Estimating soil properties with a proximal gamma-ray spectrometer using windows and full-spectrum analysis methods

2nd Global Workshop on Proximal Soil Sensing

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General structure of this talk

General structure

- Introduction
- Materials and Methods
- Results
- Conclusions
- Future research

Background

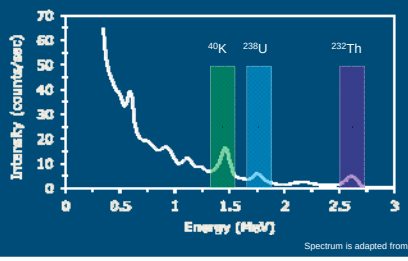
Introduction

- Why soil sensors?
  - Conventional soil analysis is expensive and laborious
- Why proximal soil sensors?
  - Remote sensors – low spatial resolution
  - Interfering factors
- What does a gamma sensor measure?
  - Gamma rays – decay of radioisotopes (^{40}K, ^{238}U and ^{232}Th)
- What does abundance of radionuclides reflect?
  - regolith features, for instance
  - Low count rate – young or sandy soil with leached profile
  - High count rate – weathered soils with clay minerals, gravels or silica

Spectral analysis methods

Introduction

- Full-spectrum analysis (FSA) method
- Conventional energy-windows (EWs) method



Spectrum is adapted from Wilford et al. (1997)

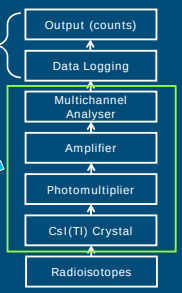
Objectives

Introduction

- To evaluate a proximal gamma-ray spectrometer "the Mole" to ascertain quantitative relationships between radiometric data and soil properties
- To compare two data analysis methods, the EWs and the FSA, to estimate soil properties using the data of the Mole

Gamma-ray spectrometer "the Mole"

Materials and methods



Picture is adapted from Van Egmond et al. (2010)

The Mole collecting the data

Materials and methods

Received from Soil Comapny (2011)

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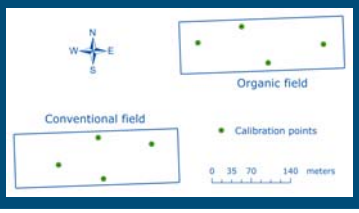
Data collection

Materials and methods

- Site – Lelystad, the Netherlands (total area = 5.5 ha)
- Calibration spectra were collected for 5 minutes
- Soil samples were taken from top 0-25 cm depth
- They were analysed for clay, OM, TN, TP, TK, Mg and pH



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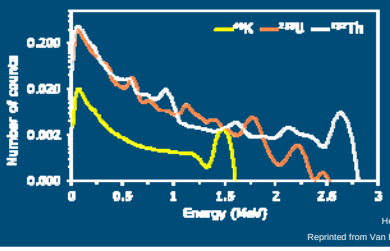
Full-spectrum (FSA) method

Materials and methods

- Fits standard spectra to a measured spectrum
- A standard spectrum is the pure response of a detector having a fixed concentration (1 Bq/kg) of a radionuclide



Hendricks et al. (2001)
Reprinted from Van Egmond et al. (2010)

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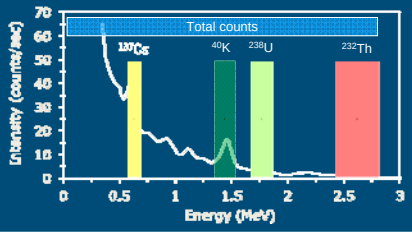
Energy-windows (EWs) method

Materials and methods

- Sums counts in EWs of ^{137}Cs, ^{40}K, ^{238}U, ^{232}Th and TC
- Calibration factors were determined from the standard spectra of the Mole



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Calibration – the FSA method

Results

Field	Soil property	R^2_{adj}	Radionuclide
Conventional	Clay content (%)	0.98**	^{232}Th
	OM (%)	0.96*	^{40}K
Organic	TN (mg/kg)	0.99**	^{238}U
	TP (mg/kg)	0.91*	^{238}U
Combined	Clay content (%)	0.54*	^{232}Th
	TN (mg/kg)	0.50*	^{238}U
	Mg (mg/kg)	0.50*	^{238}U

** Relations are significant at 0.01 level; * relations are significant at 0.05 level

- Correlations were not consistent with radionuclides
- Correlations were variable across fields
- R^2_{adj} values were higher in individual fields

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Calibration – EWs method

Results

Field	Soil property	R^2_{adj}	Radionuclide
Conventional	OM (%)	0.88*	^{238}U
	TP (mg/kg)	0.94*	^{137}Cs
Organic	TN (mg/kg)	0.82	^{238}U
	TK (mg/kg)	0.82	^{238}U
Combined	Clay content (%)	0.46*	^{232}Th
	OM (%)	0.47*	^{137}Cs
	TN (mg/kg)	0.54*	^{238}U

** Relations are significant at 0.01 level; * relations are significant at 0.05 level

- Correlations were not consistent with radionuclides
- Correlations were variable across fields
- R^2_{adj} values were higher in individual fields

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Calibration – comparison of FSA and EWs

Results

- Results in both methods were comparable; the FSA method, however, performed better
- Uncertainty in EWs – background and limited information
- Results were variable across fields and methods
- Relations were not consistent, but site-specific
- Both methods related different properties in the same field
- Correlations were higher in individual fields
- Clay content and TN showed some consistency in relationships

Validation of models across fields

Results

- The FSA models predicted clay, TN and pH across fields

Field	Soil property	R^2	RMSEP
Conventional	Clay content (%)	0.98	0.92
	TN (mg/kg)	0.69	54.37
	pH	0.75	0.05
Organic	Clay content (%)	0.83	0.66
	TN (mg/kg)	0.55	116.77
	pH	0.81	0.25

- The EWs predicted clay and TK with low correlation

Field	Soil property	R^2	RMSEP
Conventional	Clay content (%)	0.51	0.57
	TK (mg/kg)	0.51	4.59
Organic	OM (%)	0.26	0.41
	TP (mg/kg)	0.46	12.69

- The FSA method outperformed the EWs method

Conclusions

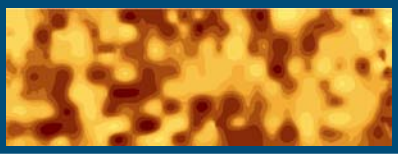
Conclusions

- The Mole is capable to relate soil properties
  - Correlations are variable across fields and methods suggesting that they are site-specific
  - Clay content shows some consistent correlation with ^{232}Th
  - TN shows some consistent correlation with ^{238}U
  - Other soil properties show mixed correlations
- FSA versus EWs
  - Both methods show potential to relate soil properties
  - FSA method outperforms the EWs method during calibration
  - FSA outperforms EWs also during validation (clay, TN and pH)
  - Both methods related different properties in the same field

Future research needed

Future research

- Site-specific behaviour of correlations needs to be understood taking more calibration samples within a field
- Next step is to make maps and compare them with existing maps or dense ground-truth samples to bring things closer to practice of precision agriculture
- Calibration spectra should also be measured on-the-go to better harmonise them with the field spectra



Thank you for your attention