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Proximal Sensing of Soil Biological Activity for Precision Agriculture

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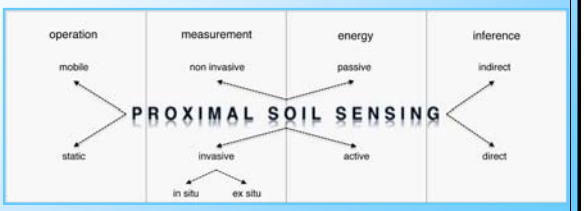
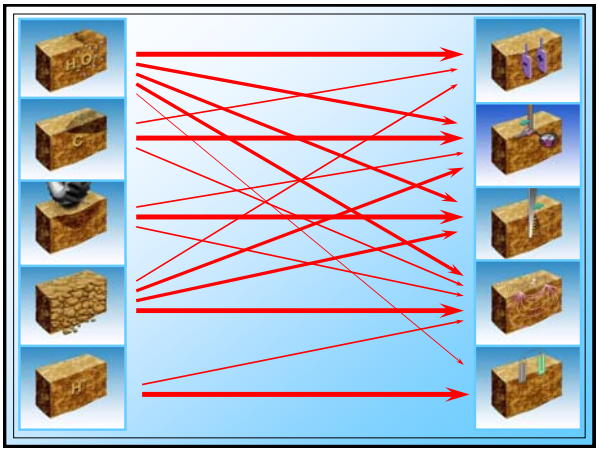
Proximal Soil Sensing

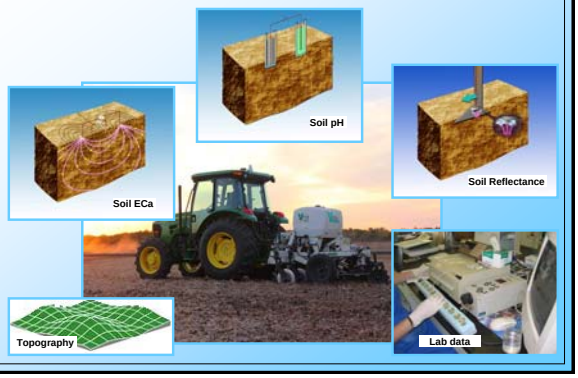
Proximal Soil Sensing (PSS) is a set of technologies developed to measure the physical, chemical and biological properties of soil when placing the sensor in contact with, or at a proximal distance (less than 2 m) to, the soil being characterized

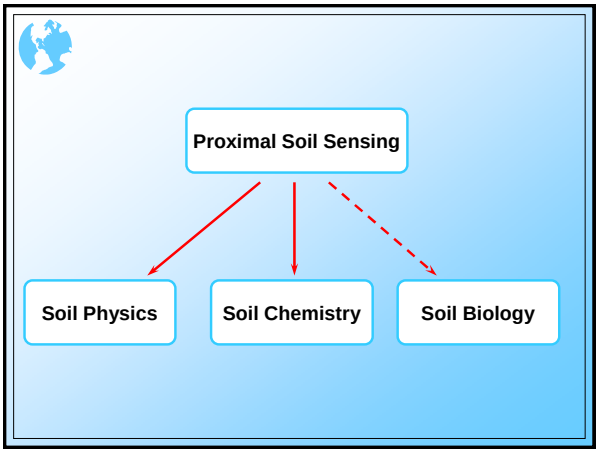


Advances in Agronomy 113: 237-283



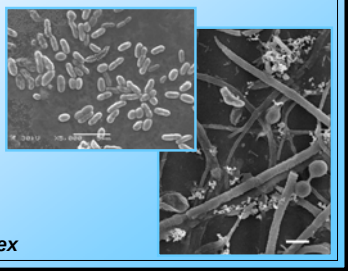
Sensor Fusion





Biofilm Approach

- 1 x 5 cm polyethylene terephtalate plastic films
- 3, 6 and 9 days in soil
- *Genera of diazotrophic bacteria*
  - *Bacillius*
  - *Azotobacter*
  - *Enterobacter*
  - *Flavobacterium*
  - *Pseudomonas*
  - *Rhizobium*
- *Phyla of fungi*
  - *Ascomycota*
  - *Zygomycota*
- *Crop Status*
  - *Excess Green Index*

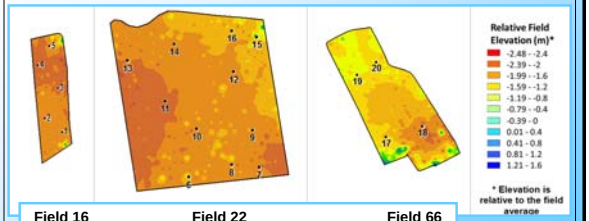


Experimental Sites

	Field 16	Field 22	Field 66
Area, ha	2.8	14.1	4.9
Number of sites	5	11	4
Season	Third year forage crop		Second year forage crop
Cultivar	Mix of alfalfa (16.8 kg/ha) and brome grass (11.2 kg/ha) planted on 5-May-2010		Mix of alfalfa (16.8 kg/ha), brome grass (11.2 kg/ha) and tall fescue (4.5 kg/ha) planted on 12-May-2011
Prior crop	Grain corn in 2010		Silage corn in 2009

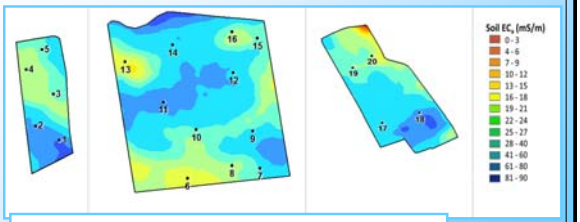
Field 16 Field 22 Field 66

Relative Elevation



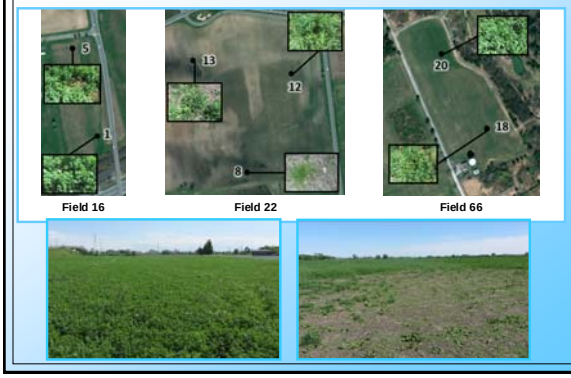
Field 16 Field 22 Field 66

Apparent Electrical Conductivity

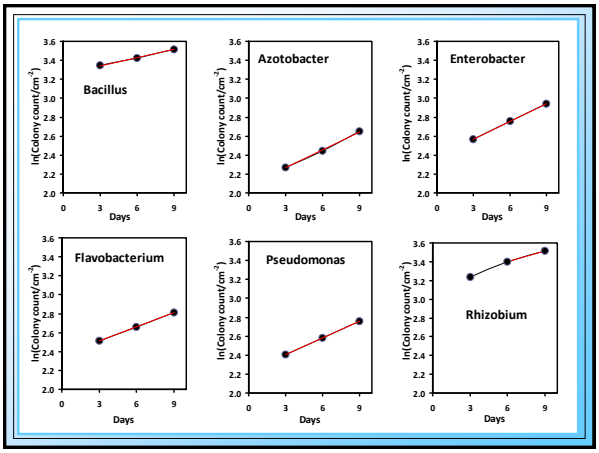


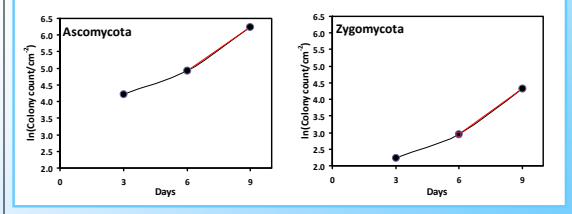
Field 16 Field 22 Field 66

Site Examples



Field 16 Field 22 Field 66





Physical Properties

Site characteristic	Genera of diazotrophic bacteria: Bacillius	Azotobacter	Enterobacter	Flavobacterium	Pseudomonas	Rhizobium	Phyla of fungi: Ascomycota	Zygomycota
SOM	0.00 (0.96)	0.04 (0.41)	0.02 (0.52)	00.02 (0.60)	0.15 (0.10)	0.03 (0.46)	0.03 (0.50)	0.00 (0.81)
Moisture	0.01 (0.64)	0.01 (0.69)	0.01 (0.66)	0.08 (0.21)	0.18 (0.06)	0.03 (0.49)	0.00 (0.85)	0.00 (0.96)
Sand	0.02 (0.56)	0.02 (0.53)	0.00 (0.83)	0.03 (0.49)	0.07 (0.24)	0.12 (0.14)	0.16 (0.08)	0.04 (0.38)
Silt	0.02 (0.51)	0.00 (0.95)	0.00 (0.93)	0.09 (0.21)	0.12 (0.14)	0.00 (0.94)	0.23 (0.03)	0.08 (0.24)
Clay	0.00 (0.87)	0.07 (0.25)	0.00 (0.79)	0.00 (0.77)	0.01 (0.73)	0.46 (0.00)**	0.03 (0.47)	0.00 (0.85)
Vegetation coverage	0.03 (0.44)	0.08 (0.22)	0.04 (0.40)	0.02 (0.58)	0.23 (0.03)	0.12 (0.14)	0.17 (0.07)	0.01 (0.64)

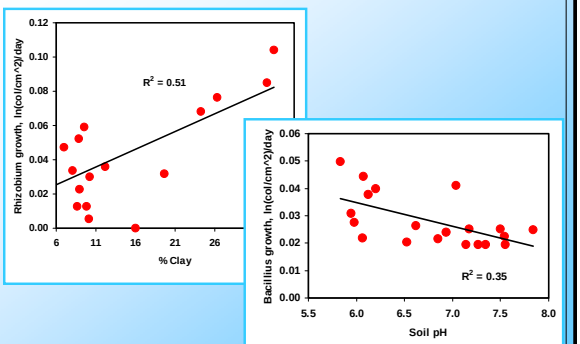
* $p < 0.01$
** $p < 0.001$

Chemical Properties

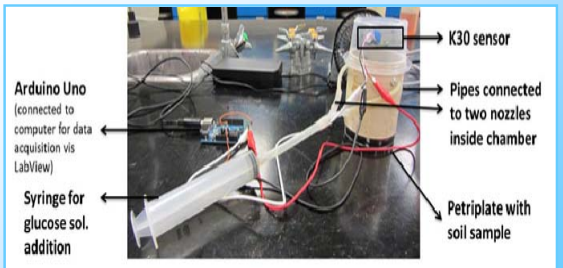
Site characteristic	Genera of diazotrophic bacteria: Bacillius	Azotobacter	Enterobacter	Flavobacterium	Pseudomonas	Rhizobium	Phyla of fungi: Ascomycota	Zygomycota
pH	0.36 (0.00)**	0.12 (0.14)	0.06 (0.28)	0.00 (0.86)	0.37 (0.00)**	0.03 (0.43)	0.04 (0.39)	0.08 (0.24)
P	0.25 (0.02)	0.00 (0.79)	0.01 (0.70)	0.02 (0.59)	0.00 (0.93)	0.06 (0.29)	0.03 (0.47)	0.05 (0.34)
K	0.00 (0.87)	0.11 (0.15)	0.03 (0.45)	0.03 (0.46)	0.36 (0.01)*	0.02 (0.52)	0.07 (0.27)	0.13 (0.12)
Ca	0.06 (0.28)	0.07 (0.27)	0.05 (0.35)	0.00 (0.85)	0.30 (0.01)*	0.05 (0.34)	0.03 (0.47)	0.01 (0.64)
Mg	0.03 (0.44)	0.01 (0.66)	0.01 (0.65)	0.06 (0.31)	0.30 (0.01)*	0.01 (0.62)	0.02 (0.52)	0.00 (0.79)
Al	0.12 (0.14)	0.18 (0.06)	0.07 (0.27)	0.00 (0.96)	0.43 (0.00)**	0.14 (0.11)	0.01 (0.65)	0.00 (0.87)
NO_3	0.04 (0.41)	0.04 (0.40)	0.02 (0.56)	0.08 (0.24)	0.17 (0.07)	0.06 (0.30)	0.00 (0.95)	0.02 (0.54)
NH_4	0.00 (0.83)	0.05 (0.36)	0.01 (0.63)	0.02 (0.60)	0.04 (0.43)	0.08 (0.22)	0.06 (0.29)	0.01 (0.71)

* $p < 0.01$
** $p < 0.001$

Regression Examples

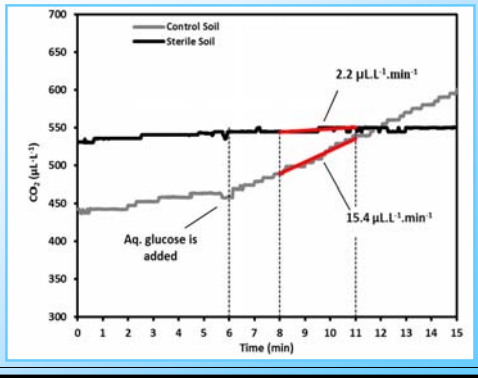


Substrate-Induced Soil CO_2 Emission Sensor System

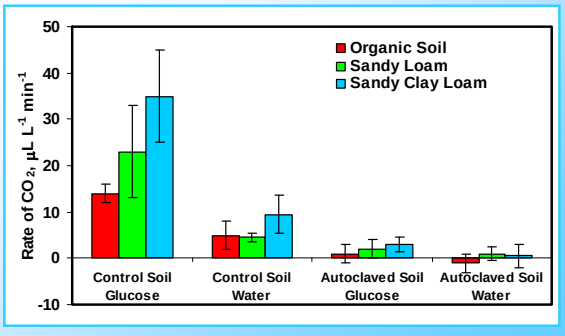


Kaur et al. (2015) Sensors 15: 4734-4748

Sensing Soil Bioactivity

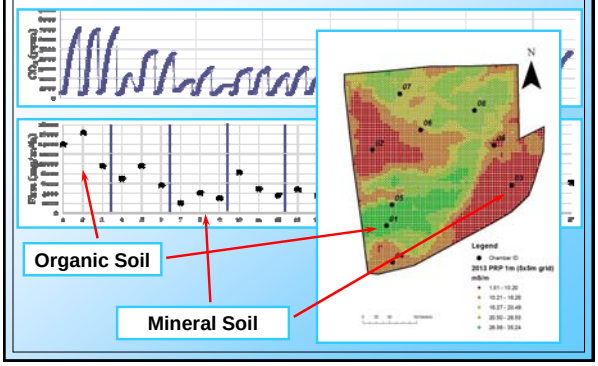


Sensing Soil Bioactivity



In Situ Soil CO_2 Sensing

In Situ Soil CO_2 Sensing



Control Experiment

Dry Soil Non-Compacted	Wet Soil Non-Compacted
Dry Soil Compacted	Wet Soil Compacted

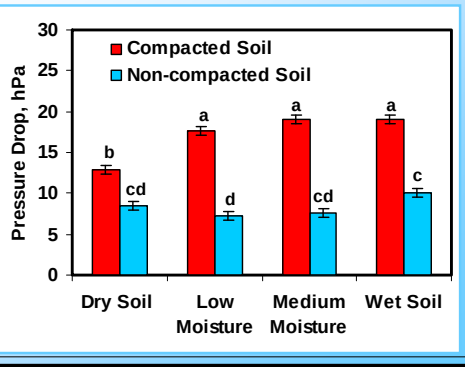
No Glucose

Dry Soil Non-Compacted	Wet Soil Non-Compacted
Dry Soil Compacted	Wet Soil Compacted

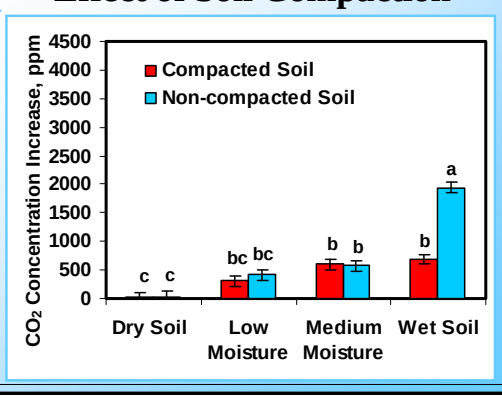
Added Glucose

Sandy Loam Soil

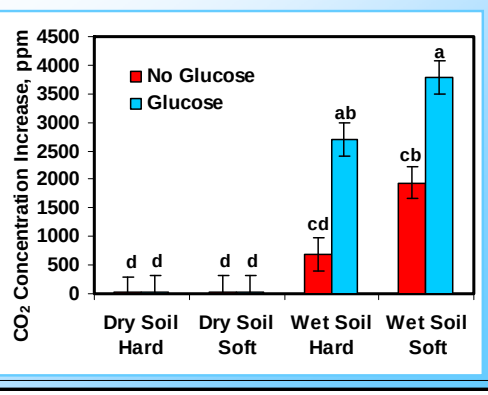
Effect of Soil Compaction



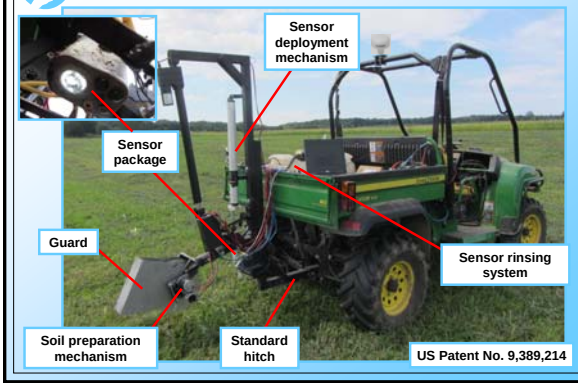
Effect of Soil Compaction



Effect of Added Glucose



On-the-Spot Analyzer (OSA)



Summary

- Spatial and temporal variability of soil biological health is important
- Soil microbial population changes significantly across an agricultural landscape
- Relationships with physical and chemical soil properties exists, but complex
- Mapping soil respiration is an attractive approach to assess biological activity
- Prototype Rapid Soil CO_2 Analyzer can be used *in situ* through two different methods:
  - Extracted soil air
  - Substrate-induced activity

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