# USING EM AND GAMMA MAPS TO MAP SOIL TYPES AND HELP LOCATE SUBSOIL CONSTRAINTS FOR MANAGEMENT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

# AIMS – SUBSOIL CONSTRAINT PROJECT

To map **zones** at the **paddock and farm scale** for **soil constraint management** .

- Bottom-up (Yvette Oliver, Mike Wong, Karen Holmes, Gonz Mata) – ground geophysics and yield data
- Top-down (Karen Homes) - National Soil Landscape Grid / national rasters

# MAP SOIL TYPES THAT FARMERS MANAGE DIFFERENTLY

| DPRID MySoil type | Soil description | Area of wheatbelt (%) | Constraint | Management |
|---|---|---|---|---|
| Sands & Sandy Earths | Sandy texture throughout<br><br>Sand grading to loam | 24% | Low pH, compaction, non-wetting, nutrient leaching | Liming, ripping, mouldboard, non-wetting agents, nutrient timing |
| Clay & Shallow loamy duplex | Loamy or clayey surface texture and clayey subsoil<br>Loamy surface texture, abrupt change to clayey subsoil | 15% | Salinity, Sodicity, Boron | Gypsum, OM amendments, slotting, water harvesting |

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|---|---|---|---|---|
| Sands & Sandy Earths | Sandy texture throughout<br><br>Sand grading to loam | 24% | Low pH, compaction, non-wetting, nutrient leaching | Liming, ripping, mouldboard, non-wetting agents, nutrient timing |
| Gravels | Ironstone gravel (>20%) within 15cm from surface, greater than 20cm thick. | 7.8% | Nutrient leaching, poor water holding capacity, non-wetting | Manage differently and care with deep ripping, nutrient timing |
| Duplex soils * | Sandy or loamy surface texture. Abrupt change to sandy clay loam or clay. | 32% | Low pH, compaction<br>Shallow or deep duplex*, depth to duplex | Liming, ripping, spading, mouldboard, delving (depth dependant) |
| Gravelly duplex | Gravel over rock or clay at < 80cm | 8.2% | Low pH, Non-wetting<br>Clay subsoil may have salinity or sodicity | Liming, nutrients<br>Gypsum, OM amendment<br>Care with management |
| Clay & Shallow loamy duplex | Loamy or clayey surface texture and clayey subsoil<br>Loamy surface texture, abrupt change to clayey subsoil | 15% | Salinity, Sodicity, Boron | Gypsum, OM amendments, slotting, water harvesting |

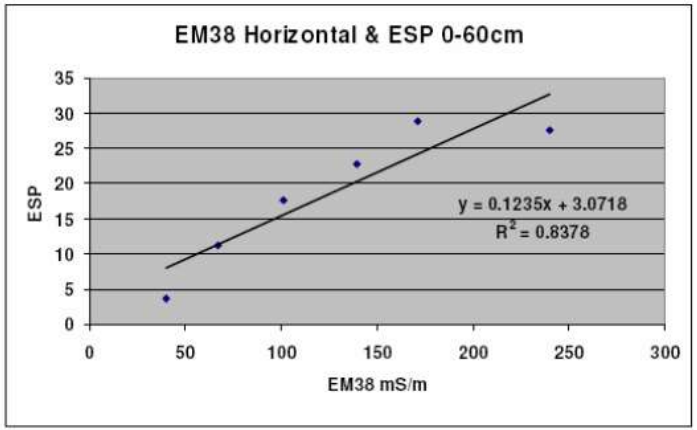
# GROUND BASED GEOPHYSICS

- Gamma radiometrics
  - Measures the natural emission of radioactive isotopes and daughter radionucliotides of uranium (238U), potassium (40K), and thorium (232Th)
  - Infers soil mineralogy, soil K, gravel, soil depth
  - Signal is mostly top 0.3m, but extend to 1m

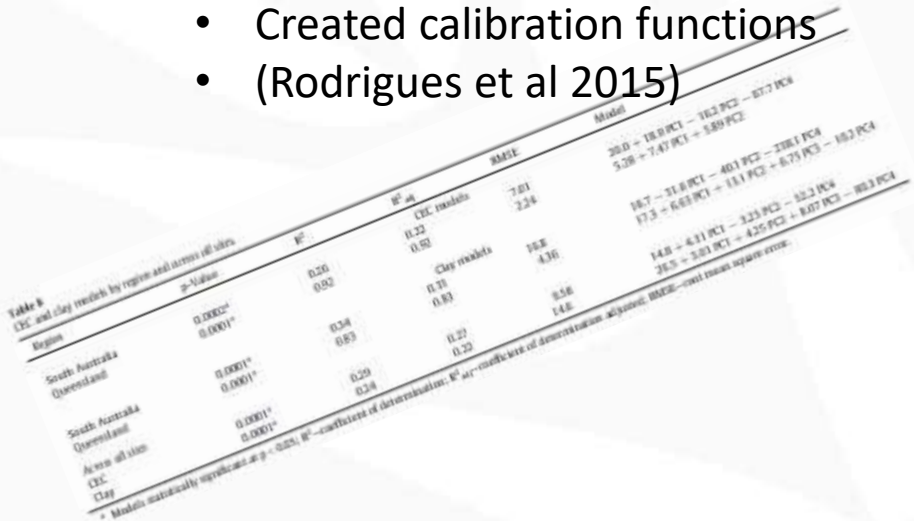
- Electromagnetic (EM)
  - Measures the soil electrical conductivity
  - Signal is related to water, salt and clay content
  - Signal from 0-1.5m depth depending on instrument

# ONE WAY OF USING GEOPHYSICS

- EM to soil property correlation,
- Create zones based on this property (and additional information about the yield)
- Knight 2007 etc




- Using gamma to soil property correlated to multiple gamma reading
- Statistical analysis (PCA)
- Created calibration functions
- (Rodrigues et al 2015)



# GEOPHYSICS TO MAP SOIL TYPE

Using low, medium and high classes of Gamma and EM

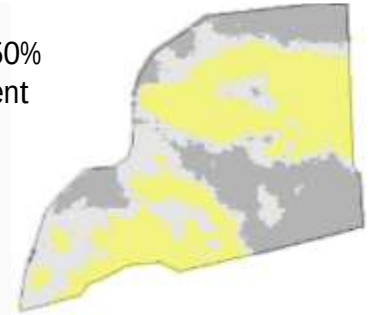
| Gamma | EM | WA MySoil type |
|---|---|---|
| Low | Low | Sand and Sandy earth |
| Low | High | Saline Sand |
| Medium | Low | Gravel |
| Medium | High | Duplex soils |
| High | Low | Gravelly duplex |
| High | High | Clay and shallow loamy duplex |

# “Digitally enhanced” soil map methodology

Gamma K

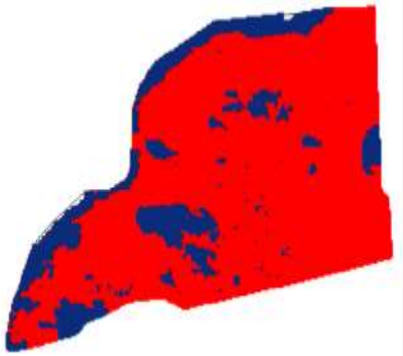
| <40 low | 40-70 Medium | >70 High |
|---|---|---|

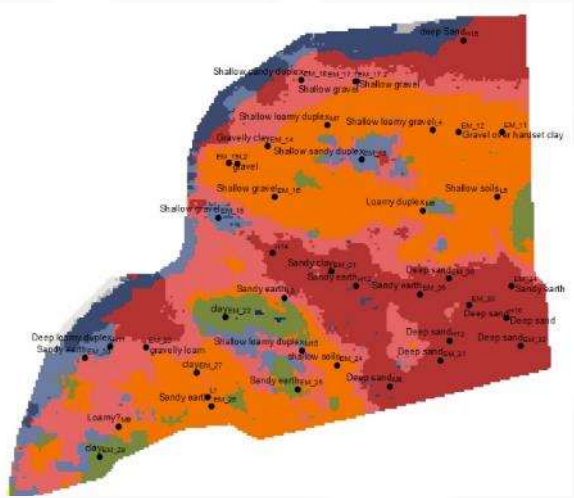
Layer is 50% transparent



EM

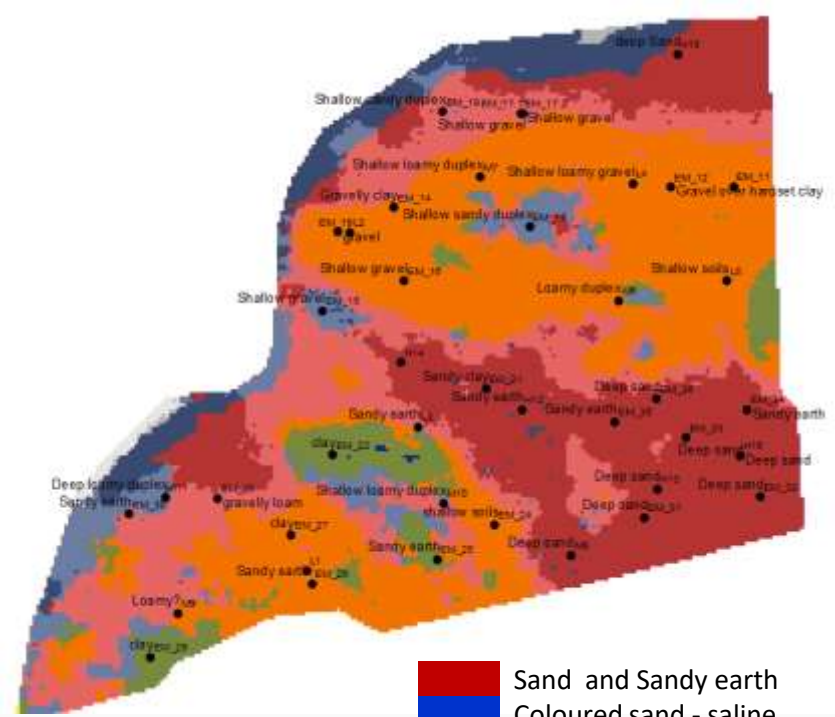
| <25 low | >25 High |
|---|---|





| | Soil type | Gamma | EM |
|---|---|---|---|
| | Sand and Sandy earth | Low | Low |
| | Coloured sand – saline/ loams | Low | High |
| | Gravel | Medium | Low |
| | Duplex soils | Medium | High |
| | Gravelly duplex | High | Low |
| | Clay and shallow loamy duplex | High | High |

# “Digitally enhanced” soil map compared to soil points




| Site ID | Soil name | Comments |
|---|---|---|
| H13 | Deep sand | Acid at depth (<4.8) |
| H14 | Deep sand | soild gravelly clay at 90 cm |
| H15 | deep Sand | Acid 20-60cm |
| H16 | Deep sand | |
| M8 | Deep sand | |
| EM_36 | Deep sand | |
| EM_33 | Deep sand | |
| EM_21 | Sandy clay | |
| H12 | Sandy earth | Gravelly clay at 80cm. Acid 20-60cm |
| EM_34 | Sandy earth | Sand increasing clay |
| EM_35 | Sandy earth | Sand increasing clay |
| L3 | Sandy earth | Compact gravel at 80cm. Not acid |
| EM_30 | Sandy earth | Some gravel |
| EM_17.1 | Shallow gravel | Hard clay at 20cm |
| EM_17.2 | Shallow gravel | Hard clay at 20cm |
| EM_18 | Gravels | Clay at 60cm |
| EM_28 | gravelly loam | |
| L1 | **Shallow soils** | coarse gravel/rock at 20-25 cm |
| L5 | **Shallow soils** | coarse gravel/rock at 20-25 cm |
| EM_24 | **Shallow soils** | Gravel below 10cm |
| EM_19 | Gravel | |
| EM_12 | Gravel over hardset clay | |
| EM_14 | Gravelly clay | >50% gravel |
| EM_27 | Gravelly clay | |
| M7 | Gravelly loamy duplex | Loam with gravel, Clay at 30cm |
| L2 | Gravelly Loamy duplex | >50% gravel then Solid clay at 60cm |
| L4 | Gravelly loamy duplex | >50% gravel then compacted at 40cm |
| M9 | **Loamy?** | Yellow clay at 80cm |
| M6 | Loamy duplex | Clay at 60cm |
| H11 | Deep loamy duplex | Yellow Clay at 50 cm |
| M10 | Shallow loamy duplex | Red clay at 40cm |
| EM_13 | Shallow duplex | Clay at 20cm |
| EM_15 | **Gravelly clay** | Hard clay at 20cm |
| EM_22 | clay | |
| EM_25 | loamy duplex | Some gravel |
| EM_29 | clay | |

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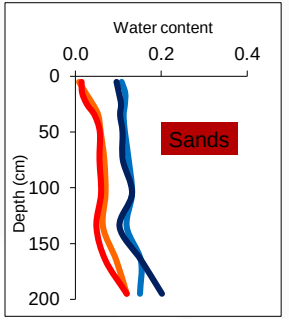
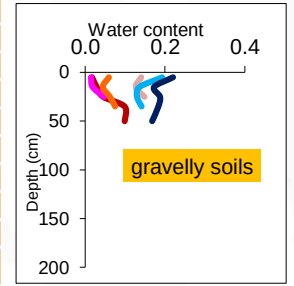
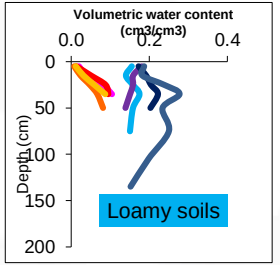


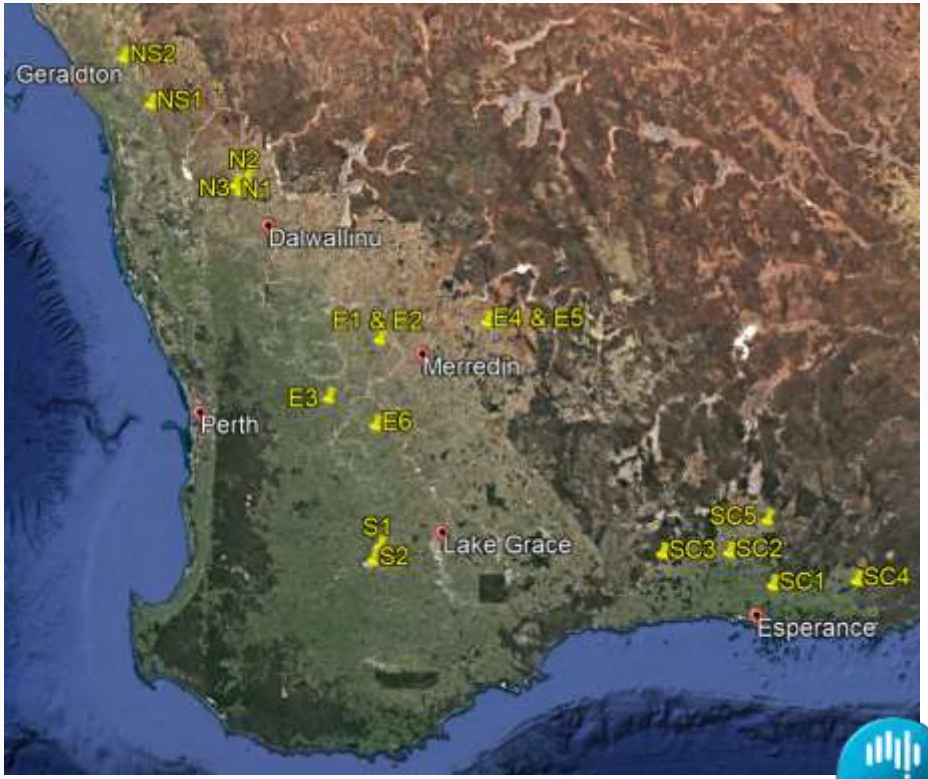



# TESTING THE SOIL MAPPING METHOD

- The case study sites included
- 16 farmers
- 29 paddocks (2733ha)
- 1 whole farm (>20 paddocks, 2466 ha)
- 355 soil sampling points

Cut-off values for EM and gamma classes estimated from “expert” opinion using all soil data available



# GAMMA CLASSES

| | | closest town | No pdks | Area | No pts | type | Visual cutoff HIGH | Mean pdk |
|---|---|---|---|---|---|---|---|---|
| Northern | N1 | Coorow | 3 | 243 | 32 | K | 70 | 68 |
| | N2 | Buntine | 3 | 168 | 26 | K | 80 | 82 |
| | N3 | Buntine | 3 | 265 | 41 | K | 70 | 67 |
| Eastern | E1+E2 | Kellerberrin | 1 | 67 | 6 | K | 70 | 40 |
| | | | 1 | 69 | 9 | K | | 85 (62) |
| | E3 | Greenhills | 2 | 142 | 8 | K | 60 | 61 |
| | E4+E5 | Bodallin | 1 | 142 | 6 | K | 70 | 114 |
| | | | 1 | 115 | 21 | K | | 56 (83) |
| | E6 | Corrigin | 3 | 89 | 15 | K | 20 | 18 |
| Southern | S1 | Dumbleyung | 3 | 332 | 21 | Kconc | 1.25 | 1.27 |
| | S2 | Dumbleyung | >20 | 2466 | 68 | Kconc | 1.25 | 1.27 |
| South Coast | SC1 | Myrup | 1 | 79 | 15 | K | 12 | 11 |
| | SC2 | Scaddan | 1 | 325 | 26 | K | 25 | 27 |
| | SC3 | Munglinup | 1 | 195 | 17 | K | 13 | 14 |
| | SC4 | Howick | 1 | 164 | 16 | K | 14 | 13.7 |
| | SC5 | Salmon Gums | 1 | 183 | 11 | K | 15 | 17 |

Cutoff for high Gamma class ~ mean gamma of paddock

# GAMMA CLASSES

| | | closest town | No pdks | Area | No pts | type | Visual cutoff LOW | SD | Mean-0.6*SD |
|---|---|---|---|---|---|---|---|---|---|
| Northern | N1 | Coorow | 3 | 243 | 32 | K | 40 | 49 | 39 |
| | N2 | Buntine | 3 | 168 | 26 | K | 50 | 38 | 59 |
| | N3 | Buntine | 3 | 265 | 41 | K | 40 | 34 | 47 |
| Eastern | E1+E2 | Kellerberrin | 1 | 67 | 6 | K | 40 | 22 | 40 |
| | | | 1 | 69 | 9 | K | | 52 (37) | |
| | E3 | Greenhills | 2 | 142 | 8 | K | 30 | 17 | 51 |
| | E4+E5 | Bodallin | 1 | 142 | 6 | K | 45 | 9 | 77 |
| | | | 1 | 115 | 21 | K | | 17 (13) | |
| | E6 | Corrigin | 3 | 89 | 15 | K | 13 | 13 | 10 |
| Southern | S1 | Dumbleyung | 3 | 332 | 21 | Kconc | 0.75 | 0.3 | 1 |
| | S2 | Dumbleyung | >20 | 2466 | 68 | Kconc | 0.93 | 0.52 | 1 |
| South Coast | SC1 | Myrup | 1 | 79 | 15 | K | - | 3.6 | 9 |
| | SC2 | Scaddan | 1 | 325 | 26 | K | 15 | 8 | 22 |
| | SC3 | Munglinup | 1 | 195 | 17 | K | 8 | 5 | 11 |
| | SC4 | Howick | 1 | 164 | 16 | K | 9 | 2.5 | 12 |
| | SC5 | Salmon Gums | 1 | 183 | 11 | K | 12 | 6 | 13 |

Cutoff for high Gamma class ~ mean gamma of paddock

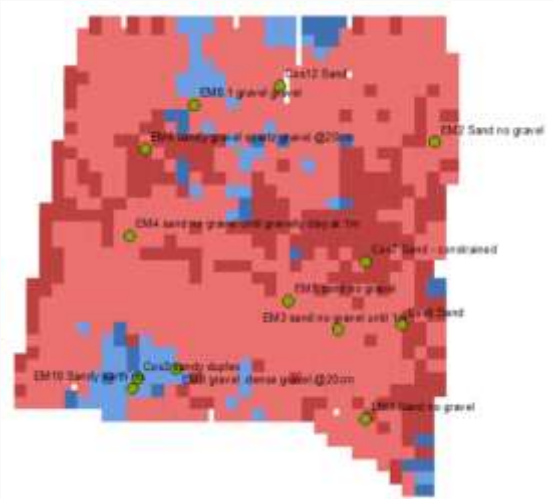
Cut-off for **low** Gamma class ~ mean-0.6SD of paddock gamma

# EM CLASSES

| | | closest town | No pdks | Area | No pts | | Visual cutoff HIGH | Mean pdk |
|---|---|---|---|---|---|---|---|---|
| Northern | N1 | Coorow | 3 | 243 | 32 | | 20 | 22 |
| | N2 | Buntine | 3 | 168 | 26 | | 20 | 32 |
| | N3 | Buntine | 3 | 265 | 41 | | 25 | 21 |
| Eastern | E1+E2 | Kellerberrin | 1<br>1 | 67<br>69 | 6<br>9 | | 15 | 9<br>22 (16) |
| | E3 | Greenhills | 2 | 142 | 8 | | 15 | 50 |
| | E4+E5 | Bodallin | 1<br>1 | 142<br>115 | 6<br>21 | | 82 | 50<br>111 |
| | E6 | Corrigin | 3 | 89 | 15 | | 10 | 7 |
| Southern | S1 | Dumbleyung | 3 | 332 | 21 | | 110 | 146 |
| | S2 | Dumbleyung | >20 | 2466 | 68 | | 45 | 74 |
| South Coast | SC1 | Myrup | 1 | 79 | 15 | | 85 | 46 |
| | SC2 | Scaddan | 1 | 325 | 26 | | 40 | 128 |
| | SC3 | Munglinup | 1 | 195 | 17 | | 55 | 131 |
| | SC4 | Howick | 1 | 164 | 16 | | 50 | 44 |
| | SC5 | Salmon Gums | 1 | 183 | 11 | | 100 | 111 |

Cut-off for **low** EM ~ mean of paddock EM

# THE EXCEPTIONS – NORTHERN SANDPLAIN



Sandplain – no high gamma

NS1

| | |
|---|---|
| Pale Sand constrained at depth | Gamma TC <135 and EM <15 |
| Coloured sand - saline | Gamma TC < 135 and EM >15 |
| Sand | Gamma TC >135 and EM <15 |
| Sandy duplex | Gamma TC >135and EM > 15 |

| | |
|---|---|
| Pale Sand | NS2 |
| Sandy Earth | Gamma TC < 195 and EM <1.8 |
| | Gamma TC < 195 and EM >1.8 |

# “Digitally enhanced” soil map methodology

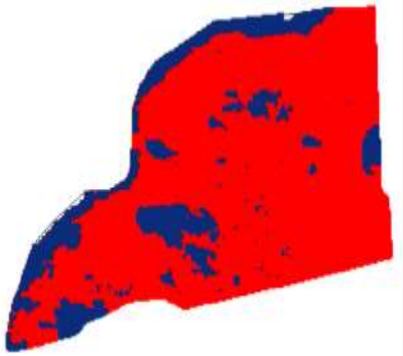
Gamma K

| Mean-0.6SD LOW | Medium | Mean HIGH |
|---|---|---|

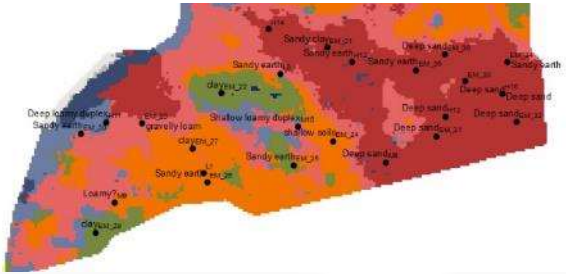
Layer is 50% transparent

EM

| <Mean LOW | >Mean HIGH |
|---|---|



Adjust with farmer knowledge!!



| | Soil type | Gamma | EM |
|---|---|---|---|
| | Sand and Sandy earth | Low | Low |
| | Coloured sand – saline/ loams | Low | High |
| | Gravel | Medium | Low |
| | Duplex soils | Medium | High |
| | Gravelly duplex | High | Low |
| | Clay and shallow loamy duplex | High | High |

# Can we use free/cheap airborne data?

Only 90m data available i.e Soil and Landscape Grid of Australia (SLGA), Gamma radiometrics

## The Good

- Eastern Wheatbelt
- Southern
- South Coast

Paddock Scale

Digital enhanced soil map

Dsmart

SLGA Regional WA
% Clay 60-90cm

## The Bad

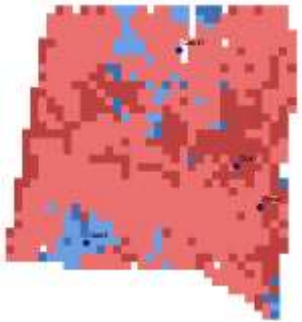
- Northern areas – (Buntine)

Digital enhanced soil map

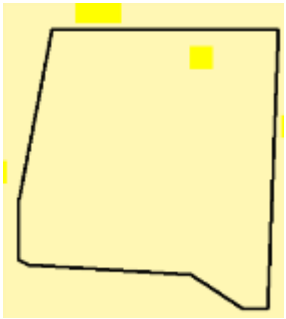
Dsmart

SLGA Regional WA
% Clay 30-60cm

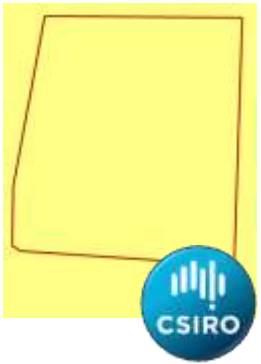
## The Ugly



Dsmart



SLGA Regional WA
%Clay 30-60cm

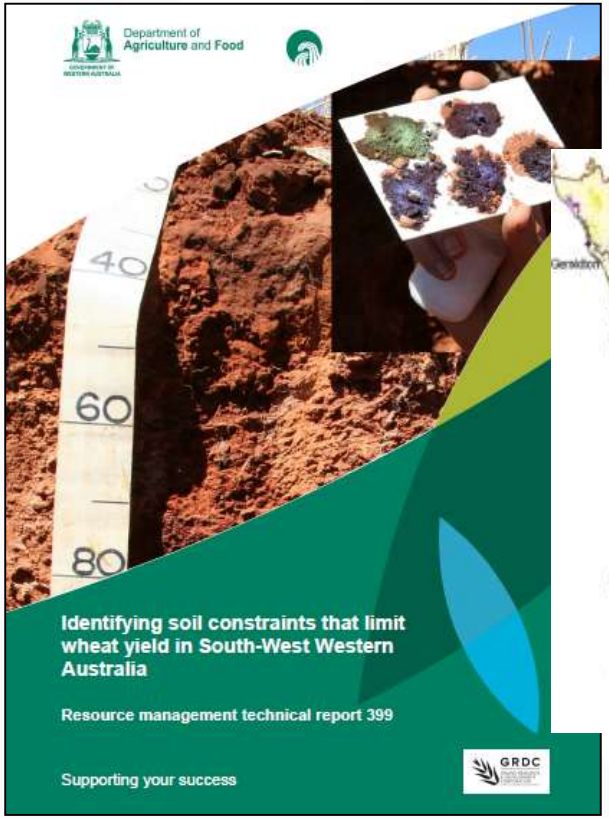


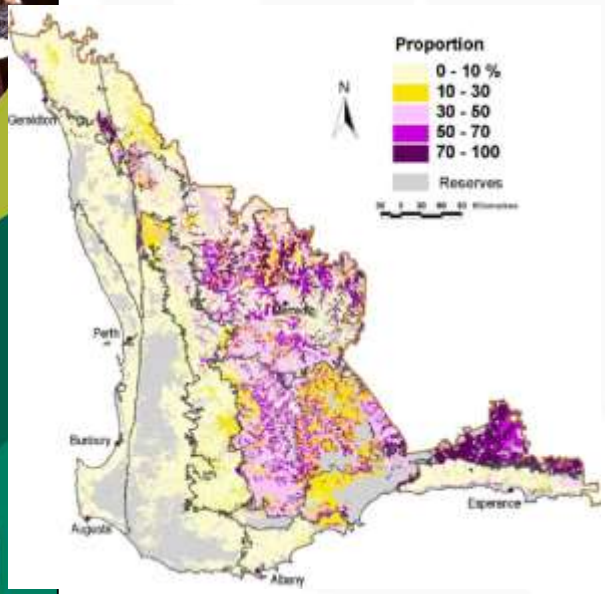
# WHAT ABOUT SOIL CONSTRAINTS?

- We know likely constraints for soil types  in our region

BUT

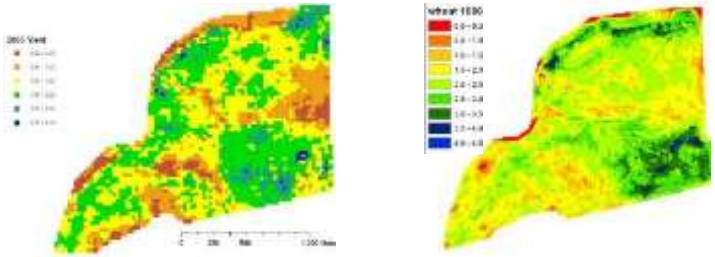
- We don't know if OUR soil is constrained?



# Is my paddock constrained?

Yield maps

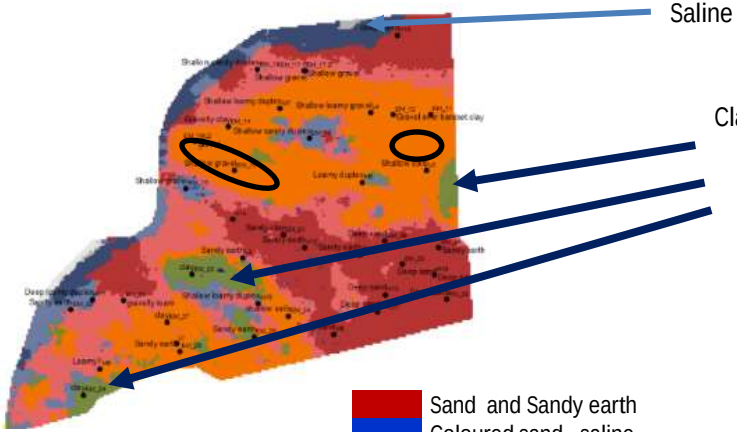


Average fraction of potential yield =
Yield/farm max potential averaged over number of years

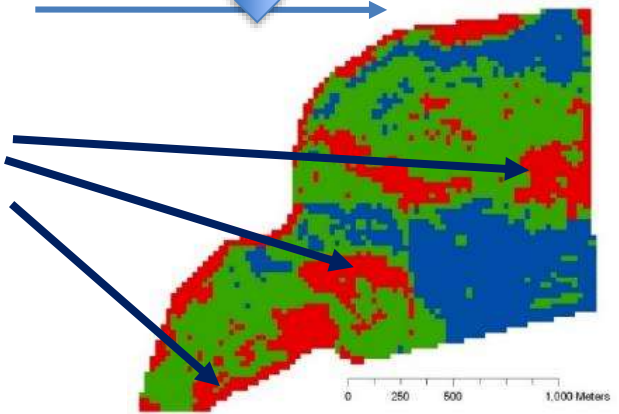
| | |
|---|---|
| Poor = 0.5 | 14% of paddock |
| Medium = 0.5-0.75 | 65% of paddock |
| Good = >0.75 | 21% of paddock |

Saline - Poor yield

Clay – Poor yield



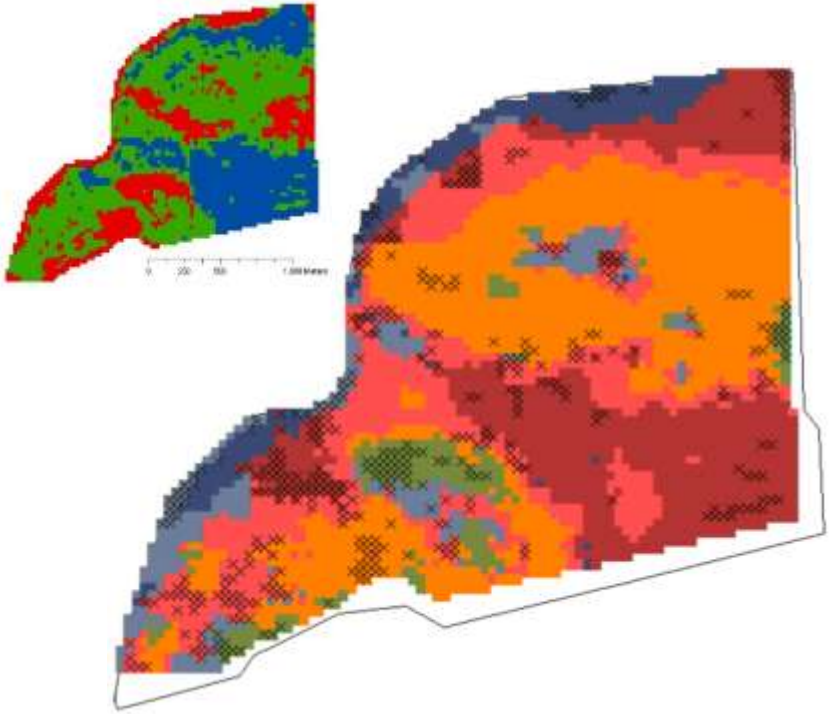
Sand and Sandy earth
Coloured sand - saline
Gravel
Deep loamy duplex
Clay
Gravelly duplex




Same soil but different yield class!!
Place to start looking!

# Is that soil on my paddock constrained?

- For each soil type determine the best yield  i.e. benchmarking
- Relative Yield (soil type) =  yield/best yield for soil type < 0.5 = < 50% of potential!!



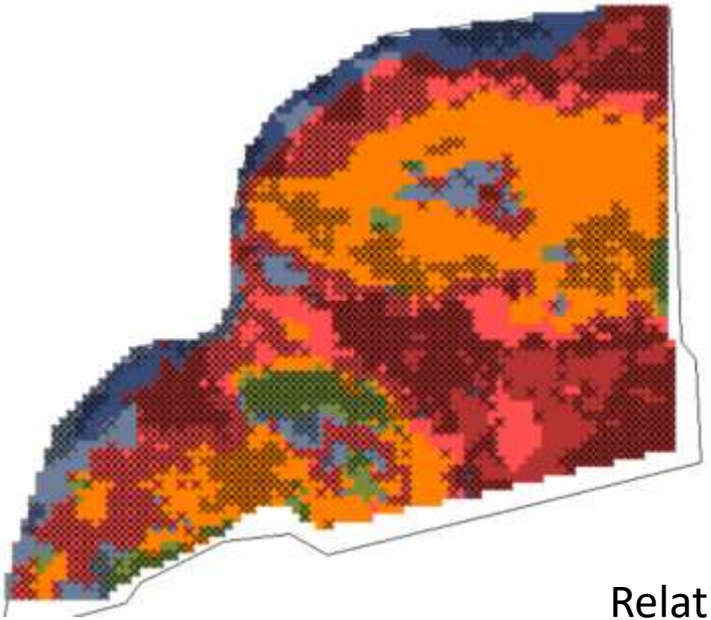
| | Soil type | Area | % area of soil type that the relative yield |
|---|---|---|---|
| | | | < 0.5 |
| | Sand  and Sandy earth | 58 | 16% |
| | Coloured sand – saline/ loams | 16 | 7% |
| | Gravel | 58 | 15% |
| | Duplex soils | 19 | 12% |
| | Gravelly duplex | 81 | 4% |
| | Clay and shallow loamy duplex | 12 | 28% |

Relative Yield (soil type) <0.5

Major soil constraint on 11% of paddock

# Is that soil on my paddock constrained?

- For each soil type determine the best yield for soil type i.e. benchmarking
- Relative Yield (soil type) = yield/best yield for soil type < 0.6 = < 60% of potential!!



| | Soil type | Area | % area of soil type that the relative yield | |
|---|---|---|---|---|
| | | | < 0.5 | < 0.6 |
| | Sand and Sandy earth | 58 | 16% | **72%** |
| | Coloured sand – saline/ loams | 16 | 7% | 22% |
| | Gravel | 58 | 15% | 68% |
| | Duplex soils | 19 | 12% | 24% |
| | Gravelly duplex | 81 | 4% | 21% |
| | Clay and shallow loamy duplex | 12 | 28% | 65% |

Relative Yield (soil type) <0.6
moderate soil type constraint on 46% of paddock

# CONCLUSIONS

- We can map soil types for farm management using ground based geophysics by overlay gamma and EM
  - Gamma into 3 classes – use the mean and mean-0.6 SD
  - EM into 2 classes – use mean
  - Refine classes with point data and local knowledge

- Analyse yield maps by 1) best part of farm or paddock and 2) best yield for soil type on farm or paddock.
- Target areas for sampling for nutrients and constraints

FUTURE – soil depth (GPR?, gamma rules), using other data sources

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