

Defining proximal soil sensing

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Abstract

We attempt to define proximal soil sensing (PSS) through a variety of modalities:- proximal/remote, in-situ and ex-situ (field and laboratory), non-invasive/intrusive and mobile/stationary. Examples of known combinations of these are given. A narrow definition only considers mobile measurement so it defines PSS as principally a mapping tool. A wider definition of PSS includes in-situ and ex-situ, mobile and stationary field methods and gives more scope for the development of PSS methods

Keywords: proximal soil sensing

Introduction

Proximal soil sensing (Viscarra Rossel & McBratney, 1998) and discussed in detail in Viscarra Rossel et al. (2010) is motivated by the need for high-resolution spatial and temporal soil information. This demand usually occurs in high-value operations where soil is an integral component such as contaminated site assessment and remediation, precision horticulture and agriculture, and sites of special scientific or cultural interest, e.g., archaeological sites and classical field experiments.

But what exactly is proximal soil sensing (PSS)? We think that it is important to reconsider this question so that this dynamic new discipline develops widely and rapidly.

In proximal soil sensing we consider there is a measuring device which may consist of a detector or a source and a detector. We can call these measuring devices sensors. The sensors work by a variety of mechanisms. By consideration of factors in relation to sensors and the nature and rate of sensing, we aim to define various kinds of proximal soil sensing. The factors dictate a number of modalities for sensing.

Modalities

Proximal/ Remote

This refers to the distance of the sensor to the soil measurement volume. The distinction between proximal and remote is somewhat arbitrary. The idea of proximal in PSS is of the order of centimetres or metres not tens or hundreds of metres or more.

In-situ/Ex-situ

In-situ systems measure the soil in its natural volume. Ex-situ refers to systems where the soil is removed from its natural position. There are degrees of 'ex-situness', soil moved a few centimetres or metres for measurement may be considered field-based however soil moved to the laboratory is quite different. When soil material is ex-situ it may undergo some processing to make it more amenable to analysis, e.g., drying or sieving etc.

Non-invasive/ Intrusive

This refers to the position of the sensor relative to the soil measurement volume. In a non-invasive system the sensor is outside the measurement volume. The source and detector might

not be collocated. In intrusive systems the sensor is contained within the soil volume being measured. Intrusive measurements are by definition proximal.

Passive/Active

This refers to the mode of operation of the sensor. Active systems will have a source and detector, e.g., the reflection of energy applied to the soil by the system's source is measured by a detector. In passive systems the soil is either the direct source of the signal or reflecting a naturally generated signal e.g., heat energy, gamma-ray energy, natural light. Therefore in these systems there is only a detector.

Mobile/Stationary

This refers to whether the sensing system is capable of readily moving and measuring across the soil space, if they can they are mobile sensing systems. Systems which are stationary are generally used to track soil properties through time. This modality essentially results in (spatial) mapping or (temporal) monitoring. While any mobile system can be used in a stationary mode, most stationary systems are intrusive, e.g., capacitance probes for measuring volumetric soil water status. A cost-effective proximal sensing modality that allows repeated high-resolution soil measurement over time and space does not seem to exist. At present the closest proximal systems are the non-invasive electromagnetic induction instruments, but this realm seems to be dominated by remote sensing.

Putting it together

So now we have remote/proximal, in-situ/ex-situ(field/lab), invasive/non-invasive, active/passive, mobile/stationary systems. Everything that can be done on the run can theoretically be done in a stationary mode. Everything that can be done in the laboratory can theoretically be done in a field mode. So this gives us many possibilities. Known examples are presented in Table 1.

Table 1. Modalities of measurement/sensing

Mode a	Location	Mode b	Mode c	Mode d	Mode e	
In-situ	Field	invasive	Active	Mobile	NIR tine, disc resistivity	
				Stationary	TDR, neutron probe	
			passive	Mobile	Strength tine, penetrometer	
				Stationary	Temp probe	
		Non-invasive	Active	Mobile	GPR, EMI, optical	
				Stationary	Surface gamma probe	
			passive	Mobile	Gamma radiometry, optical	
				Stationary	Gamma radiometry optical	
Ex-situ	Field	invasive	Active	Mobile	Sampler pH electrode, field chem. Lab, NIR	
				Stationary	Field texture (by hand)	
			passive	Mobile	Sampler /radiation	
				Stationary	----	
		Non-invasive	active	Mobile	----	
				Stationary	----	
			passive	Mobile	----	
				Stationary	Munsell colour book	
		Lab	invasive	active	Stationary	AAS
				passive	Stationary	
	Non-invasive		active	Stationary	NIR MIR	
			passive	Stationary	Gravimetric methods	

---- possible, but nothing useful springs to mind

Do we want a narrow or wide definition of proximal soil sensing?

Given these possibilities we can strive for a narrow or wider definition of proximal soil sensing.

Proximal soil sensing, sensu stricto In the narrow sense one could define PSS as *in-situ, mobile, field* methods or more widely *in-situ and ex-situ, mobile, field* methods.

Proximal soil sensing, sensu lato More widely one could define PSS as *in-situ and ex-situ, mobile and stationary field* methods.

The narrow definition only considers mobile measurement so it defines PSS as principally a mapping tool. The wider definition includes stationary measurements which are probably best used in a temporal monitoring mode. In mobile mode measurements are made for a short time and at many points in space. In stationary mode soil is measured at a (limited) network of points repeatedly in time. So the wider definition includes both mapping and monitoring.

The definitions do not consider laboratory soil measurement methods. Some consider laboratory NIR and MIR as proximal sensing probably because of the 'proximity' of the material and the non-destructive nature of the measurement. We feel however that PSS is best considered a suite of field techniques, but no doubt that is a matter of debate.

Conclusions

1. Proximal soil sensing can be defined by a set of modalities. The list given here is not exhaustive.
2. Using these modalities a narrow definition of PSS is a set of *in-situ and ex-situ, mobile, field* soil measurement methods
3. A wider definition of PSS includes *in-situ and ex-situ, mobile and stationary field* methods. The wider definition perhaps gives more scope for the development of PSS methods and cross-fertilisation between modalities.
4. We question whether laboratory-based methods constitute PSS. Nevertheless, understanding laboratory NIR and MIR will inform their improved use in the field.
5. A cost-effective proximal sensing modality that allows repeated high-resolution soil measurement over time and space appears to be one of the major development challenges.

References

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