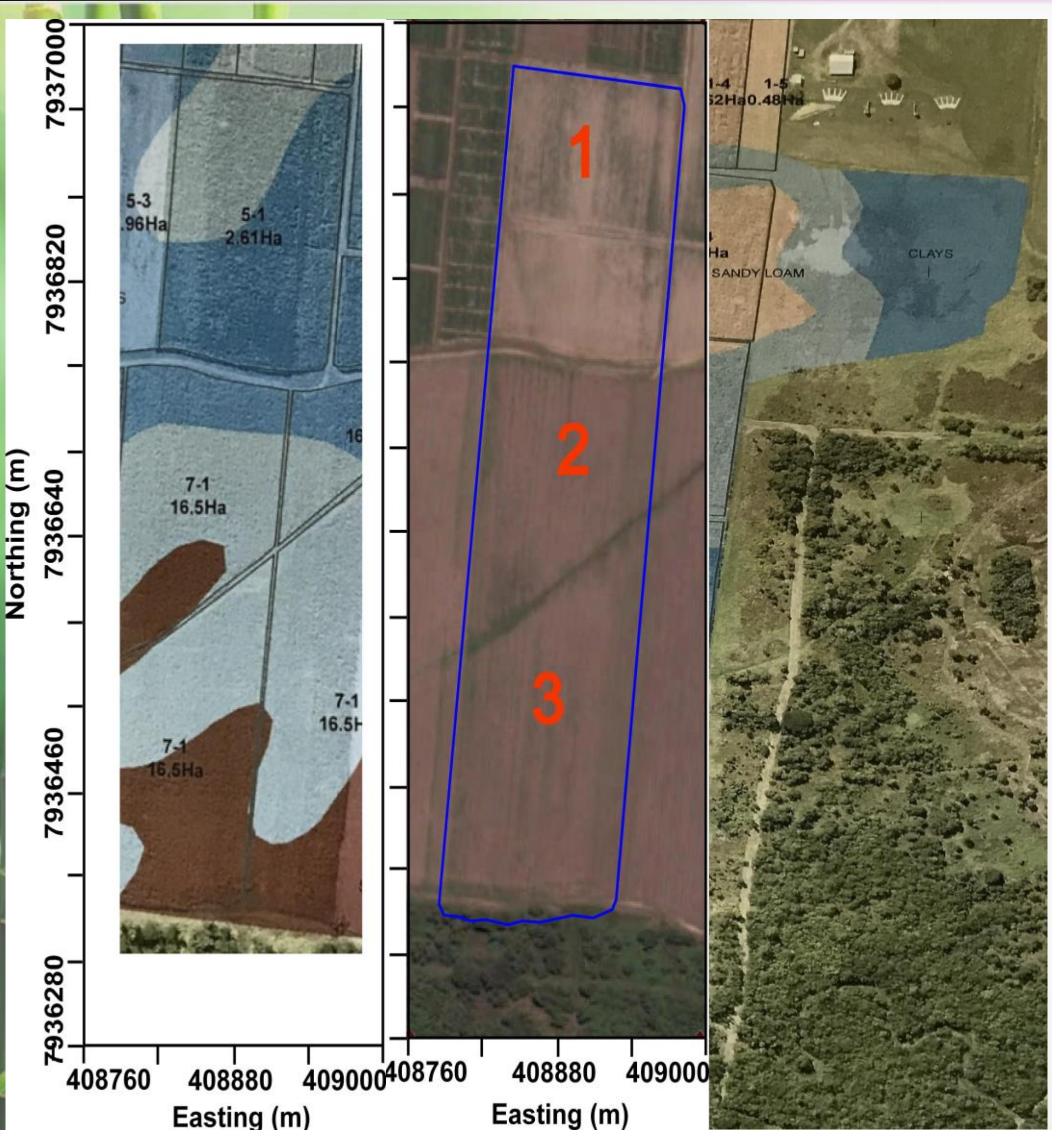
ESP (%)	Gypsum rate (tonnes/ha)
< 5	0
5 - 10	2
10 - 15	4
> 15	6

Six-Easy-Steps (Herbert Valley)

Soil ameliorants

Lime	Gypsum
	
Infertility CEC (cmol(+)/kg) Apply	Sodictiy ESP (%) Apply

Management zones: Traditional/Field



Herbert Sugarcane

Alluvial soil varies and has been mapped using Traditional Soil texture map

- Clay
- Silty Clay
- Terrace Silt Loam

Best-practice requires knowledge of variation to max. yield and min. losses

When soil texture map is unavailable farmers use Field delineations

- Field 1
- Field 2
- Field 3

Aim

In multiple fields at HCPSL:

a) Can we generate a **DSM**s of management zones to manage **Soil;**

i) Infertility (CEC) and

ii) Sodicity (ESP)

using mathematical models and proximally sensed **Digital data**

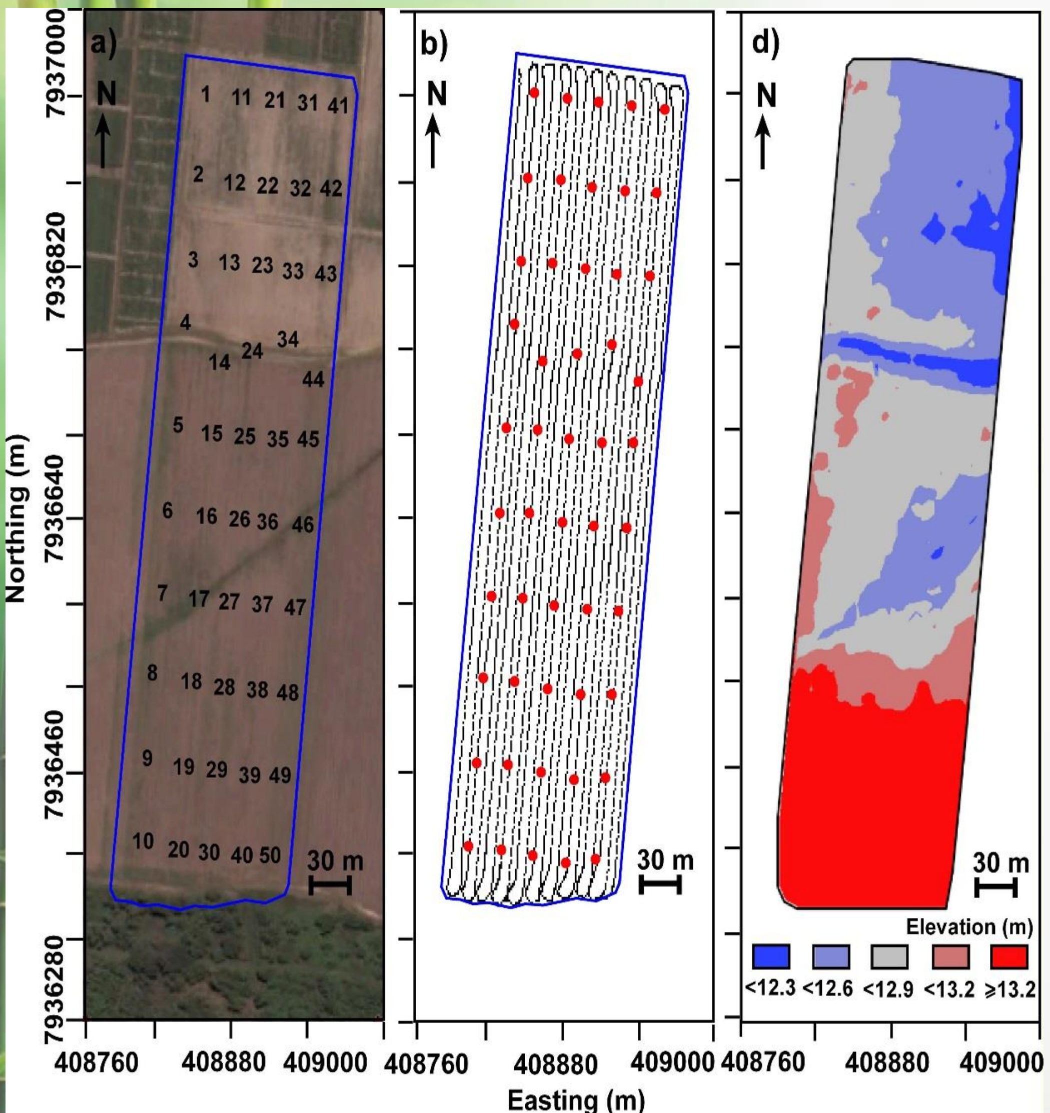
b) Which method of creating management zones is optimal

i) **DSM** (DEM, γ-ray and EM)

ii) Traditional soil texture map

iii) Field delineations

Data collection: Digital & Soil

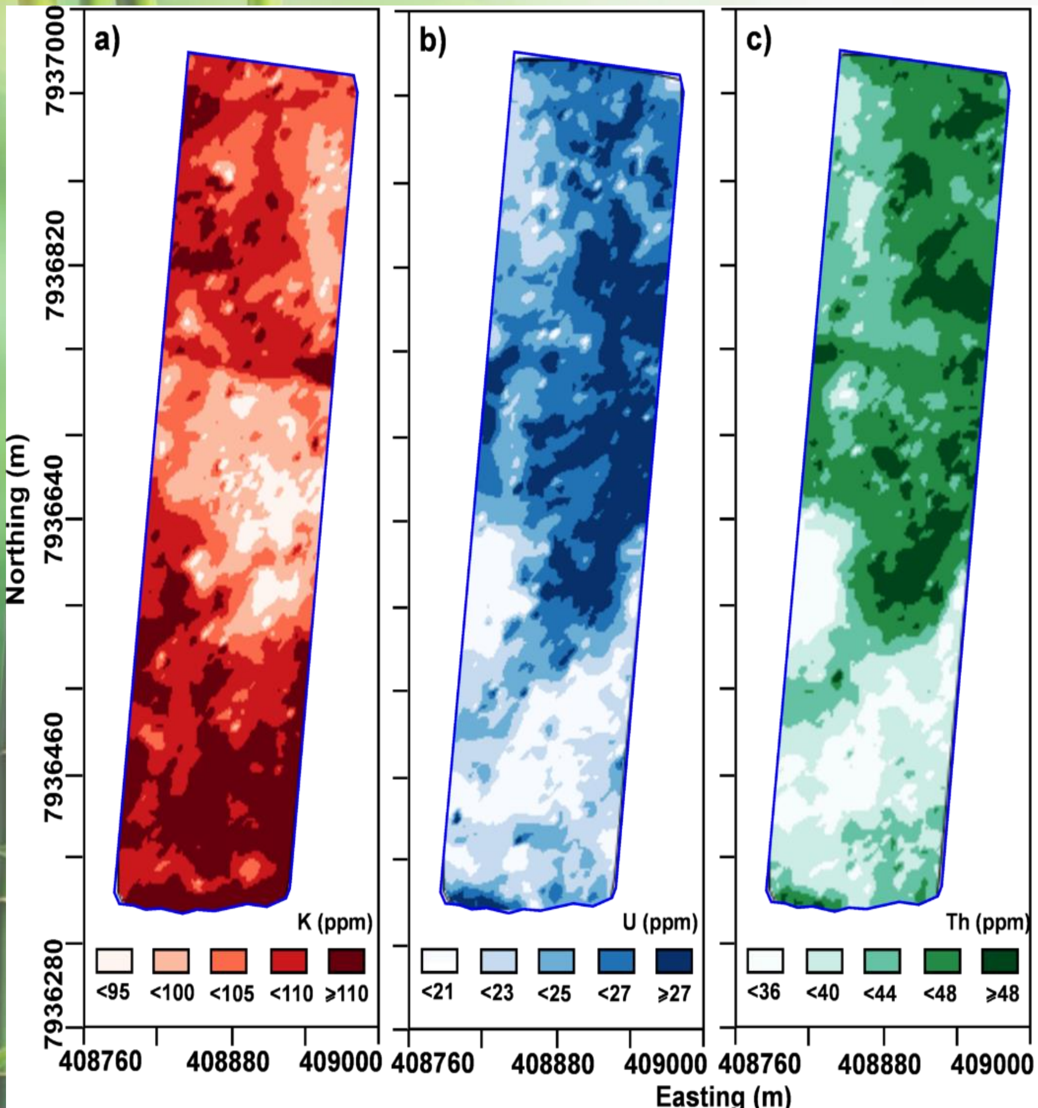


Data collection and sampling

Digital data was collected from
- 21 transects (6 m apart) using
  - **Digital Elevation Model**
  - **γ-ray spectrometry**
  - **Electromagnetic EM**

Soil samples were collected from
- 50 sites
  - Topsoil (0-0.3 m)

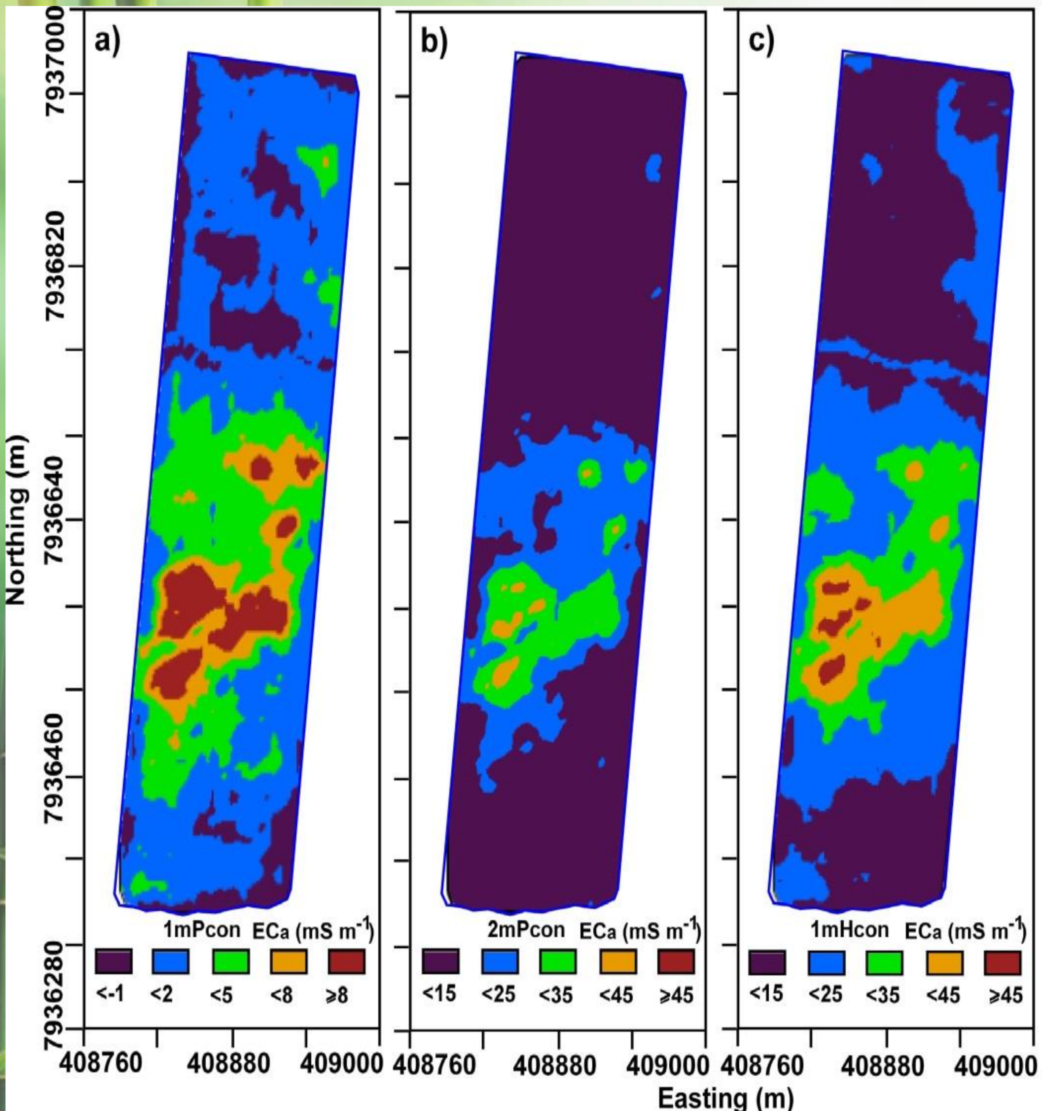
Digital data



Gamma-ray spectrometer- RS700

K,
U and
Th

Digital data



Electromagnetic induction: DUALEM-421

1mPcon,
2mPcon and
1mHcon

Soil data

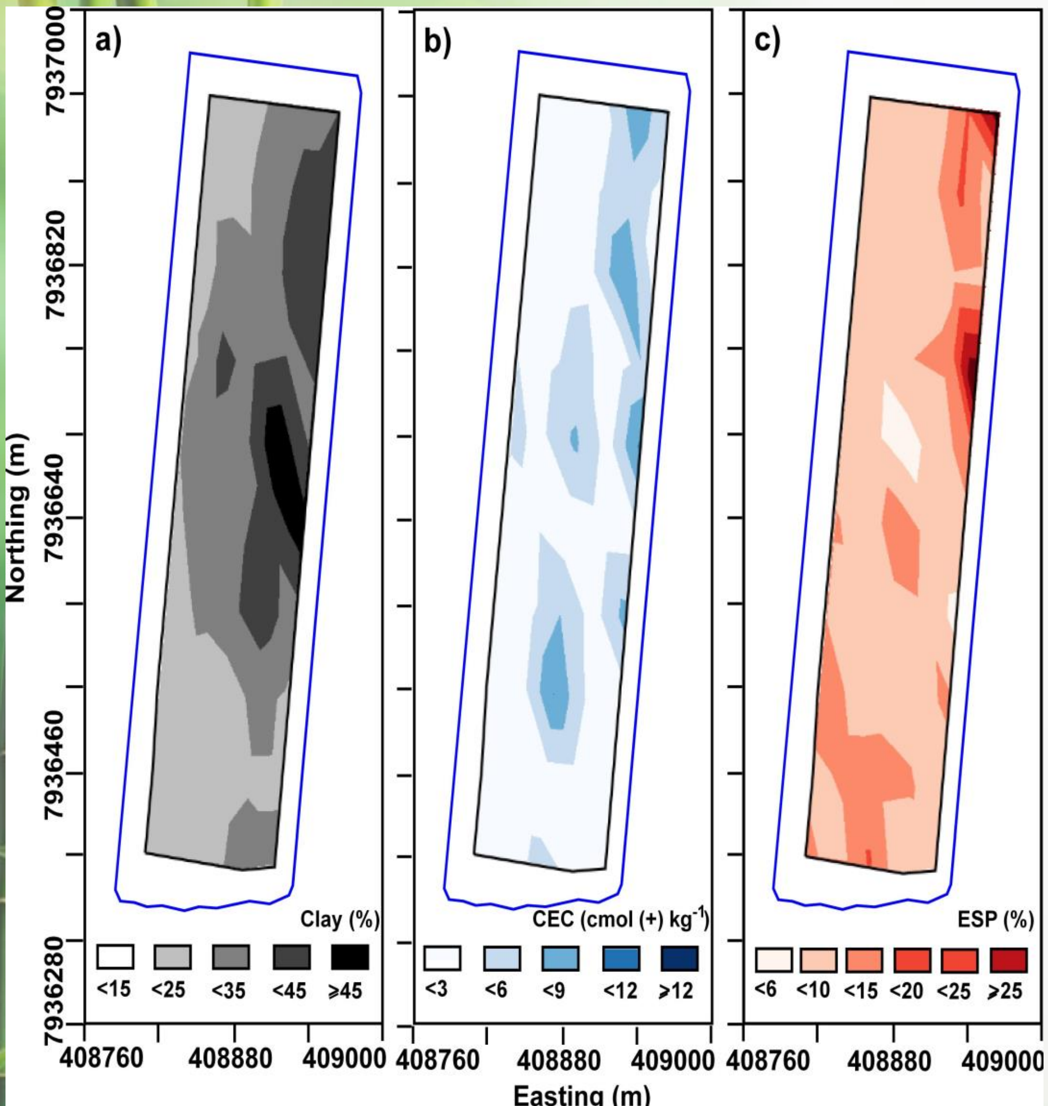
Analysis: time consuming

Chemical (CEC and ESP) ~24 hours

- Washing
- Extraction
- Analysis
- Calculations

$180

Soil data

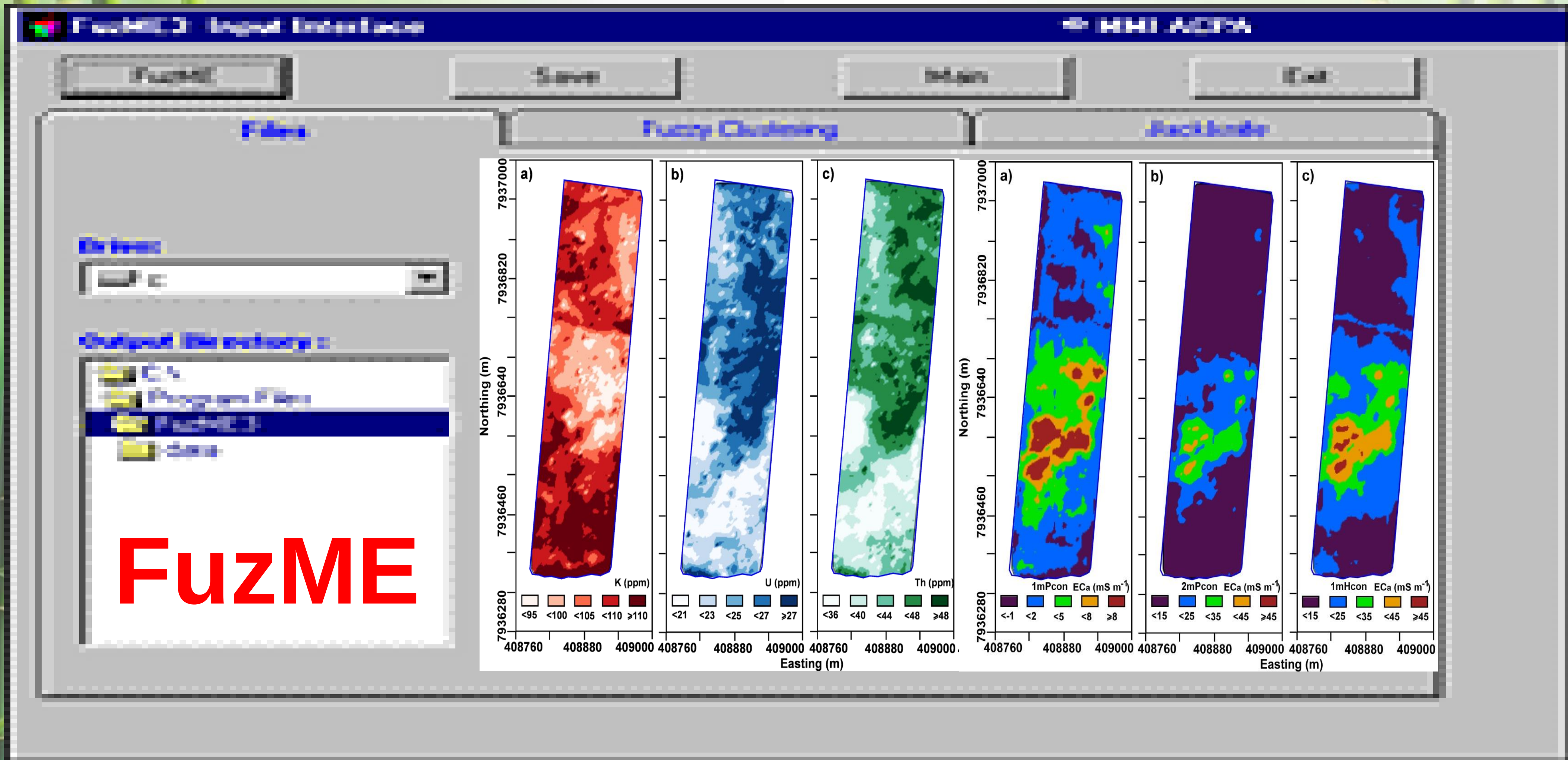


Test data to compare

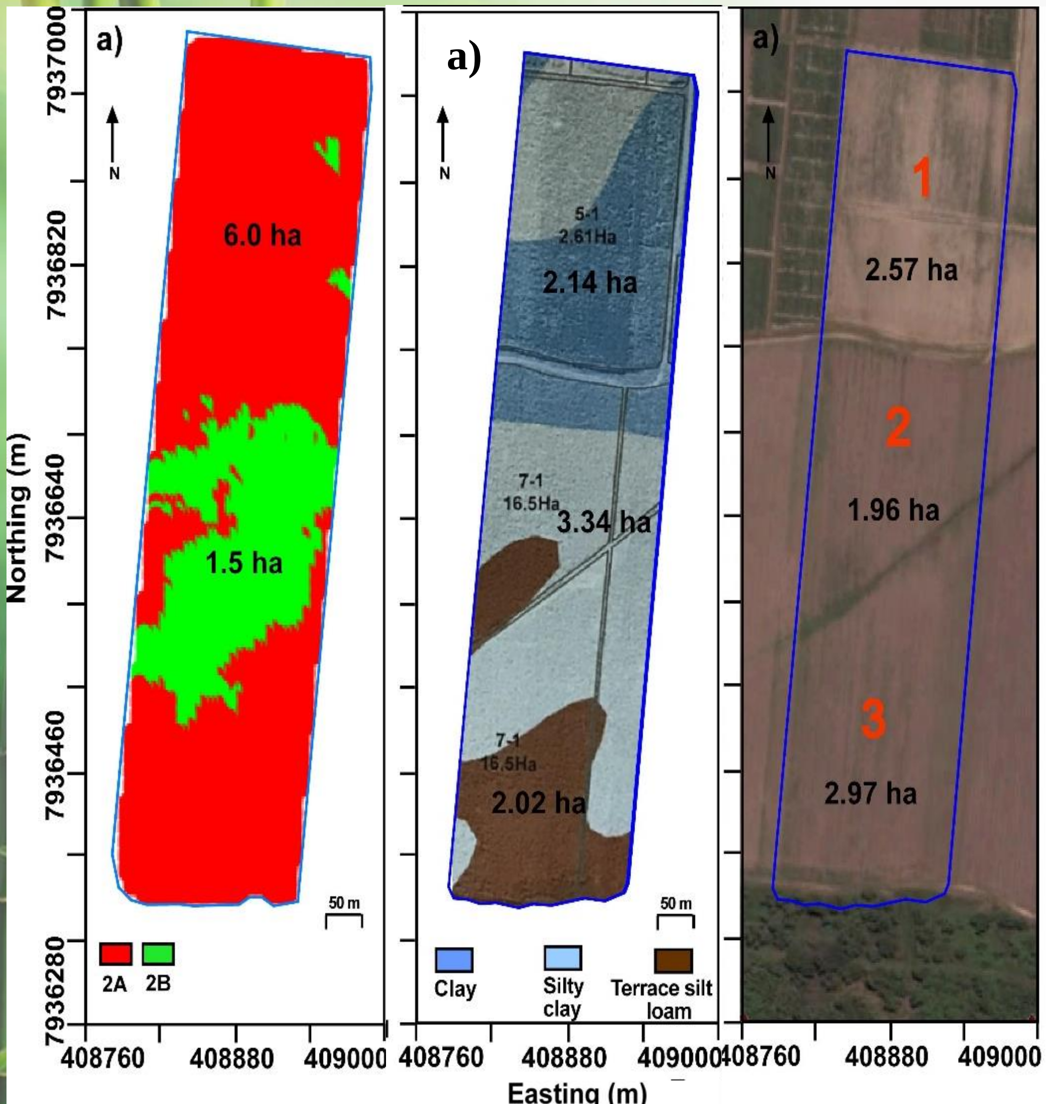
Clay,
CEC and
ESP

Model: Clustering digital data

DSM - zones



Management zones

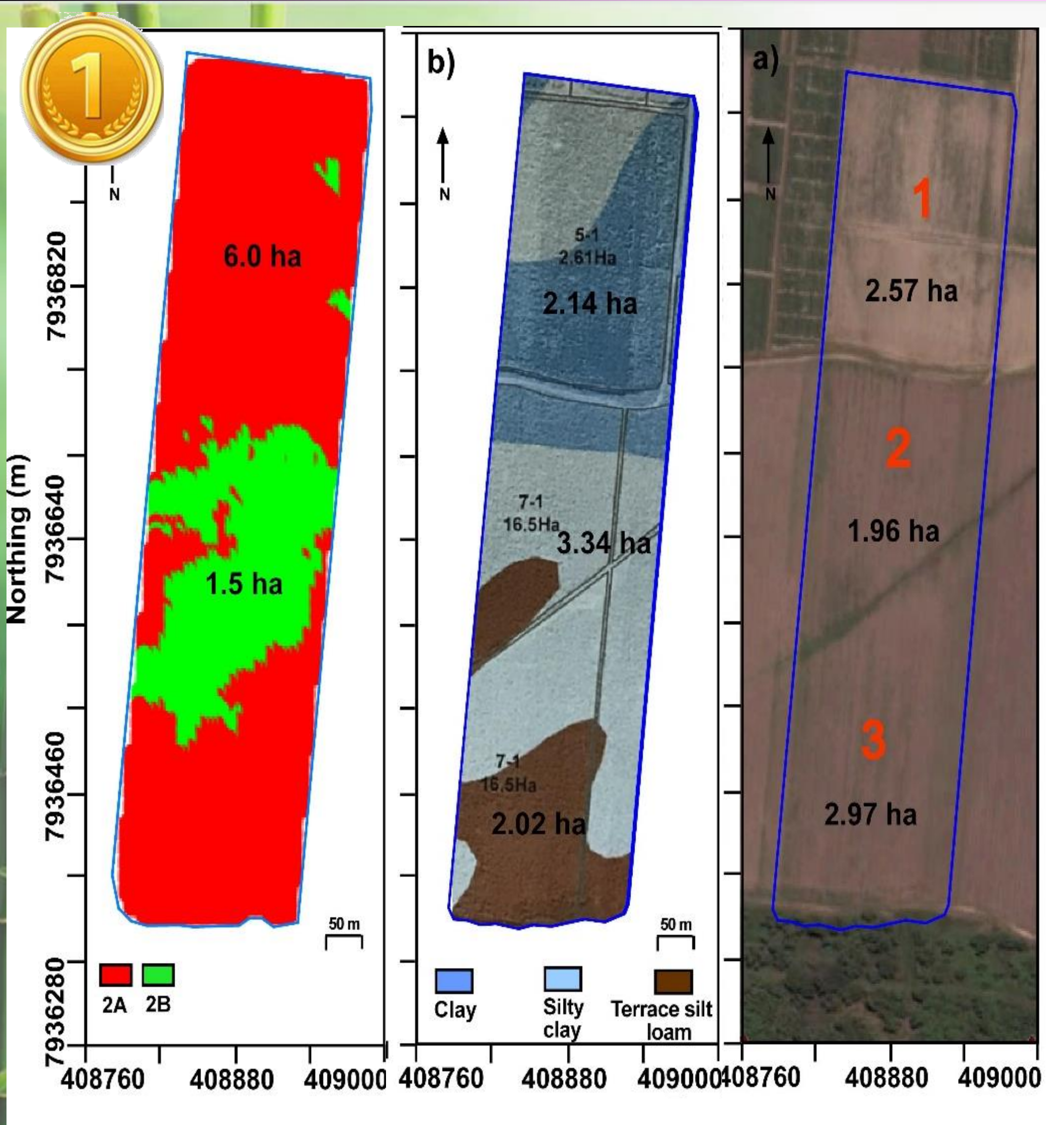


DSM = Digital data + clustering

Traditional map = Soil Texture

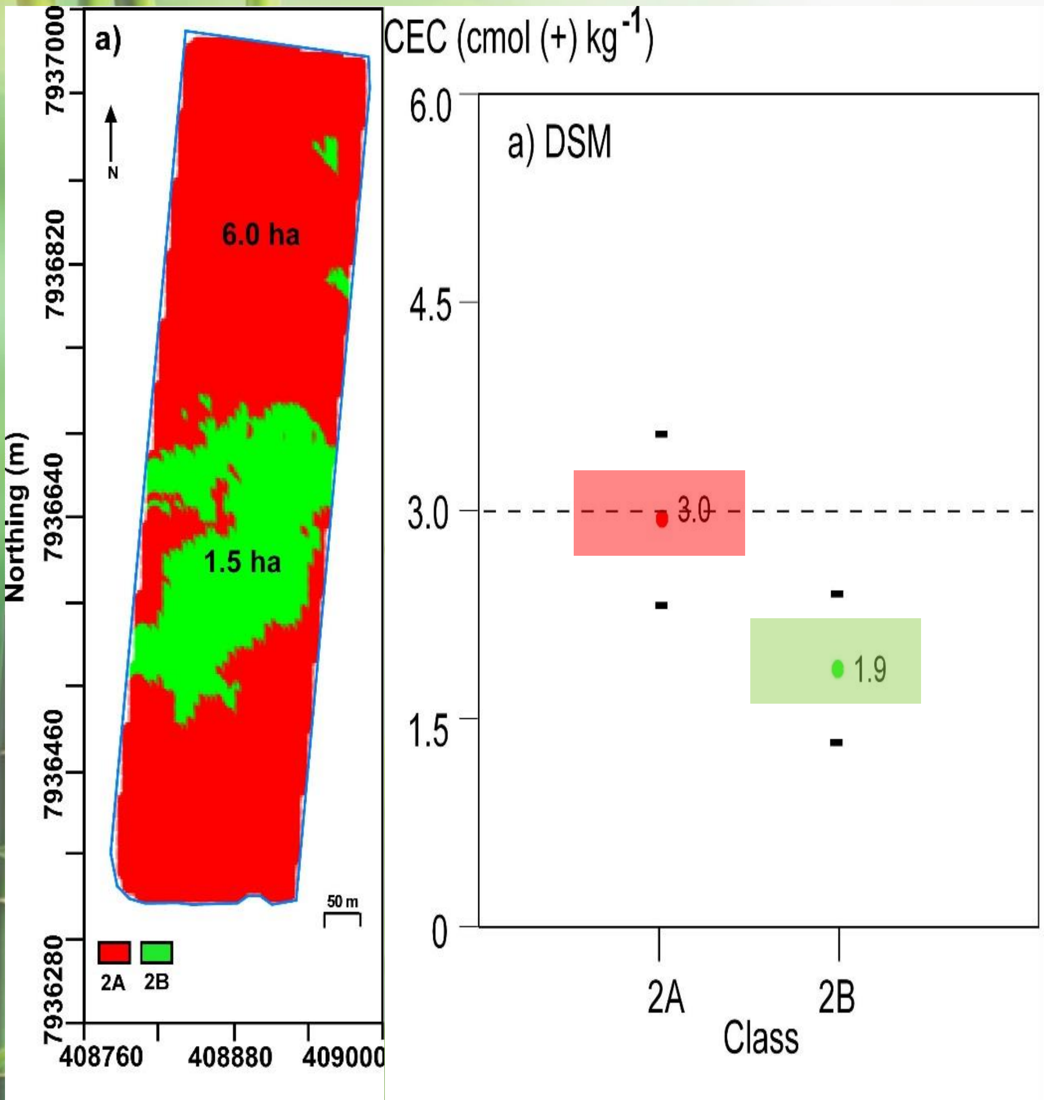
Field delineation = 3 fields

Which one best to manage Soil infertility?



Mean square prediction error (MSPE)					
Properties	DSM k = 2	DSMk = 3	DSM k = 4	Traditional (k = 3)	Field (k = 3)
CEC ([cmol(+)/kg])	**2.20**	2.21	2.34	2.37	2.41

Lime application rate to DSM



Six-Easy-Step (Herbert Valley)

Infertility

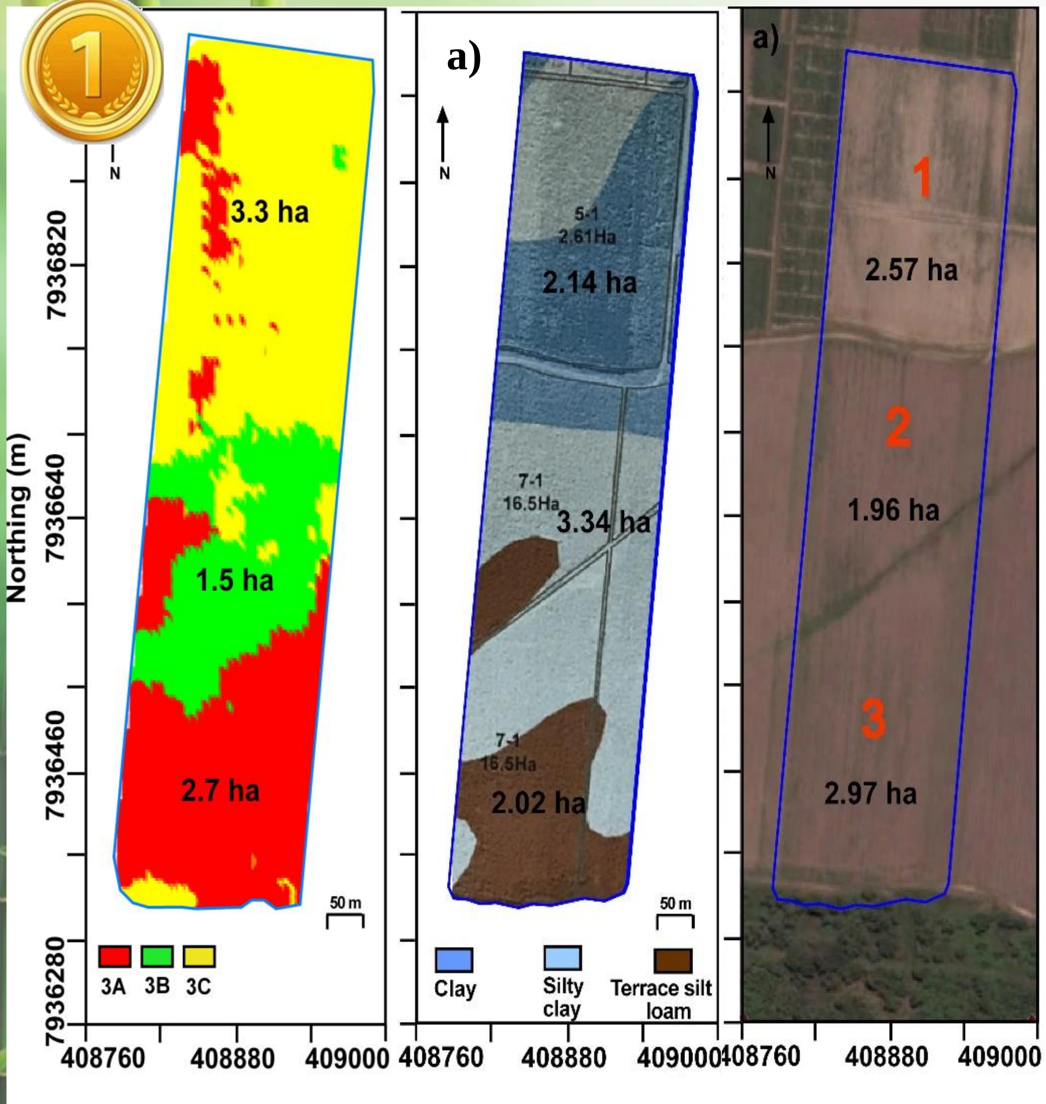
CEC (cmol(+)/kg)

Apply

Table 1 – Lime guidelines for acid soils (when pH water < 5.5)

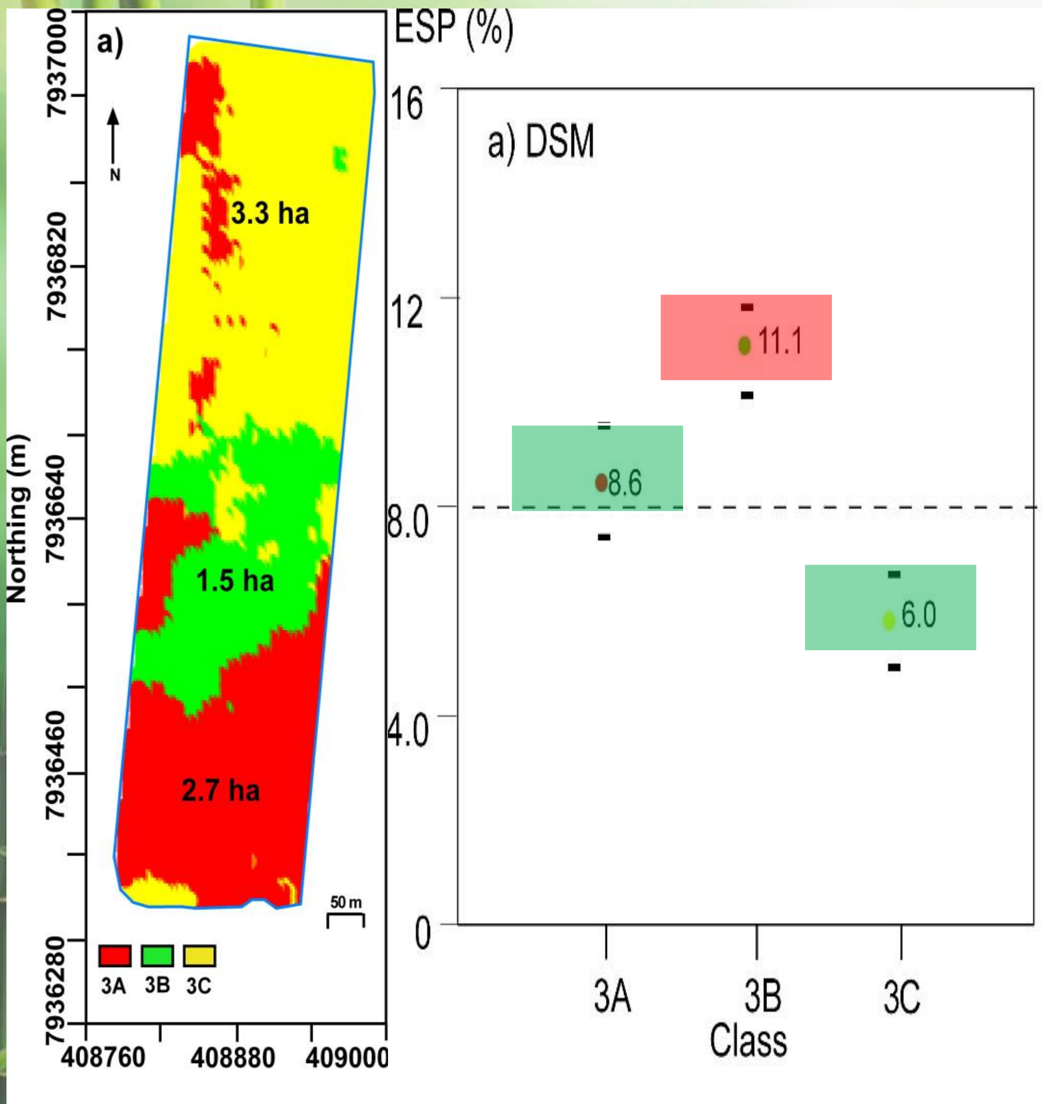
CEC (meq/100g)	Lime application (tonnes/ha)
< 3.0	2.25
3.0 – 6.0	4
> 6.1	5

Which one best to manage Soil sodicity?



Mean square prediction error (MSPE)					
Properties	DSM k = 2	DSM k = 3	DSM k = 4	Traditional (k = 3)	Field (k = 3)
ESP (%)	5.76	5.60	6.91	7.04	6.2

Gypsum application rate to DSM



Six-Easy-Step (Herbert Valley)

Sodicity

ESP (%)

Apply

Table 4 – Gypsum guidelines for sodic soils

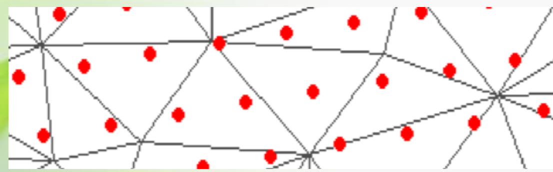
ESP (%)	Gypsum rate (tonnes/ha)
< 5	0
5 - 10	2
10 - 15	4
> 15	6

Determining an optimal mathematical model, sample size and ancillary data for mapping Exch. Ca and Mg

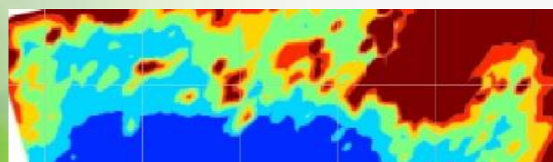
Nan Li,
Michael Sefton, John Triantafilis

Introduction

Problem Definition



Soil sampling and digital data



Results and conclusion

DSM – An innovative "Soil"ution?

DSM

Step 1: Meeting

Step 2: Measurement

Step 3: Modelling

Step 4: Mapping

Step 5: Management

Step 6: Monitoring

Burdekin – DAVCO Pty Ltd.

Soil: Calcium (Ca), Magnesium (Mg)

Digital: γ-ray spectrometry, Electromagnetic EM

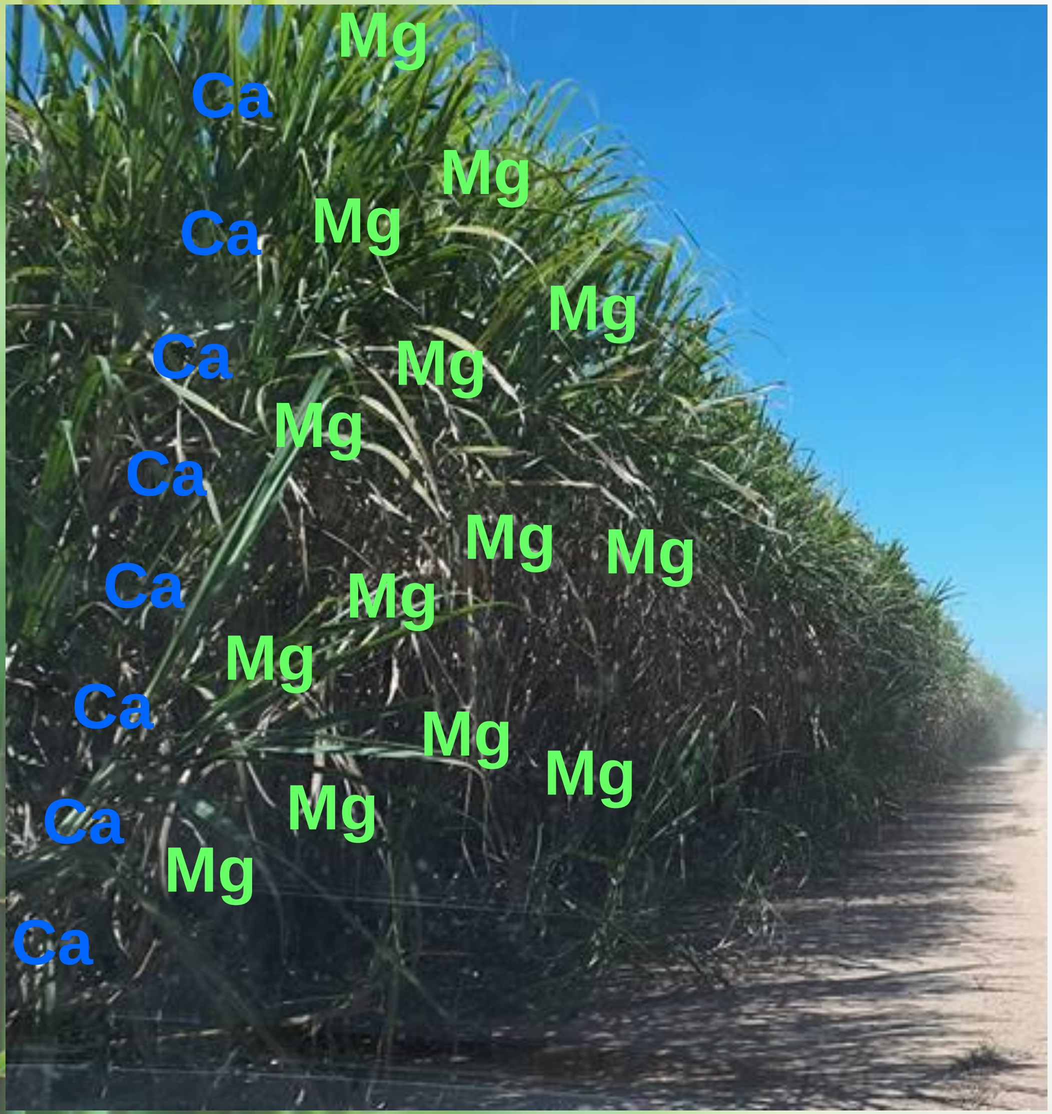
Model: Correlate Digital + Soil

Comparison: LMM, RK, RF, SVM

Exch. Ca
(cmol(+)/kg)
Apply

Exch. Mg
(cmol(+)/kg)
Apply

Introduction



Why Ca and Mg

Ca is important:

i) plant roots and leaves

ii) neutralize excess acid or alkaline soil

Mg is central component of chlorophyll

i) drive photochemistry

ii) harvest solar energy

iii) major role in N uptake

Soil deficient in Ca and Mg leads to issues like

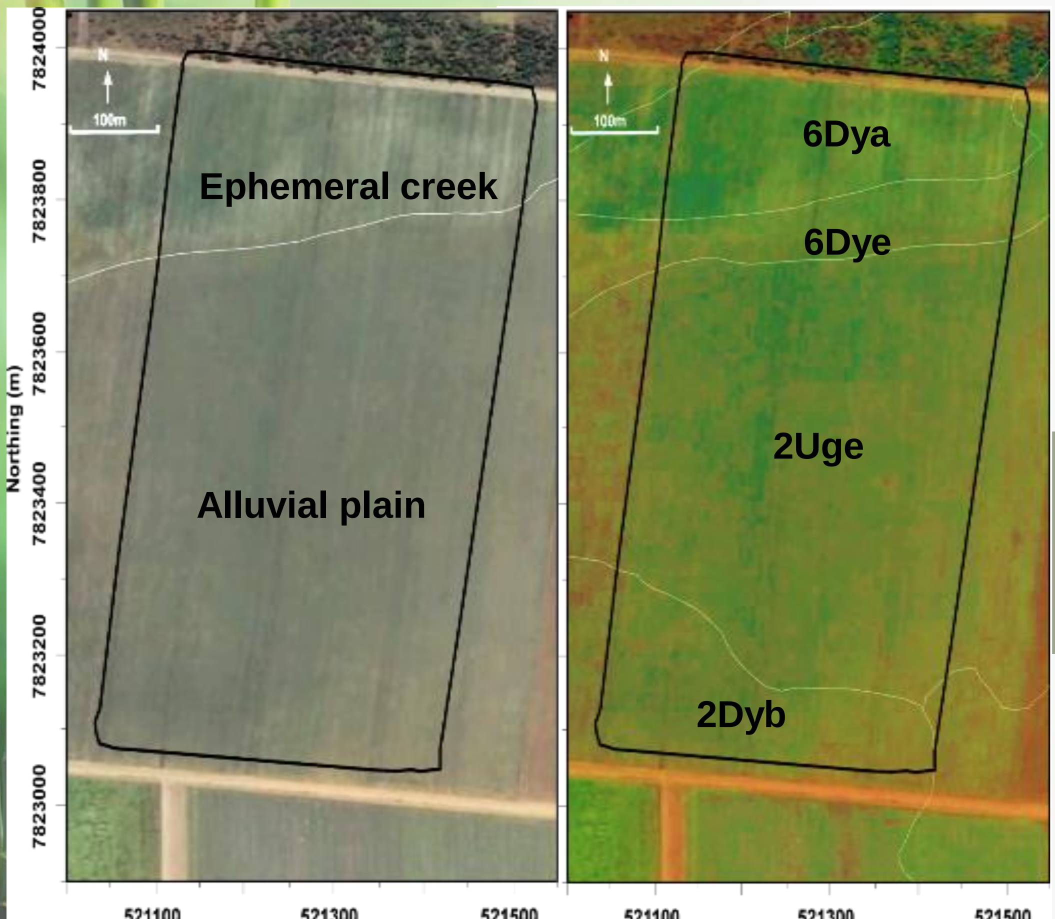
chlorosis,

necrosis,

curling of plant leaves with

ultimate cessation of plant growth

Problem definition



Lime guidelines based on Exch. Ca	
Exch. Ca (meq/100g)	Lime (t/ha)
<0.2	3
0.2-0.4	2.5
0.4-0.6	2
0.6-0.8	1.5
0.8-1.1	1
1.1-1.5	0.5

Magnesium guidelines based on Exch. Mg	
Exch. Mg (meq/100g)	Mg (kg/ha)
<0.05	150
0.06-0.10	125
0.11-0.15	100
0.16-0.20	75
0.21-0.25	50
>0.25	0

Burdekin Sugarcane growing area

Sugarcane farmers apply fertilisers for

Ca and

Mg

using "*One rate fits all*" approach.

It could be using '*One rate fits all*' approach based on

Soil Order map

In Burdekin, this is done using six-easy-steps nutrient management guidelines

Problem definition

Nutrient Management

Fertilizer application practice requires prior soil information about

Exch. Ca

Exch. Mg

Unfortunately, obtaining these information using traditional method is

time-consuming and

expensive

Moreover, information are required

across the field

to optimise yield and productivity

Amis

In a sugarcane field in Burdekin Valley:

Generate DSMs of

Exch. Ca and

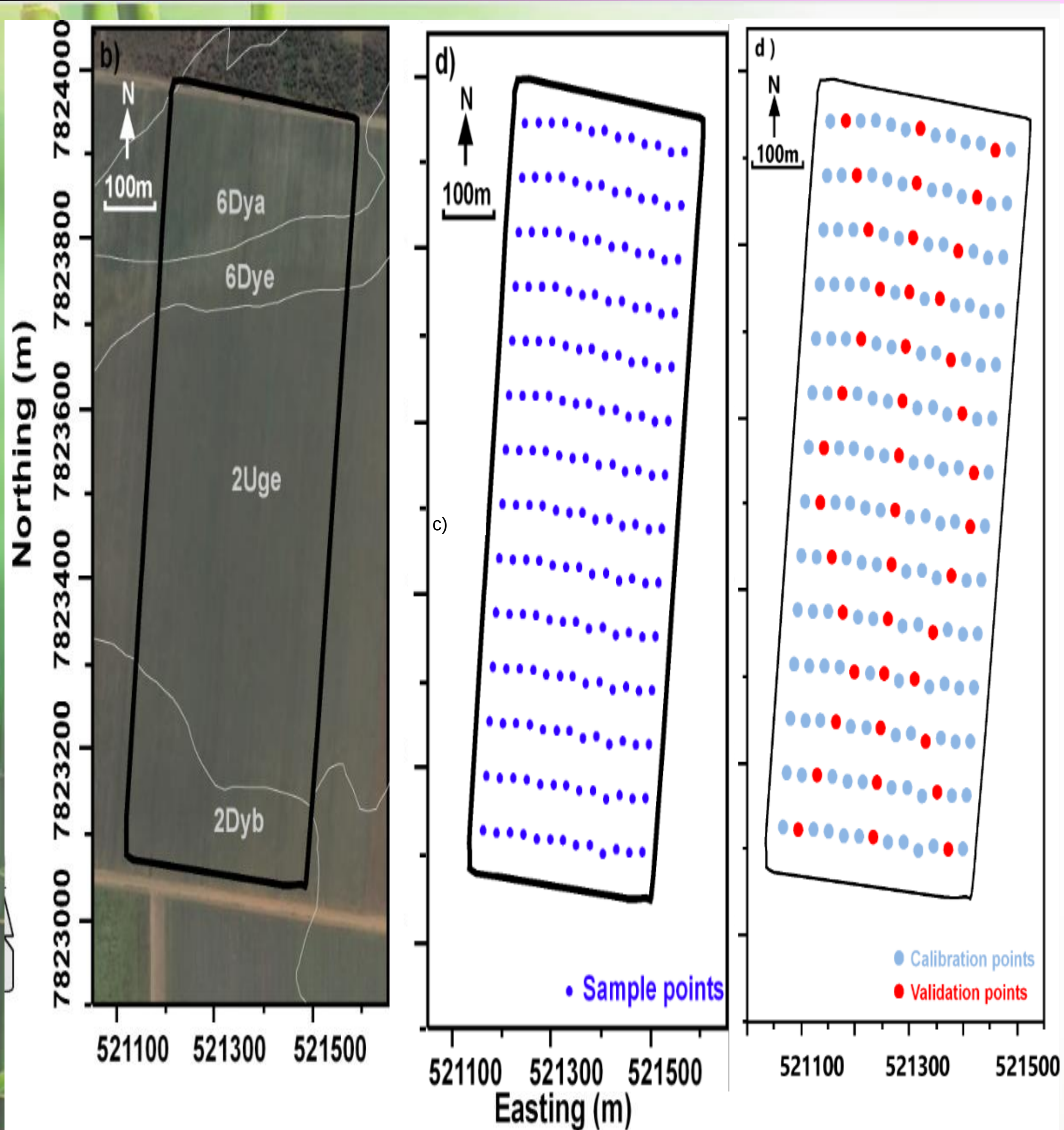
Exch. Mg

1) Which mathematical model is best?

2) How many soil samples do we need?

3) Which digital data is superior?

Soil sampling and analysis



Soil sampling and analysis

Soil samples 182

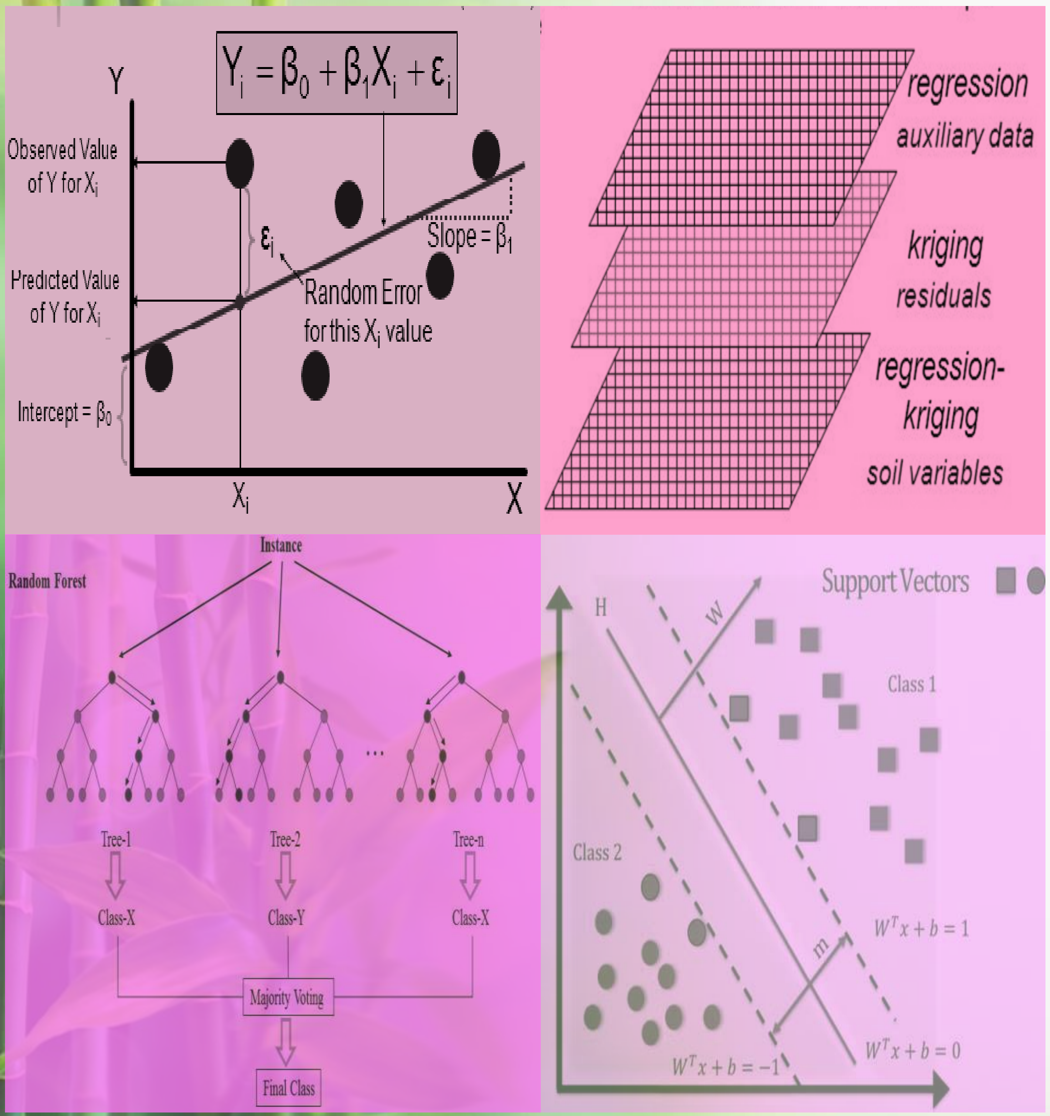
Calibration 140 samples

Validation 42 samples

Laboratory analysis

Tucker's method (1974)

1) Which model is best?



Mathematical models

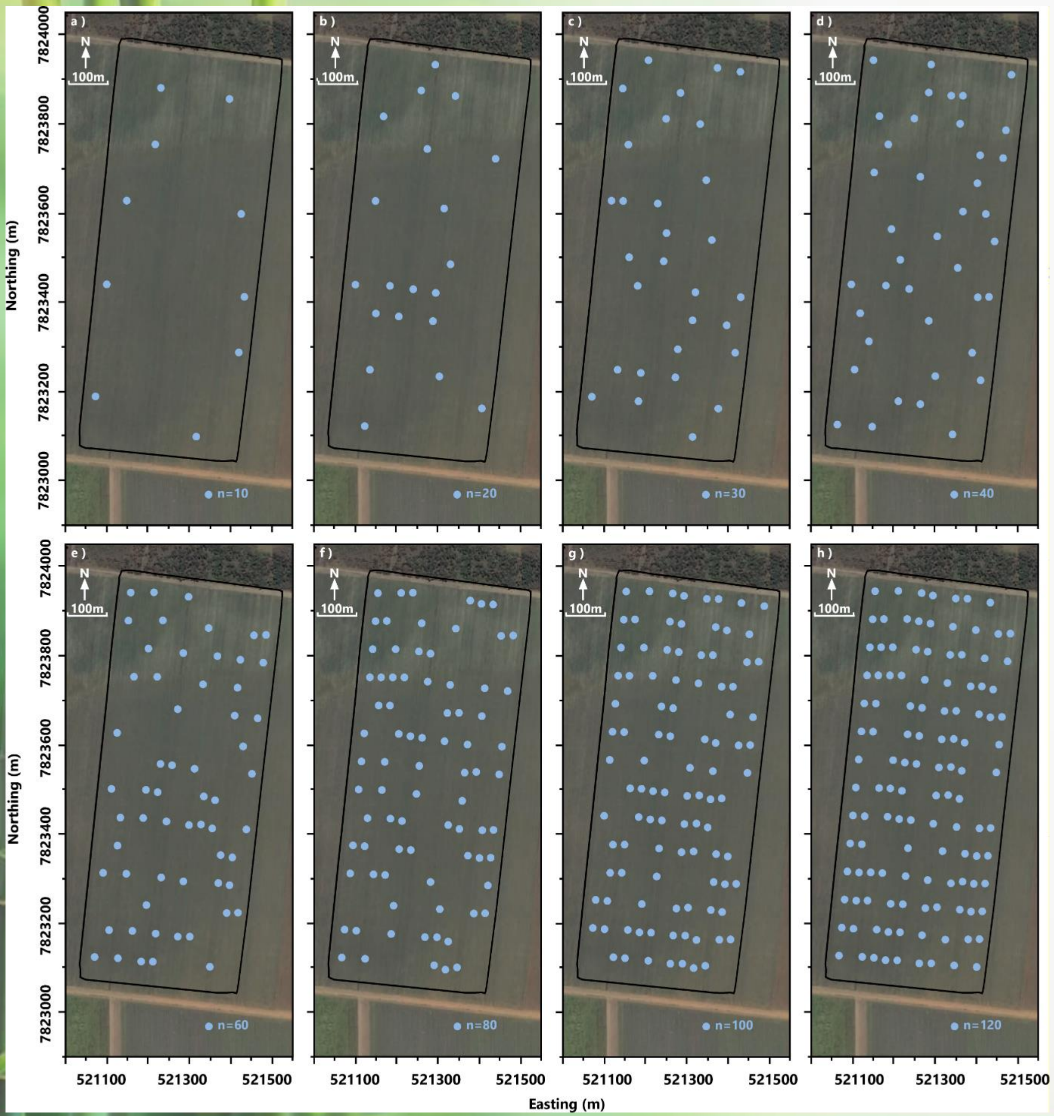
Linear Mixed Model (**LMM**)

Regression Kriging (**RK**)

Random Forests (**RF**)

Supportive Vector Machine (**SVM**)

2) How many soil samples?



Conditioned Latin hypercube

10 20 30 40

60 80 100 120

3) Which digital data is best?

Digital data

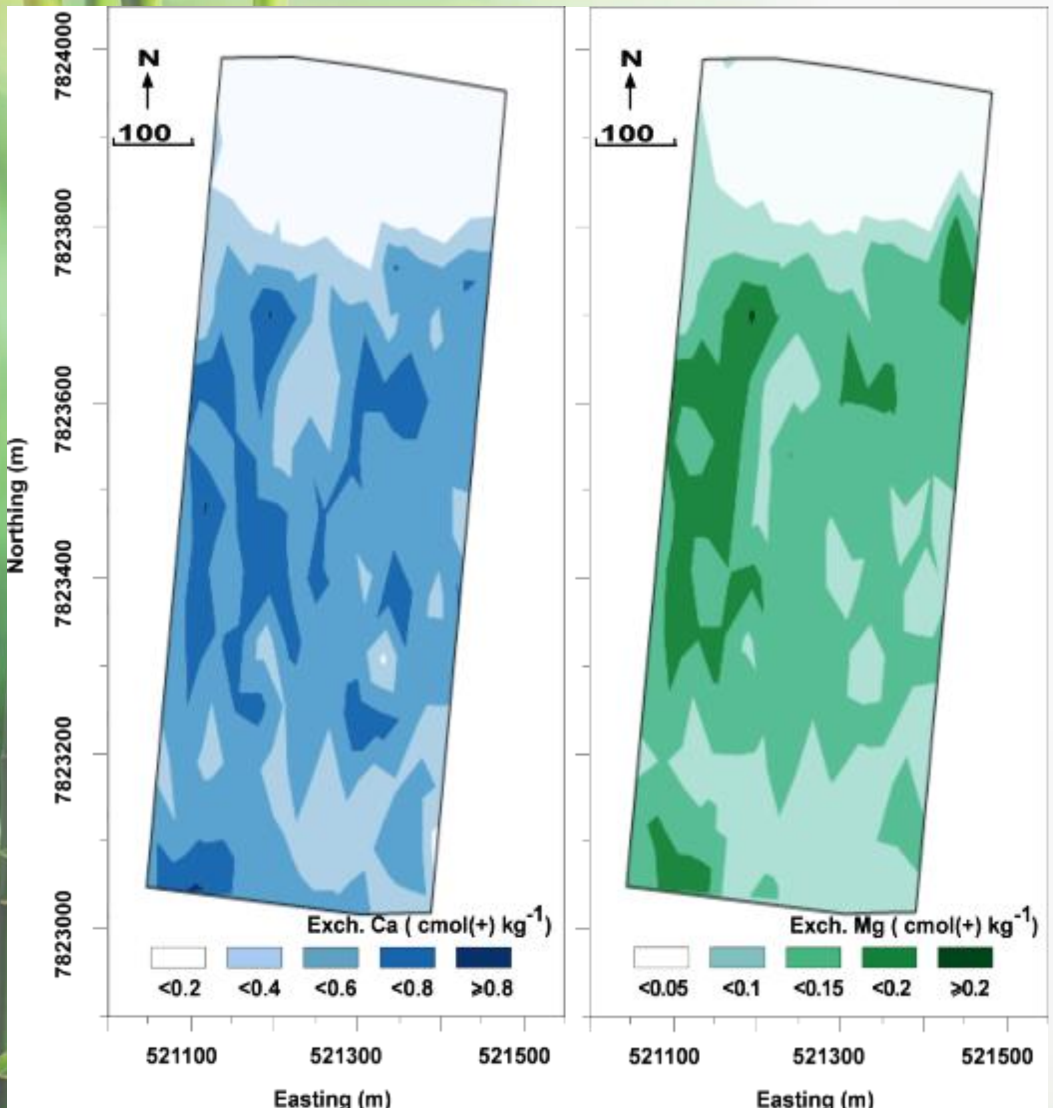
Gamma-ray spectrometry: RS700

Potassium (K),
Uranium (U),
Thorium (Th) and
Total count（TC）

DUALEM-421

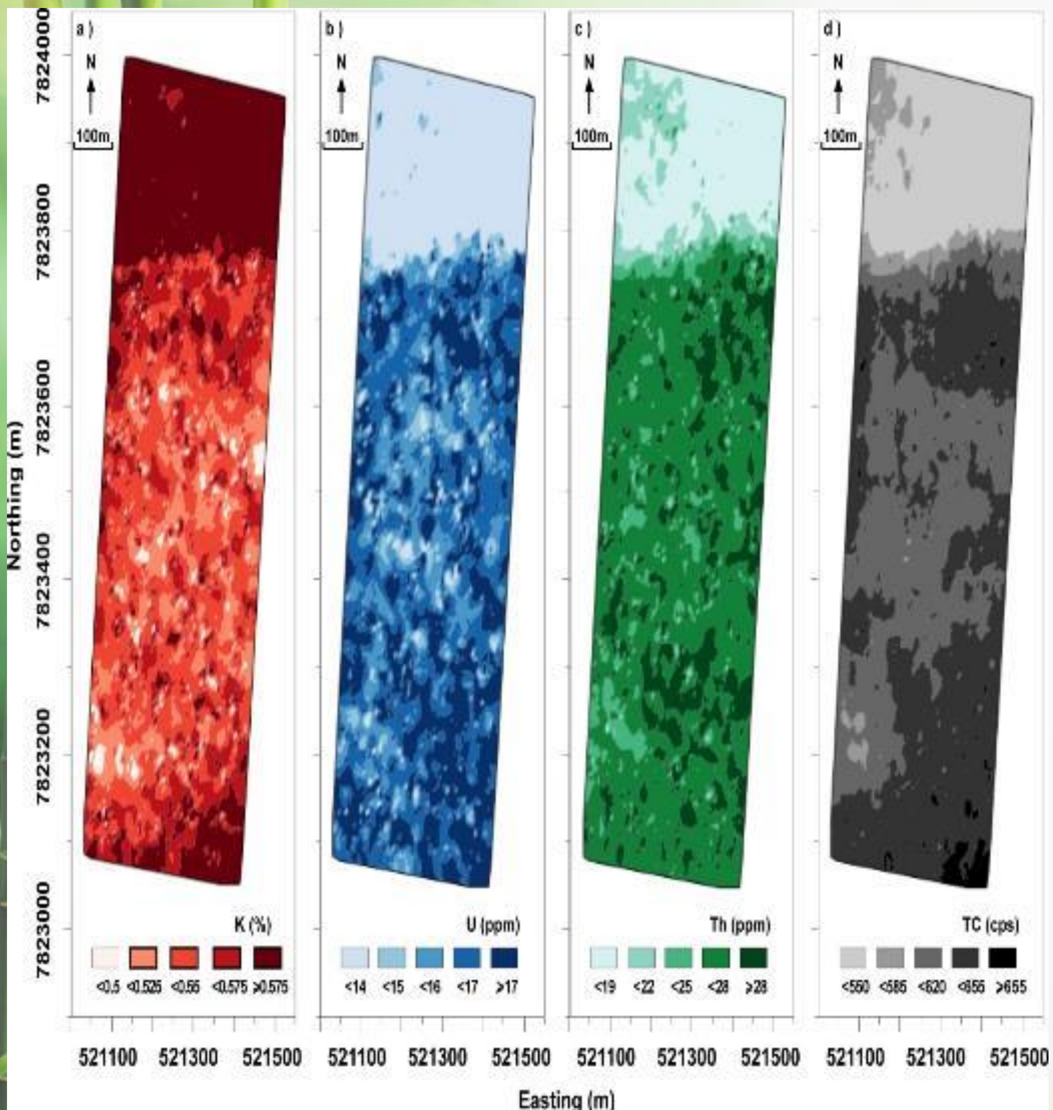
1mPcon (0-0.6 m)
1mHcon (0-1.0 m)
2mPcon (0-1.2 m)
2mHcon (0-3.0 m)

Results: Soil data



Exch. Ca and Exch. Mg

Results: Digital data (γ-ray)

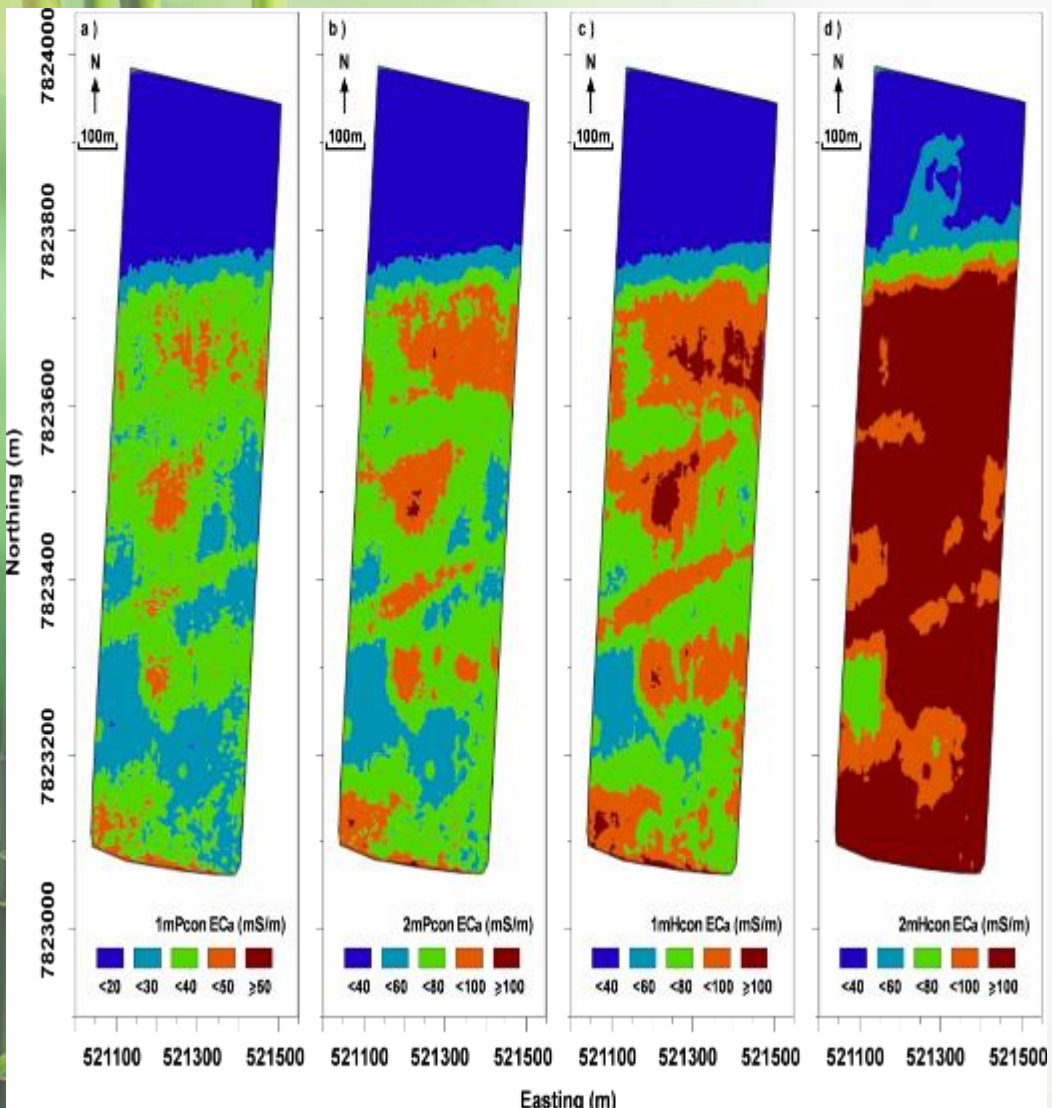


Gamma-ray spectrometry: RS700

Potassium(K),
Uranium(U),
Thorium(Th) and
Total count（TC）

Measures γ-rays in topsoil (0-0.45 m)

Results: Digital data (EM)



Electromagnetic induction: DUALEM-421

1m coils

Measures EC_a in topsoil

1mPcon 0-0.6 m

1mHcon 0-1.0 m

2m coils

Measures EC_a in subsurface

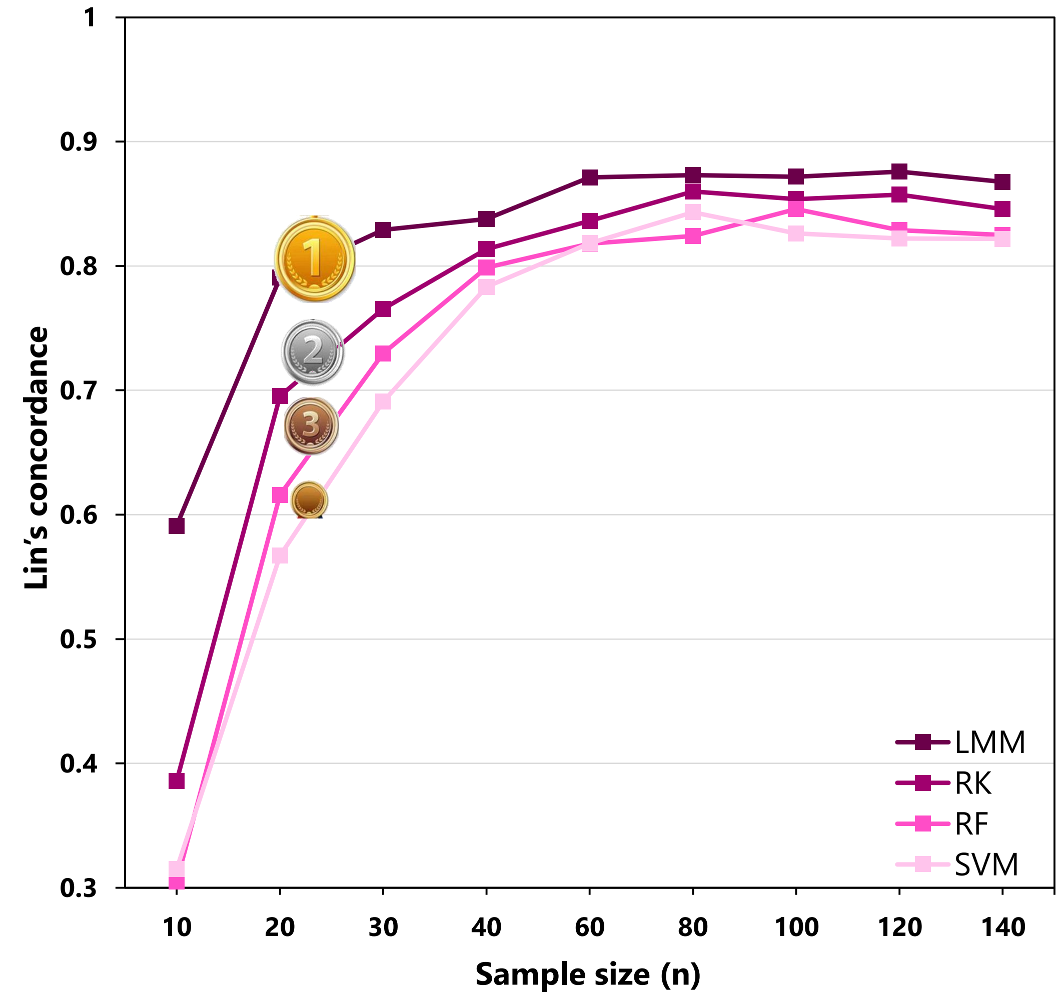
2mPcon 0-1.2 m

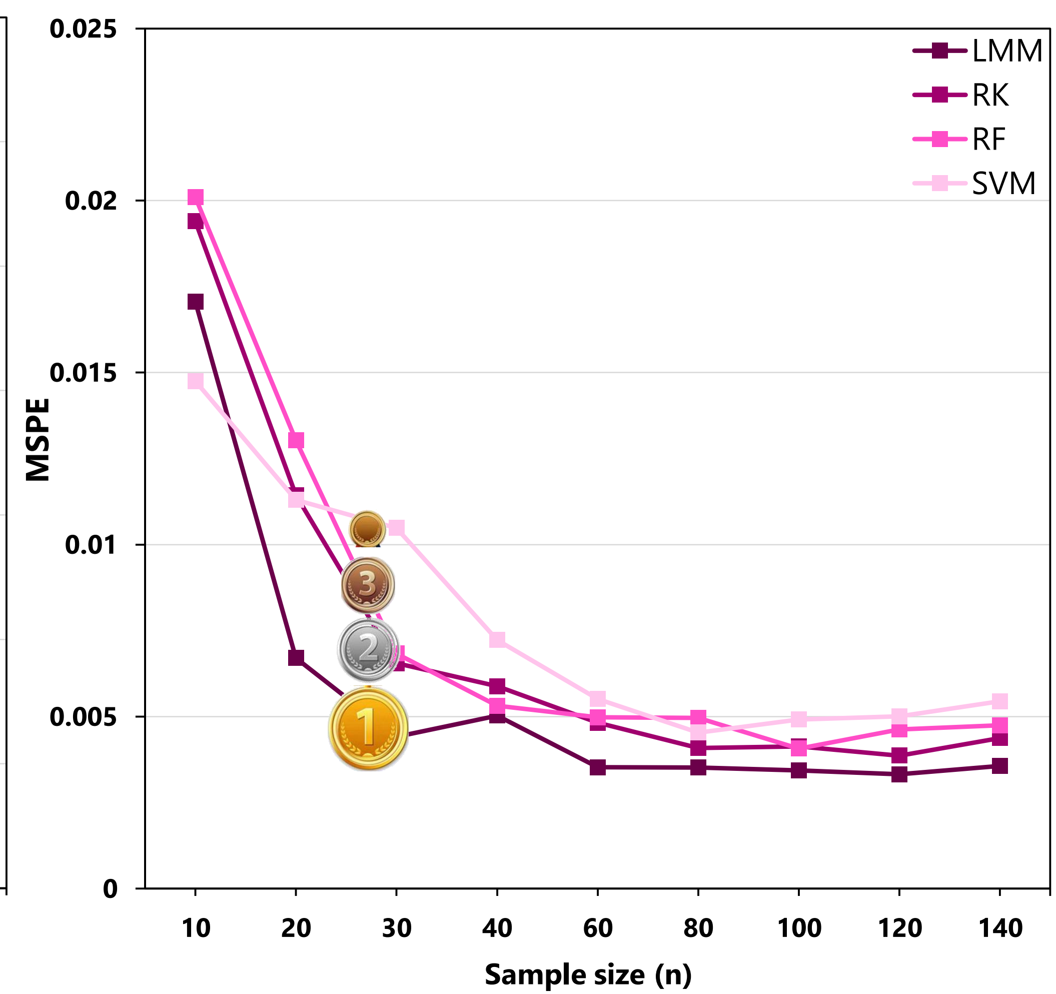
2mHcon 0-3.0 m

Measures EC_a

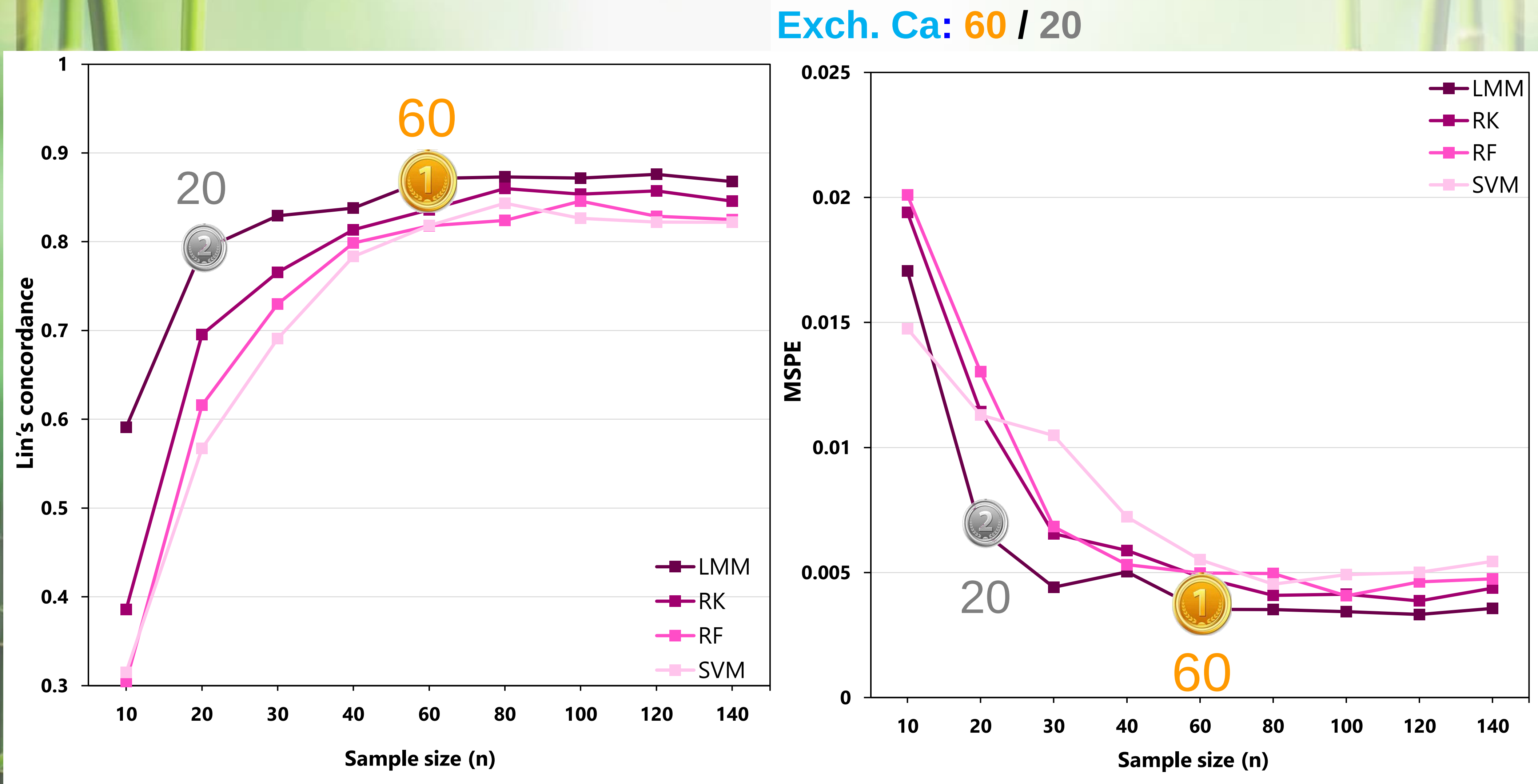
1. Which model is best?

Exch. Ca: LMM



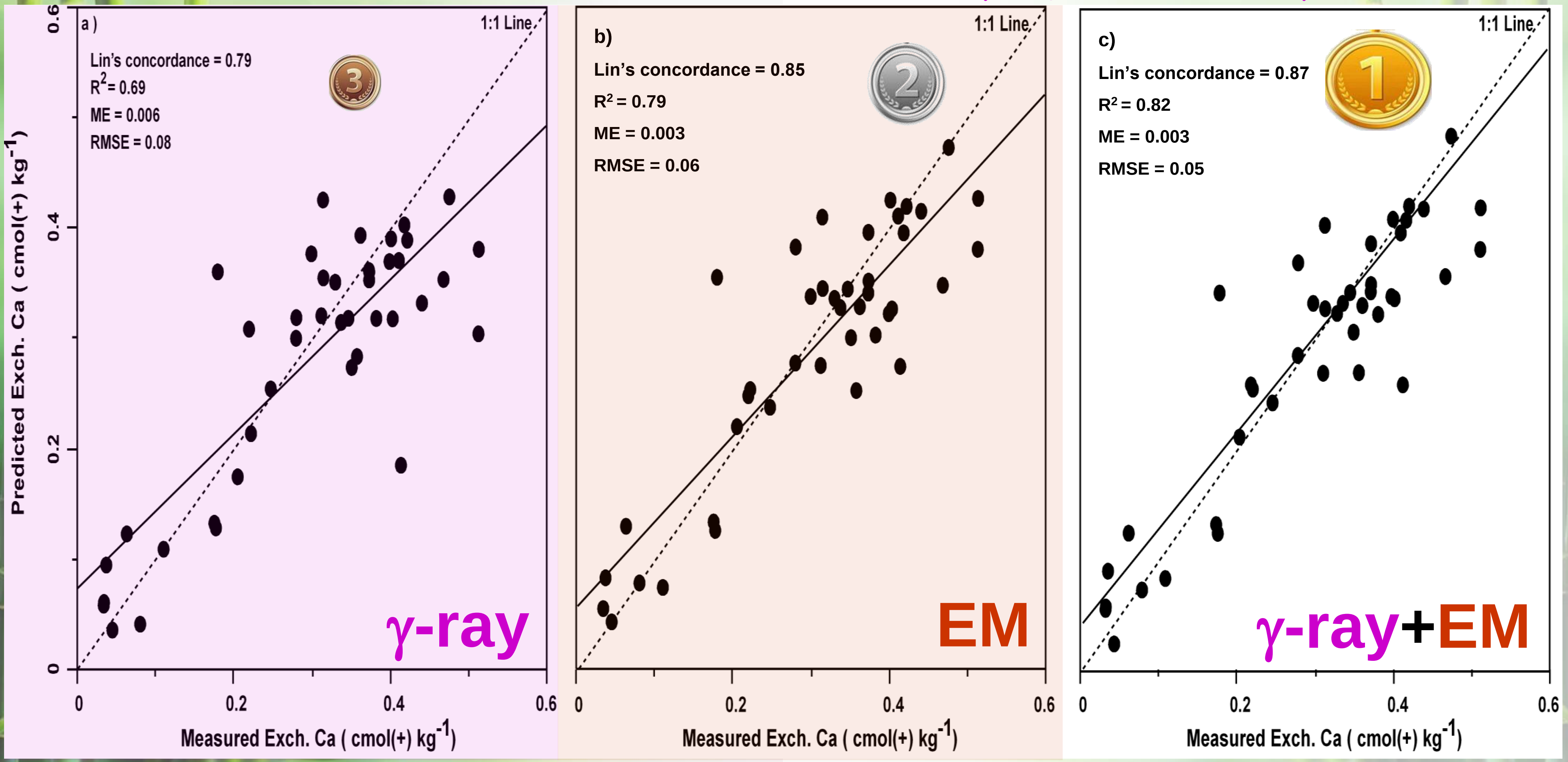


2. How many soil samples?

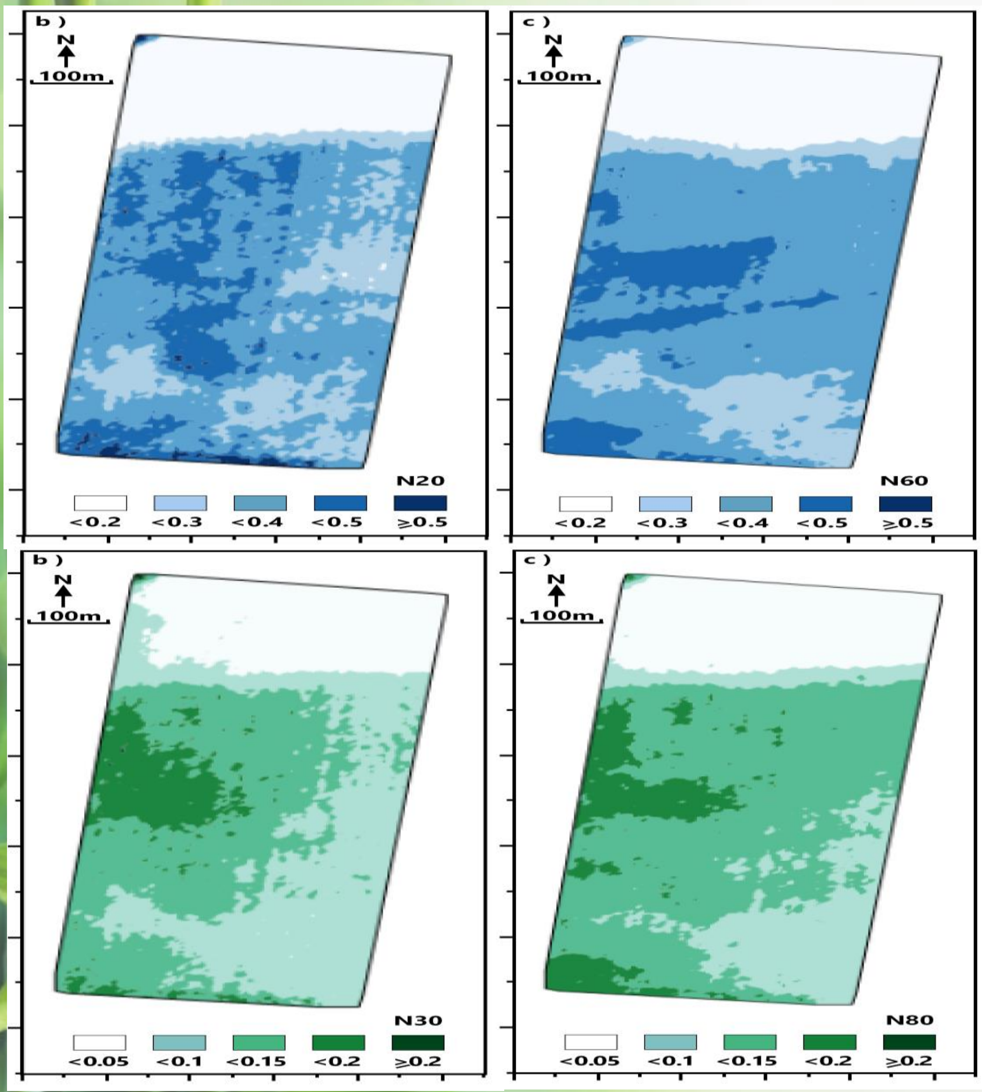


3. Which digital data: γ-ray or EM

Exch. Ca: γ-ray+EM > EM > γ-ray



Conclusions



In a sugarcane field in Burdekin Valley:

We can generate DSMs of

i) Exch. Ca and

ii) Exch. Mg

using easier to acquire γ-ray and EM data

1) Which mathematical model is best

LMM > RK > RF > SVM

2) How many soil samples do we need

Exch. Ca: 60 / 20+LMM

Exch. Mg: 40 / 30+LMM

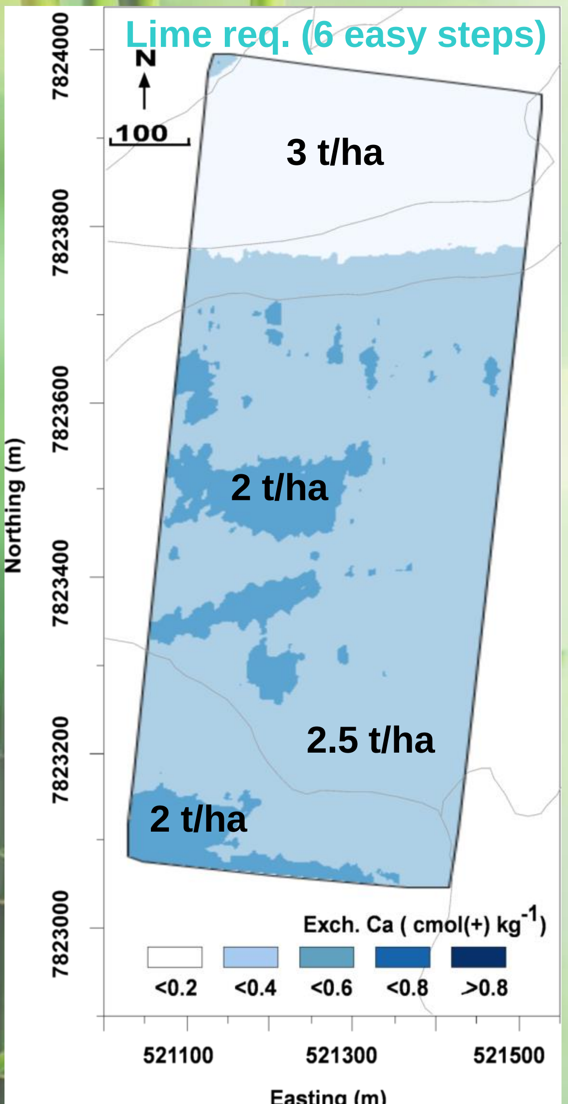
3) Which digital data is superior

γ-ray + EM 1

EM 2

γ-ray 3

Conclusions



In a sugarcane field in Burdekin Valley:

Calcium (Ca)

Table 1 – Lime guidelines based on exchangeable calcium (Ca)	
Soil calcium (meq/100g)	Lime application (t/ha)
<0.2	3
0.2-0.4	2.5
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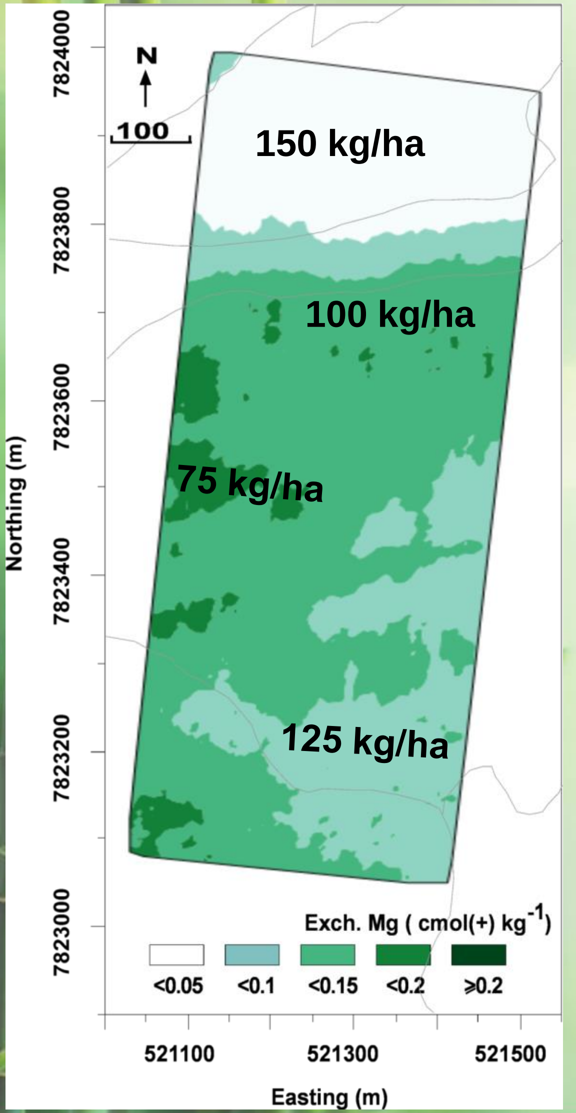
1.1-1.5	0.5

Conclusions



In a sugarcane field in Burdekin Valley:

Magnesium (Mg)

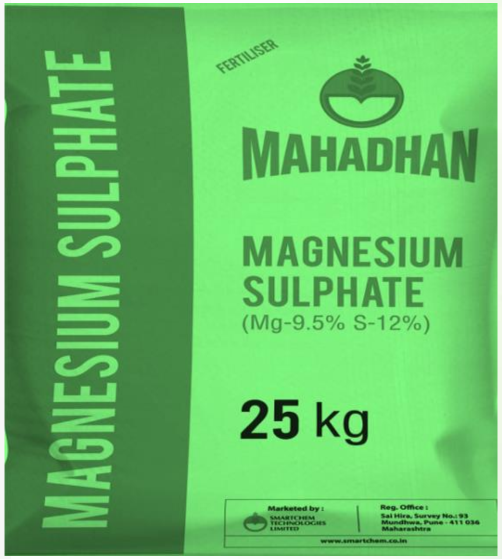


Table 2 – Magnesium guidelines based on exchangeable Mg	
Soil Mg (amm-acet) (meq/100g)	Mg rate (kg/ha)
<0.05	150
0.06-0.10	125
0.11-0.15	100
0.16-0.20	75
0.21-0.25	50
>0.25	0

DSM – An innovative “soil”ution?

What is working?

Conclusions

DSM: **Management zone**
CEC and
ESP
Individual soil properties
Calcium (Ca) and
Magnesium (Mg)

What do we still not know?

Whether this increases yield and has economic benefit? Cost-benefit of doing DSM and SIX-EASY-STEPS?

What constraints?

Yield data (satellite, airborne, proximal)?

Immediate priorities?

Train and retain (international) students who understand needs of industry.

Acknowledgements

HCPSL

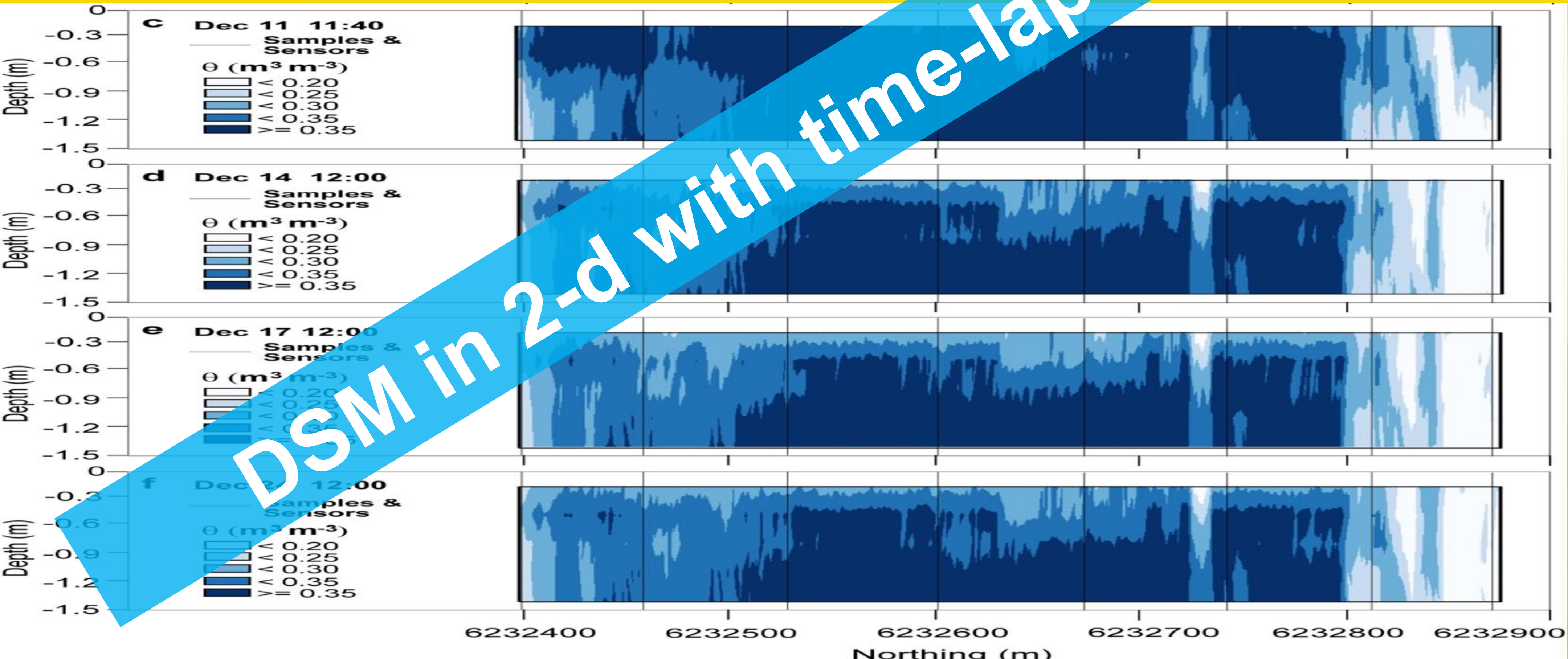
Herbert Cane Productivity Services Ltd.

sra Sugar Research Australia

Monitoring soil water dynamics using electromagnetic conductivity imaging and the ensemble Kalman Filter

Jingyi Huang, Alex B. McBratney,
Budiman Minasny, John Triantafilis

DSM in 2-d with time-lapse (θ)

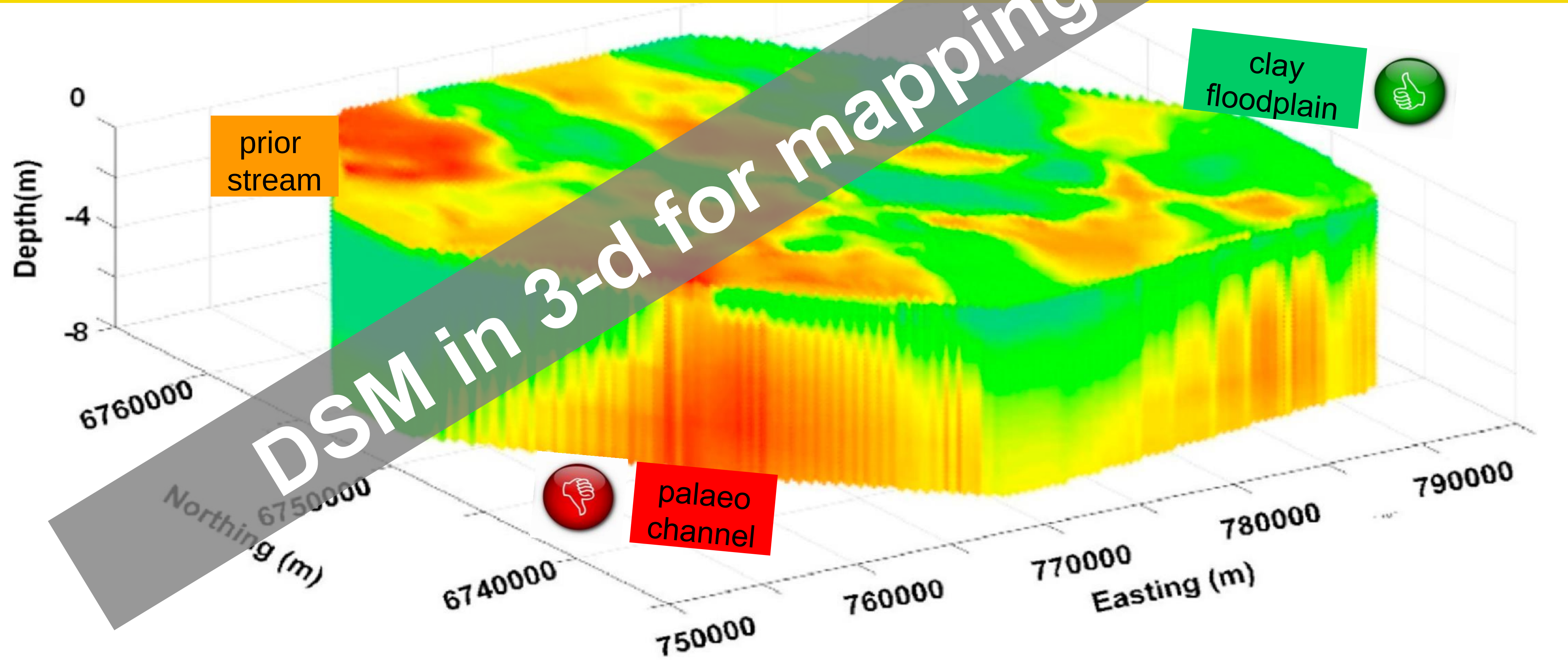


GEODERMA 285, 76-93

3-d regolith mapping of clay using inversion of EM38 and EM34

Zhao, X, Wang, J, Zhao, D, Li, N, Zare, E, Khongnawang, T, Muzzamal, M, Triantafilis, J.

DSM in 3-d for mapping clay



GEODERMA 346, 18-29