Soil Change Matters International Workshop – Overview

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Abstract. Soils change in response to land use, land management and climate. Understanding the mechanisms and rates of change in fundamental soil properties, their extent across landscapes, and the drivers of change, is critical for management of soil and land to ensure enduring productivity and the provision of ecosystem services. A reliable evidence base for soil change can be created through research into fundamental soil properties and processes, which coupled with monitoring, can be used to develop models to support management and policy decisions. Soil scientists, land managers and policy makers occupy different intellectual domains and each can contribute to a soil change dialogue focussed on providing the best science for managers, policy and decision-making. Clarity is needed concerning the knowledge needs of policy makers and the latter need to understand what is achievable by science and at what cost. However, communication is often limited by the discipline-specific language used by each group. Facilitated communication would improve the impact of science on policy by enabling scientists to better understand policy maker needs and enabling policy makers to better understand scientific data interpretations, limitations, and gaps. The international workshop 'Soil Change Matters' in Bendigo, Australia 24-27 March 2014, brought together 200 delegates across these intellectual domains to talk to each other, share conclusions, questions and data, and to learn about scenarios for soil change and for soil policies.

1. Introduction

The International Workshop 'Soil Change Matters' in Bendigo, Australia, 24-27 March 2014, was convened to explore and discuss changes to soil in the Anthropocene (the era of human influence on the environment) – specifically, how our use of land and soil has affected soil quality and what policy responses are needed to ensure sustainability of the soil resource. The workshop brought together scientists, policy makers, land managers and other stakeholders for a forum in which over 70 separate presentations were made, ranging from the newest perspectives on soil biology to international policies for soil protection.

Two hundred delegates attended, representing 11 countries (Australia, USA, UK, New Zealand, France, Netherlands, Germany, Russia, Slovakia, Italy and Canada). Of the 200 delegates, 45% were identifiable as actively engaged in research (14.5% in Academia, 30.5% in Government), 20% as engaged in extension services or land management (including a few landholders), 15% engaged in policy at some level (including international, national, state, and catchment authorities), 9.5% were consultants, 5% students, and the remainder (6%) communications, journalism and sales.

A field trip prior to the workshop provided an opportunity for 40 of the delegates to get to know each other, visit some farm sites, interact with farmers and local government officials to discuss the

land management and production issues relevant to the soils and sites visited. Spaces on this trip were preferentially allocated to all of the invited and sponsored speakers and to representatives from across the groups mentioned above.

The format for the workshop itself allowed over 40% of the time for discussion by limiting 50% of the presentations to 5 minute synopses. In an intensive 2.5 days, excluding breaks, 14 hours were scheduled for talks and 10 hours for questions and discussion, in plenary and parallel sessions. Seventeen of the speakers were invited to provide concise keynote and thematic talks (15-25 minutes each).

Twenty-three presenters have provided papers for review and publication in this volume of the IOP Earth and Environmental Science series, and eleven presenters have contributed papers to a special issue of Soil Research. All of the abstracts and some information for the workshop can be viewed online at www.soilmatters.org.

2. Workshop objectives

The workshop objective was to gain a better understanding of current trends and critical changes in soil to determine future research, development and policy priorities. Specifically, the workshop goals were to:

1) provide a forum to present scientific research related to understanding changes happening to soil under current land uses and management;
2) facilitate a workshop to clarify the role of policy in soil security and define the scientific capacity to provide technical understanding and guidance to policy;
3) stimulate collaboration across research organisations and four International Union of Soil Science working groups (soil monitoring; proximal soil sensing; global soil change; digital soil mapping);
4) provide a forum for the latest developments in soil science to engage a variety of stakeholders, including other scientists, land managers and the general public; and
5) showcase policy development and priorities for investment at a national level through the National Soils Research, Development and Extension (RD&E) strategy, and explore the possible synergies with international initiatives such as the United Nations Food and Agriculture Organization's (FAO) Global Soil Partnership.

3. Papers presented by the OECD sponsored speakers

The Organisation for Economic Co-operation and Development (OECD) Cooperative Research Program (CRP) funded eight international invited speakers. The papers from each of the OECD supported delegates are included in this volume and are as follows. With their co-authors, Ms Maxine Levin ('Delivering solutions to questions regarding soil change—examples from USDA and the National Cooperative Soil Survey'), and Dr Mari-Vaughn Johnson ('The Conservation Effects Assessment Project (CEAP): a national scale natural resources and conservation needs assessment and decision support tool') give accounts of the USDA's contribution to understanding and monitoring soil change, as well as providing some insights into how scientific information informs soil and natural resource policy in the United States.

Dr Daniela Sauer (Germany) and Professor Daniel Richter (USA) provide two pedological perspectives for the temporal scales of soil change, firstly that of landscape evolution and soil research spanning soil changes over millennia ('Soil development over millennial timescales – a comparison of soil chronosequences of different climates and lithologies') and secondly, the importance of recognising the Anthropocene era as a period of accelerated soil change for which human activity is responsible ('Soil in the Anthropocene'). Professor Johan Bouma ('Policy and effective action for soil security: a need for reframing the soil story') makes an appeal for examples of soil scientists engaging in inter- and transdisciplinary action for real world problem solving. He calls this 'reframing the soil narrative' and provides an example from the Netherlands where a program, with soil scientists as knowledge brokers at the hub, successfully addressed five major environmental issues (food security,

water and energy availability, climate change and biodiversity loss) in an effort that resulted in a change of policy for dairy farmers' use of fertiliser and manure.

Dr Ben Marchant and Dr Allan Lilly present two case studies for monitoring soil change using legacy data and samples. The paper by Marchant et al. ('What can legacy datasets tell us about soil quality trends? Soil acidity in Victoria') presents an innovative geo-statistical approach to the use of large datasets, time-stamped but geographically generalised, from laboratory services to create a statewide map of changes in soil surface pH over time. Lilly and Chapman describe the approach used to resample Scottish soils and re-analyse archived soil samples, taken 20-30 years previously, to determine whether soil organic carbon (SOC) has changed ('Assessing changes in carbon stocks of Scottish soils: lessons learnt'). Their sampling and analytical methodology is thorough, including the use of Fourier transform infrared spectroscopy (FTIR) to confirm comparable samples from the locations for the earlier and recent dates. Their conclusion is that there is no detectable loss of SOC from Scottish soils in that period. Dr Pierre Roudier ('The rise of information science: a changing landscape for soil science') introduces the notion of a 'data deluge' and addresses major questions concerning the implications for large volumes of data generated in soil science and the potential for their analysis.

4. Structure of this volume of IOP Earth and Environmental Sciences, including other invited and contributed papers

The workshop was divided into sessions that focussed on different aspects of soil change including fundamental soil properties, monitoring, mapping and modelling soil change, land use and land management, policy and soil change, and the issues around data and data management. The papers included in this volume represent only 30% of the total presentations given at the workshop and have been grouped according to their major emphasis, although they may cover more than one of these aspects. Other workshop presentations, not included here, that help to complete a picture of the scope of the workshop are mentioned below and, where possible, citations of their publication in other journals are included.

4.1 Integrating soil science into policy

A primary objective for the workshop was to discuss policies supporting soil management. Policy related papers accepted for this volume include Luca Montanarella's explanation of the Global Soil Partnership (GSP), Drs Jane Fisher and Michael Crawford's perspective on a state government's approach to soil policy ('The policy and science of soil change – a Victorian perspective'), Professor Robert White and Dr Brian Davidson's analysis of the cost effectiveness of C-sequestration in Australian agricultural systems, and Professor Johan Bouma's paper on reframing the soil narrative. 'Soil Security' is a term that has recently emerged and is particularly relevant to policy. A paper by Dr Damien Field et al. explained the term, its breadth and inclusions, and is published in the journal Geoderma [1]. The paper by Mr Ron Aggs ('Soil news – the soil carbon and climate policy journey in Australia and the role of different media'), tackles the important topic of communication for soil science and the issues affecting success of policy development and acceptance, using, as an example, the Carbon Farming Initiative in Australia. Aggs points out the roles and limitations for different media in getting messages across to the voting populace.

4.2 Fundamental soil properties and rates of change

The fundamental science of soil properties and soil change is found in the invited papers by Drs Helaina Black and Pauline Mele ('Advances in Soil Biology: What does this mean for assessing soil change?'), Professor Mike McLaughlin ('The Soil and its Chemistry - Critical Futures'), and Dr Brian Murphy's review of relationships between organic matter and soil properties ('Key soil functional properties affected by soil organic matter – evidence from published literature').

Understanding how individual soil properties change over time, rates of soil formation and the drivers of change is essential if we are to model the impacts of land use practices and their effects on

soil sustainability. The workshop heard three presentations that addressed this topic. The papers by Drs Sauer and Richter have already been referred to above. Sauer and her co-authors show how the study of chronosequences of soil, aged from a few hundred to several hundred thousand years, can reveal rates of soil forming processes, and Richter et al. focus on the important anthropogenic influences. A third complementary paper was presented by Dr Uta Stockmann where she and her fellow researchers have developed algorithms for modelling soil formation rates over millennia. Some of this work is published in the journal Geoderma and can be referred to there [3].

4.3 Monitoring soil change

In order to understand, quantify and model soil change in the Anthropocene (the era of human influence on the environment) there is a fundamental need for primary data on soil properties, in different land use, landscape and climate contexts. The collection of such data occurs primarily in specific research projects since examples of long-term soil condition monitoring are rare; however some examples were presented at the workshop. Professor Josef Kobza ('Permanent soil monitoring system as a basic tool for protection of soils and sustainable land use in Slovakia') describes the 20 year old network of 318 sites on agricultural land in Slovakia and how the data collected are included in broader EU data sets. An important aspect of the monitoring is that it provides the evidence base for development of policy and legislation for land use practices and soil protection. The CEAP project in the United States, described by Dr Mari-Vaughn Johnson, is a more recent monitoring and modelling exercise, in which the baseline data were collected ten years ago and follow-up data collection is scheduled for 2015-16. The data are analysed and applied to process-based modelling exercises across 10 river basins, the results of which are used to interpret the adequacy of current conservation and to determine areas of land in need of additional conservation practices. The CEAP project is a clear example and demonstration of the important contribution that science-based monitoring and modelling can make to the development and support of soil conservation policies.

Remote sensing continues to develop and offer opportunities for monitoring. The paper by Drs Kathryn Sheffield and Liz Morse-McNabb ('Using satellite imagery to assess trends in soil and crop productivity across landscapes') presents current research into application of MODIS satellite to monitor crop productivity across the landscape, and a legacy of Landsat data over 40 years to look for trends and patterns. Crops integrate the properties of the soil with the practices of the land manager and the seasonal climate so there is potential for the satellite NDVI to be used as an indicator of soil condition if the other factors are known and sufficient soil ground truth exists or is collected. At the paddock scale, the paper by Dale Boyd ('Soil moisture monitoring for crop management') describes a soil moisture monitoring network created for farmers in Victoria as an input into the seasonal decision making for strategic fertilizer application.

4.4 Land use and soil change

A major focus of soil research currently is SOC driven by the climate change debate and the desire to engineer land use practices that can remove more CO_2 from the atmosphere, sequestering the carbon in the soil. Reflecting this interest, 20 of the papers offered to the workshop had SOC as their focus. This includes papers by Professor Robert White and Dr Brian Davidson, referred to in 4.1, Dr Brian Murphy's paper referred to in 4.2, and Lilly and Chapman's paper on SOC in Scottish Soils. Dr Garry O'Leary and his co-authors ('Modelling soil carbon in agricultural systems: a way to widen the experimental space') stress the need to develop and apply process models for SOC (rather than purely statistical models) and to link biophysical and economic (agricultural productivity) models in order to provide more realistic or practical scenarios for C sequestration. Their point is that land use practices will remain unchanged unless there are productivity gains, not merely C sequestration, and better modelling is needed to predict the outcomes for land use change scenarios.

Several papers presented surveys, modelling and analyses of SOC under particular land uses: Susan Orgill's presentation ('Soil carbon under perennial pastures; benchmarking the influence of pasture age and management') suggests a relationship between SOC land use management and parent material

and emphasises the importance of pasture species and fertiliser additions in maintaining or increasing SOC in pasture, but there are many research questions to be answered on this topic. Dr Sharon Aarons and co-authors ('Can soil change be assessed for the Victorian dairy industry?') describe the use of legacy data, firstly to quantify the areas of different soil orders under dairy management in Victoria, Australia, and secondly to assess if soil properties for electrical conductivity, pH, potassium and phosphorus had changed under dairy management. They caution that while legacy data can be useful for assessing soil change, researchers need to be mindful of 'fit for purpose' sampling when interpreting data.

4.5 Data, information and knowledge management

Soil samples, field descriptions, laboratory analyses, aerial photography, and imagery from satellite sensors provide the primary data for understanding soil, landscape and land use. These samples and data have lasting value, particularly to answer questions regarding soil change. Many presentations and discussions at the workshop referred to this and there are principles in policy that mirror this concern– in pillar four of the GSP to 'Enhance the quantity and quality of soil data and information: data collection (generation), analysis, validation, reporting, monitoring and integration with other disciplines'[4] – and in the goals of the (Australian) RDE strategy for soils to 'Improve quality, availability and access to soil data and information'[2].

Legacy data from soil surveys, field experiments and monitoring projects are invaluable for applications such as digital soil mapping (DSM) and interpreted products for planning, assessing land capability or, in conjunction with ancillary data on land use practices, for assessing likely and actual changes in soil quality. The paper presented by Ms Maxine Levin describes how use of the National Cooperative Soil Survey (NCSS) data has evolved in the USA and is increasingly being used to support a variety of end users and policy objectives for land use and ecological monitoring. The work reported in the paper by Marchant et al (this volume) referred to above used legacy data from 75,000 routine soil tests on samples submitted by farmers over two decades (1973-93) to map change in surface soil pH.

In the context for understanding soil change, we need to be aware that data on soil properties can be unlocked from a sample at any time if sufficient sample has been carefully archived. The value of soil archives is increasingly being recognised, particularly as methods of analysis are improved over time to achieve greater precision and accuracy. A contemporary sample can be more reliably compared with an archived sample if both are subjected to identical analytical methods and, an archived sample can be retrieved and analysed to yield data on properties not previously measured. Linda Karsies and Peter Wilson ('Soil Archives: supporting Research into Soil Changes') explain the process and value of the national soil archive managed by CSIRO in Canberra and provide an example of how samples in the Victorian soil archive were used to correct SOC measurements recorded over a period during which the laboratory had applied changes to the Walkley-Black method. Without the archived sample to re-analyse, changes in SOC would have been predicted – a similar example for the value of archiving is given for the Scottish study presented by Allan Lilly in these proceedings. Currently, soil archives around the world are proving their worth through the acquisition of spectroscopy, such as mid infra-red, to create predictive calibration sets for a suite of soil properties.

Making information available to others is a critical function of all research, and although the traditional practice is to publish research in peer-reviewed journals, these published papers only represent a fraction of the data generated during the research and only reach a fraction of the potential audience of stakeholders. In the case of soil survey, publication online of primary data sets as well as maps is now expected. Kelly Bryant and co-authors ('Accessing Queensland's soil information – an open data revolution!') describe one State Government's approach to data and information delivery via the web. Pierre Roudier and co-authors' keynote paper was the final for the workshop and provides a clear overview of the changes in information technology and the challenges and opportunities for soil scientists. Roudier makes an important point in this paper, saying, '…the challenges raised by the

"data deluge" are not so much the amount of data per se, but the novel analysis to produce knowledge and help insightful decisions'.

5. Soil Change Matters – The Policy Dimension

Policy for soil is currently a conspicuous matter in national and international agenda. The recent formation in 2012 of the 'Global Soil Partnership' [4] and the Australian RDE strategy for soils [2], as well as the long-standing regional catchment bodies in Australia, provide a platform for integration of policy from global to local geographical scales. The Australian government's Advocate for Soil Health, Major General Michael Jeffery, provided a considered perspective on the challenges that are being faced for land management in Australia ending with a memorable quotation 'To save the planet, we have got to save the soil'. International delegates were particularly impressed by the fact that Australia has an advocate for soils, who is not a soil scientist, but, as an ex-Governor General for Australia, is well connected to Commonwealth and State politicians and is operating at a high level in government. The opening address from the Advocate, the presentations by Montanarella, Fisher and Crawford, and Bouma (this volume), and the launch of the RDE soil strategy set the atmosphere for some informed conversation and exploration of issues and solutions.

A half day facilitated soil science-soil policy workshop was attended by 45 of the delegates representing a range of interests from farming, planning, education, research, extension and policy.

Participants were invited to 'Imagine a future where:

- Our soil is secure – scientists and policy makers have made this a success;
- Governments provide long-term vision, guidance and assistance;
- Research is targeted and timely;
- Scientists and policy makers work as a team; and
- Researchers provide policy makers with exactly what they need.'

The task was then to determine what questions need to be addressed in order to achieve this future. Two rounds of discussions were held at tables of 4 and recorded on paper tablecloths. The discussions were then summarised into 5 focus areas for discussion: 'Our Message', 'Knowledge Brokers', 'Evidence to Drive Policy', 'What Does Success Look Like', and 'Connection Between Community and Soil'. Graphic templates, designed and prepared prior to the workshop in consultation between the conference executive and the contracted facilitators, were used to provide structure for recording the focussed discussions. The completed template for the 'Knowledge Brokers' focus group and an example of a tablecloth record from the world café can be seen in the workshop photographs (figures 22 and 23). The exercise was useful in that the many conversations held on that afternoon served to inform and excite the participants. To what extent this activity will engender action and stimulate change in any science or policy arena is indeterminate, however the primary objective - to get stakeholders from different domains to engage in these important questions - was achieved.

6. Conclusion

The workshop was described as highly successful by Dr John Sadler, OECD's CRP representative, particularly for the role it performed in encouraging a debate to clarify the science policy dimensions, highlighted by a full afternoon of 'world café' table-based and group discussions. A highlight for Australian policy at the workshop was the launch of the National Soil Research, Development and Extension Strategy [2] and an outline of its goals and strategies given by Dr Michele Barson from the Commonwealth Government's Department of Agriculture. The continuance of Major General Michael Jeffery as the advocate for soil health provides a strong presence in the policy arena for Australia.

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