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Soil data for biophysical models in Victoria, Australia: Current needs and future challenges

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ABSTRACT

The use of biophysical models to support increased food production and environmental protection is on the rise. This paper reviews the demand for, and trends in, soil property data for various biophysical models being used in Victoria, Australia, over the 2009–2014 period. The study used surveys, workshops and interviews with public sector modellers to examine perceptions of the soil parameters that affect model sensitivity and error. Although the data requirements of models have remained similar over the 5 year period, the diversity of models used has decreased. There is evidence of increased application of models at point/site scale to support grains, dairy and livestock production industries in Victoria. Opportunities are identified to deliver finer scale soil data from digital soil mapping to better meet modelling requirements for agricultural industries in Victorian landscapes.

1. Introduction

Since the seminal modelling of global population and resources by the Club of Rome (Meadows et al., 1972), increased computing power has led to more sophisticated biophysical models that are used to support agricultural industries' management for increased food production and environmental protection. Such biophysical models simulate the biological, chemical and physical processes of agricultural systems (Keating and Grace, 1999; Boote et al., 2010) and are increasingly implemented as tools to model agricultural landscapes and support decision making processes by farmers and their advisers (Bergez et al., 2010). These biophysical models enable users to test and answer important questions on land use and condition as well as management and production scenarios.

1.1. Model limitations

Models must become more robust to represent scenarios that can include critical changes in climate, management practices and farming systems in the future (Sinclair and Seligman, 1996; Asseng et al., 2013). Successful modelling relies on available and accurate topographic, climatic, land use and soil data (Bouma et al., 1986). Soil data may represent steady state and/or dynamic processes depending on the complexity of the model. Data from soil survey and mapping has focused on static properties rather than those that change (Bouma et al., 1986). While static properties have an important role in modelling, dynamic properties must also be modelled for many soil processes and interactions between biosphere, hydrosphere and pedosphere (Wagenet et al., 1991). There are likely consequences as estimation of soil properties may introduce considerable error into models.

Soil scientists need to understand the role and importance of soil data in the modelling process to enable the delivery of available, current, reliable and plausible soil data for these models. Model developers understand the soil data required to support their model, including error and uncertainty from parameter estimation, systematic bias and sensitivity. Baker (1996) suggests that model developers need to be honest about the limitations of models and the research required to address these. Making end-users (e.g. land managers) aware of these limitations in soil data or the model itself is central to the ongoing success and utility of farming systems models for decision making and management (Keating and McCown, 2001).

1.2. Soil data availability

Due to the rapid expansion and use of soil data in digital form provided by sensors, conventional soil maps have become largely unsuitable for many users who wish to view soil data at finer scales (Bouma, 1989). Advances in technology and development have seen a global surge in sensing and acquisition of data, its collection, management and availability.

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Referred to as the 'New Digital Age' (Schmidt and Cohen, 2013), or 'Era of Big Data' (Boyd and Crawford, 2012; Mayer-Schonberger and Cukier, 2013), the current period provides unprecedented opportunities for an improved understanding of our global environments including agroecosystems. The use of volunteered geographic information and citizen science is also contributing substantially to the volume of soil (Rossiter et al., 2015) and environmental data (Fienen and Lowry, 2012; Werts et al., 2012; Sui et al., 2013). As governments adopt open data policies (Zuiderwijk and Janssen, 2014) this emerging collaboration of large data arrays and analytical procedures with progressive and complex modelling will potentially enhance management philosophies of agricultural industries globally.

1.3. Understanding soil data needs of biophysical models

Research into users' soils data needs is scarce (Omuto et al., 2013). Wagenet et al. (1991) discuss the data requirements of simulation models and how existing soil survey plus predictive functions (pedotransfer functions) can supply a minimum dataset that includes dynamic soil properties that respond to land management change or climatic impacts such as flooding. Nichol et al. (2006) in a review of models and methods for landscape analysis defined the key model sub-domains that require soil and land attributes such as: hydrological, plant growth (crop, pasture or forestry), carbon and climate change, ecology, and biodiversity. This review of qualitative and quantitative biophysical models identified their soil data requirements and examples of where they have been implemented. A complementary study by Robinson et al. (2010b) collated modellers' opinions regarding the key soil properties affecting sensitivity for these same biophysical models. Wood and Auricht (2011) defined current and future soil information requirements for the Australian Soil Resource Information System (ASRIS) based on interviews with selected modellers and the responses given to requests for data and information from ASRIS. This review identified a suite of physical, chemical, hydrological, biological and site characteristics at various scales that were sought by ASRIS users.

1.4. Collection of soil data for modelling

The synthesis and delivery of soil data to support modelling is subject to government priorities (MacEwan et al., 2014), advances in research, and changes in user needs for soil data to address questions posed. There is a constant need to adapt and enhance soil survey information as new questions arise (Bouma, 1989). Questions relate to systems that operate at different scales, requiring soil data at different levels of detail (Bouma, 2001).

Given the multiple challenges of scale, evolving needs of users and the availability of soil data in various formats, it is timely to ask if the right soil data to support sustainable agricultural development is being provided. This should then focus delivery of soil data on properties of direct relevance to improve model predictions and consequent decisions. In this paper, we present an example for the state of Victoria, Australia, that identifies (i) the simulation models used in agricultural industries, and the application scale at which these models are implemented, to support government policies and programmes, (ii) the soil data that modellers perceive as affecting model sensitivity and uncertainty, and (iii) any changes and trends in the demand for soil property data in the last 5 years. Future challenges in soil data and information provision to support modelling are discussed, including the context of demand, availability of soil data in various formats and how this will assist in the parametrization process of biophysical models for optimising agriculture management.

2. Methods

The study uses qualitative and quantitative data from surveys, focus groups and unstructured interviews summarised from an expert workshop in 2009 (Robinson et al., 2010b) and a follow up survey in 2014. The workshop was conducted in March 2009 to establish what biophysical models were applied and used soil data, what were the sources of the data, how sensitive were these models to the data, and what the future requirements for data in modelling applications were. The 2014 survey was undertaken to investigate changes in demand for soils data in models and included modellers that attended the 2009 workshop. Responses from 2009 and 2014 were collected using different evaluation techniques and it is recognised that participants respond differently between questionnaire and interview prompts (Oei and Zwart, 1986). While focus groups enable thorough and engaging dialogue on complex topics, and surveys enable objective assessment of responses, a desirable approach is to combine the two approaches that enable qualitative and quantitative responses to be collated. Sound quantitative data analysis and interpretations can be explained and reinforced by qualitative responses. This supports the utilisation of these two evaluation techniques in the workshop in 2009 and justified a comparison with those of the 2014 survey.

2.1. Study design and data collection

Researchers from the former Victorian state government agencies (Department of Primary Industries and Department of Sustainability and Environment) and the University of Melbourne participated in the study. Participants include 23 model developers and practitioners in 2009 and 31 in 2014, operating in a diversity of model domains and sub-domains including agricultural production, ecological sciences, catchment hydrology, environmental pollution and nutrient flow. These modellers were chosen as they are recognised as specialists in operating these models for landscape modelling and assessment (Nichol et al., 2006).

Modellers that participated in the workshop were assigned to four modelling sub-domains that use soil data, including:

- Forestry and biodiversity (FB)
- Carbon and greenhouse (CG)
- Crops, pastures and nutrients (CPN)
- Hydrological processes (HP).

Responses from participants were recorded using a survey questionnaire and focus groups as part of the workshop representing these modelling sub-domains. This approach enabled exploration of questions and associated issues further with all workshop participants.

The knowledge gained from responses at this workshop was used to refine questions for the online survey in 2014. This online web-survey was conducted using Survey Monkey® (www.surveymonkey.com). The questions that were developed for this study include:

1. What models are being used, at what spatial modelling scale are they applied and what soil data are being used to run these?
2. To what industry/land use are the models applied?
3. What are the key soil data for the models applied including the spatial scale of the input soil data?
4. Are the applied models sensitive to the soil property data?

This study synthesizes results from both the 2009 and 2014 surveys. After the completion of the 2014 survey, additional follow-up interviews were conducted with selected modellers to test initial conclusions and to identify logic for changes observed between the surveys.

Responses recorded from the online survey and workshop included whether a modeller applied a model at a particular scale (not how frequently). Model implementation has been reported as an 'application' and no specific time constraints were stipulated to respondents on this application of the model.