APSoil-providing soils information to consultants, farmers and researchers

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Abstract

The APSoil database was first developed to collate soil input information for the APSIM (Agricultural Production Systems Simulator) farming systems model developed by the CSIRO and Queensland Government agencies in the 1990s. Whilst initial data acquisition was focussed on northern Australia, measurement of plant available water capacity (PAWC) and database development has since expanded to include all Australian states with over 800 soils of regional importance now described. While the primary aim of APSoil continues to be to provide location specific soil parameter information for use in APSIM and its derivatives e.g. Yield Prophet, other uses that are external to the modelling domain have also been identified including the provision of PAWC information to farmers, agribusiness and consultants for use in general crop management decision making.

The database is accessible as a standalone product (www.apsim.info) or through Google Earth (www.apsim.info) or ASRIS (www.asris.csiro.au), both of which provide a spatial context to the data. The current development of a computer tablet based soil identification 'app' will further enhance accessibility to this information by busy professionals requiring in-field access to soil information relevant to crop management decision making.

Key Words

APSoil, plant available water capacity, soil moisture monitoring, soil characterisation

Introduction

Globally, soil water is one of the key drivers of rainfed agricultural production. Historically, in Australia, the estimation of available soil water has been undertaken by the farmer or consultant as part of an intuitive process at key seasonal decision points such as at time of crop sowing and fertiliser application. In hindsight, the estimation of one of the key drivers of crop production, without the support of empirical data (apart from rainfall data and information on the presence of moisture in the soil surface) should be seen as surprising given the magnitude of the investment that is based on having sufficient soil moisture (stored and through in-crop rainfall) to grow the crop.

Over the past 15-20 years, there has been an increasing realisation within the farming and research communities of the importance of improved soil water information to crop production. This has resulted from the increasing in-season variability in rainfall, which has highlighted the importance of stored soil water to crop production, and the increased understanding of the production and financial risks associated with crop production in environments where soil water is often the main limiting factor. These insights have resulted from the ability to analyse the contribution of inputs including soil water and nutrition to crop production through the use of simulation models such as APSIM (Keating *et al.* 2003) and Yield Prophet (Hochman *et al.* 2009). However, whilst decision support tools can offer insight into the risks associated with particular cropping strategies, these tools only operate at optimal efficiency when provided with reliable and accurate soil information.

Consequently, there has been a need to provide relevant soil information to practitioners that allows them to a) make better informed decisions at critical seasonal decision points, and b) realise the potential for tools such as Yield Prophet to contribute to decision support. Tools and information that contribute to both of these goals are described in this paper.

Methods

Soil characterisation

National collaboration between CSIRO, state departments, consultants, catchment managers and farmer groups has been critical to the identification of sites and the collection of relevant information on agriculturally important soils. The characterisation of soils for plant available water capacity (PAWC) has been field based using methods which are relatively slow, labour intensive, technically demanding and rely on site selection which adequately represents a particular soil type. Drained upper limit (DUL) is measured after irrigating an area of soil (typically 4 x 4 m^2) to saturation (SAT), followed by drainage to a steady water state which is assumed to be DUL (Figure 1). On reaching assumed DUL, gravimetric water content and bulk density (BD) are measured to the depth of crop rooting. Soil chemical and physical attributes including Particle Size Distribution, Electrical Conductivity, Chloride, Boron, Organic Carbon, etc are also measured at this time (Table 1).

During the subsequent growing season, the crop species of interest is established on the same, or an adjacent site on the same soil type and allowed to grow through to maturity when the lower limit of crop extraction, the Crop Lower Limit (CLL) is determined. To ensure water extraction to crop potential, and maximum depth of rooting, it is important that the crop is established on an area with a near full profile of water and is supplied with adequate nutrition. At around the time of crop flowering a rain exclusion shelter is erected to minimise the effects of late season rainfall on crop water supply (Figure 2).

While laboratory measurement of a soil's Field Capacity (-0.1 bar) and lower limit of extraction (-15 bar) (Ritchie 1981) is more likely to provide an accurate estimate of its ability to hold water, field based techniques continue to be used for 2 important reasons. The first is that the field site becomes the focus of local farmer and consultant learning which is critical to the development of understanding on soil water, and the second is that the most important soil water extraction measurement to the farmer or modeller is one that explains the potential extraction capability of a particular crop on the soil type of interest. This differs from the lab based measure of -15 bar, which accounts for the impact of soil physical properties on water extraction but does not account for the integrated effect of physical and chemical conditions in the root zone, as well as the water extraction performance of specific crops (or varieties).

Figure 1: Typical field setup for the measurement of DUL and BD using trickle irrigation, a plastic cover and water supplied from a header tank.

Figure 2: A rain exclusion shelter used to protect the crop from late season rainfall prior to the measurement of CLL.

Soil moisture monitoring

While the characterisation of soils for PAWC provides the basis of understanding of crop water use, it is only part of the story. To draw an analogy, PAWC may be considered as the bucket in which water is stored within a particular soil, with the bucket size varying between soil types and between individual crop types grown on a particular soil. However, PAWC does not inform the user on the quantity of water within the bucket at a particular point in time. This is determined through seasonal monitoring of plant available water (PAW) which describes the current available water status.

The conventional means of determining PAW has been to physically sample the soil and determine its gravimetric water content (g/g) (Dalgliesh and Foale, 1998). Whilst this method could be considered to be reasonably accurate, it is labour intensive and only describes water content at a particular point in time. Consequently, in recent years, there has been a move towards the use of a range of in-situ electronic monitoring devices such as capacitance probes that have the ability to continuously log soil moisture content. Whilst relatively expensive to purchase and install, they do provide a continuous picture of PAW for a particular point in the landscape. The disadvantage of many of these devices, however, is that data output is not easy to interpret in terms of the true moisture status of the soil.

Results

Soil characterisation

Collaborative effort has seen over 800 soils of national and international agricultural importance described in terms of PAWC with data stored in the APSoil database. Parameters are described that directly relate to PAWC and soil chemical and physical attributes that impact on a soil's ability to hold water, or on a plant's ability to extract that water (Table 1). The database also includes the information required to parameterise the APSIM and Yield Prophet models. The logical setting of these parameters and the rules used in their development are described in the technical document, 'A protocol for the development of appropriate soil parameter values for use in APSIM' (Dalgliesh *et al.* 2012).

Table 1: PAWC, soil chemical, soil physical and simulation attributes included in the APSoil database.

Attributes		
Soil water properties (units) (data collection)	**Soil chemical and physical properties(units) (data collection)**	**Modelling (description) (units) (data collection)**
Drained Upper Limit (mm/mm) (m*)	Rock presence (%) (m)	Kl *(Fraction of PAW able to be extracted/day* (day) (r)
Crop Lower Limit (mm/mm) (m)	Soil colour (Munsell-hue, value and colour) (m)	Xf *(Root exploration factor)* (scale 0-1) (r)
Bulk Density (g/c^3) (m)	Electrical conductivity (dS/m) (a*)	Salb *(Bare soil albedo-reflectance coefficient)* (scale 0-1) (r)
Depth of soil (cm) (m)	Chloride (mg/kg) (a)	Diff Const and Slope *(Diffusivity as a ration of water content)* (r/e)
Air Dry moisture content (mm/mm) (r*/e*)	Boron (hot CaCl^2) (mg/kg) (a)	CN2-bare *(Runoff curve number for bare soil)* (scale 30-100) (r)
-15 Bar moisture content (mm/mm) (r/e/m)	Cation Exchange Capacity (cmol+/kg) (a)	SWCON *(Proportion of water above DUL which will drain to adjacent soil layers/day)* (scale 0-1) (e)
SAT (mm/mm) (c*)	Exchangeable sodium (%) (a)	FBiom *(Microbial biomass fraction?)* (scale 0-1) (c)
PAWC (mm) (c)	Organic Carbon (Walkley Black) (%) (a)	FInert (*Proportion of initial organic carbon assumed to be inert*) (scale 0-1) (r/m)
	Aluminium (cmol+/kg) (a)	KS *(Saturated hydraulic conductivity)* (mm/day) (m/e)
	Manganese (mg/kg) (a)	
	Particle size distribution (%) (a)	
	pH (1:5 water) (a)	
*m=measured data; e=estimated; c=calculated; r=based on developed rules; a=analysed		

Access to information

Soil characterisation information is available for public use though a range of products that have been developed for both modelling and consultant use. The primary database, APSoil, contains all of the above information and is the source of soils information for the above models. The database provides the user with the flexibility to utilise values from the database or to modify them for use in simulation. The challenge with APSoil is that local knowledge is required to identify the most appropriate soil type for use. Consequently, an embedded link to Google Earth provides a spatial representation of the location of all soils and allows for data download in either .xml or Excel format. The database may be downloaded at www.apsim.info or from the Australian Soil Resource Information System (ASRIS) (McKenzie *et al.* 2005) at www.asris.csiro.au.

As a result of the increasing use of mobile devices in agriculture, a soil 'app', designed for use on the IPad tablet, is currently under development (Thomas *et al*, these proceedings). The application aims to provide the user with in-field identification of the most appropriate soil type for use in general consultancy or for use in simulation.

Soil water monitoring - making the link

With the increasing demand from farmers and consultants for real-time knowledge of soil water status, there has been a move to the monitoring of plant available water (PAW) using devices such as capacitance probes (eg. Enviroscan), Time Domain Reflectometry (TDR) and Electromagnetic Induction (EM) which output data in units that cannot be immediately equated to soil water status. However, observation of seasonal soil water dynamics using these devices allows the user to develop an intuitive understanding of the relationship between probe output and wettest and driest soil profiles measured in whatever logging units the device outputs. Where APSoil data exists for the particular soil type, it is then possible to match observed probe output for wettest and driest profiles with known soil DUL and CLL information (in volumetric water % or mm/mm), thus developing a PAWC profile relevant to probe output. The prediction of water content at any point during the season is then possible, assuming that there is a linear response between lower and upper limits of extraction. The tool 'Soil Water Express' (http://www.apsim.info/Wiki/) has been developed to operationalise this process (Burk and Dalgliesh, these proceedings).

Conclusions

Public domain access to soil information directly related to the productive capacity of Australian soils is an important tool to consultants, farmers and researchers aiming to optimise production in a climatically variable environment. Whilst APSoil and the techniques described provide a reasonable coverage of soils, they do not represent the inherent spatial diversity of the agricultural landscape commonly found at the paddock or lesser scales. The next challenge in this domain is to tackle spatial variability in terms of monitoring and characterisation using rapid assessment tools including vis-NIR (visible near infrared spectrometry) and EM.

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