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A preliminary spatial quantification of the soil security dimensions for Tasmania

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ABSTRACT

Soil Security is a holistic soil assessment approach that cogitates soil as a multi-dimensional medium. Rather than traditional single dimensional assessment approaches such as land capability mapping that largely considers only soil and landscape biophysical attributes, the Soil Security concept considers social aspects, education, policy, legislation, current land use, condition and the soils natural and economic value to society. It can identify discrete soils that are currently being used within their capacity, and areas where a use might be unsustainable, i.e. not secure. It would therefore make sense to map this concept, which aligns well with the aspirational and marketing policies of the Tasmanian Government, where increased agricultural expansion through new irrigation schemes and multiple-use State managed production forests co-exists beside pristine World Heritage conservation land, a major drawcard of the economically important tourism industry. The spatial quantification of soil security is seen as an emerging tool to effectively protect the soil resource in terms of food and water security, biodiversity maintenance and safeguarding fragile ecosystems. The recent development and application of Digital Soil Mapping and Assessment capacities in Tasmania to stimulate agricultural production and better target appropriate soil resource use has formed the foundational system that can enable the first efforts in quantifying and mapping Soil Security, in particular the five Soil Security dimensions (Capability, Condition, Capital, Codification and Connectivity). This forms a preliminary mapping product that demonstrates the feasibility of mapping the Soil Security concept. To provide a measure of overall soil security, it was necessary to separately assess the State's three major soil uses; Agriculture, Conservation and Forestry. These outputs provide an indication of where different activities are sustainable or at risk, where more soil data is needed, and develops a tool to better plan for a State requiring optimal food and fibre production, without depleting its natural soil resources and impacting the fragile ecosystems providing environmental benefits and supporting the tourism industry. The following paper demonstrates why and how we might map Soil Security, describing a preliminary approach to mapping the separate dimensions; this approach could be adapted and applied elsewhere as an evaluation tool to identify soil threats relevant to current land use, biophysical properties, policy and management, and stimulate further research and debate into developing a global Soil Security mapping methodology.

1. Introduction

The Soil Security concept has been well-described and documented as an emerging tool to effectively assess and protect the soil resource in terms of food and water security, biodiversity maintenance and safeguarding fragile ecosystems (McBratney et al., 2014; Morgan et al., 2017). Rather than a traditional single-dimensional assessment approach, such as land capability mapping that largely considers only soil and landscape biophysical features (FAO, 1976), the Soil Security concept also considers other important allied soil facets, including societal connections, education, policy, legislation, current land use, condition and the soil's natural and economic value. It aspires to not only identify discrete soils that are currently being used according to their biophysical capacity, but quantify additional stimuli which could cause this use to become unsustainable, or not secure.

A spatial context would be necessary to fully apply a Soil Security

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assessment for any given area, due to spatial variations in soils, land uses, legislation, and governance; it would be therefore considered advantageous to map this concept. This paper demonstrates a possible approach and first attempt at spatially quantifying each of the dimensions of Soil Security, as described in McBratney et al. (2014), using soil and ancillary data available for Tasmania. In particular, this work has focused on the agricultural, forestry and recreational services that soil in Tasmania provides. The choice of these three activities is not only determined by the significant economic benefit to this state of Australia (Tasmanian Government, 2015; Tourism Research Australia, 2016; West, 2009), but is useful when demonstrating that the multi-dimensional nature of Soil Security requires an assessment approach that considers the variations in soil characteristics, land use and how it is used (Koch et al., 2013). All of which answer the question "*why would we map Soil Security*"? *But* "*how are we to map it*"?

This is complex, but using the separate dimensions that encompass the biophysical, social, economic and political aspects, this paper demonstrates how the concurrent consideration of these components could contribute to a first spatial approximation of a soil security assessment (McBratney et al., 2014). In this case, using a Digital Soil Assessment (DSA) framework, the approach becomes more powerful by separately and spatially assessing each dimension, pixel-by-pixel, to highlight where soils are considered "secure" or "not secure", the degree of this security, and what dimension of security is problematic; for example, whether soils are being used beyond their biophysical capacity, lacking in the necessary policy to protect them, or a lack of understanding or education in soil conservation practices by relevant land managers.

The five dimensions of overall Soil Security, as conceived and described in detail by McBratney et al. (2014) is considered for use in Tasmania and are summarized as follows;

(1) Capability: What can this soil do? i.e. Focusing on what the soil is used for.
The dimension aligns with the biophysical capacity of the soil to perform a task, and is interrelated with the soil's condition. This, as well as more specific land suitability, has been one of the major forms of soil assessment in the past, generally applied globally according to the FAO (1976). This has historically been applied in Tasmania as a seven class land capability assessment (Grose, 1999a; Grose, 1999b), assessing soil attributes, landscape position, parent material and climate.

(2) Condition: Can the soil do this?, (McBratney and Field, 2015). i.e. 'Is the soil being improved, maintained or degraded by a particular land use'?
In this case, the soil's condition can be considered as the deviation of key soil attributes from known or perceived soil condition target or threshold values for different soil-land use combinations. This is often measured by long-term monitoring of the soil attributes, for example, soil carbon or pH, for different soil type and land use combinations, and is often considered as a measure of soil health or quality (Cotching and Kidd, 2010a).

(3) Capital: Placing a value on "things" ensures its contribution to decision making processes (Robinson et al., 2009) and asks, 'What economic or ecosystem value does the soil provide?'
Soil capital can be difficult to quantify, also containing several different elements; economic, social and natural. For the purposes of this example, we will consider the economic and natural components. Economic capital is considered as the potential earnings a soil landscape could deliver for a particular land use or enterprise. Natural capital is considered a function of ecosystems services (Costanza and Daly, 1992), such as the capacity of the soil to store carbon, provide riparian filtration, and biodiversity maintenance.

(4) Connectivity: Those who know care, and those who care lobby (MacEwan et al., 2017), and is focused on, 'How much is known about the soil and its appropriate use?'
This dimension encapsulates the social aspects of the soil; how it is treated, valued, understood and/or respected. Although difficult to quantify for many land uses, in this case it is focused on the knowledge of the land manager in regards to appropriate and sustainable soil management, identification of soil vulnerabilities, and risk minimization strategies. This could also concern whether the land manager has access to the appropriate tools to effectively manage their soil, for example, soil mapping, education, and training.

(5) Codification: 'What regulations guide or control appropriate soil use?'
Soil codification is considered as the public policy, regulation, guidelines and legislation pertaining to soil use, management and conservation. In Tasmania, as per many parts of the world, soil regulation and policy is limited; however, in determining soil security, appropriate policies and incentives can have a large bearing on the other four dimensions in guiding, encouraging or enforcing appropriate uses, management, identification of degradation and education.

Mapping the dimensions of Soil Security provides an indication of where different activities are sustainable or at risk, where more soil data is needed, and provides a tool to better plan for a State requiring optimal food and fibre production, without depleting its natural soil resources and impacting on the fragile ecosystems supporting environmental benefits and the tourism industry. Each dimension is multifaceted, and could be broken-down further into more complex components; this paper is a first attempt at holistically mapping soil security to demonstrate the benefits of such an approach, however, additional work and adaptations is considered necessary before applying this methodology as a Government tool to facilitate effective natural resource management.

The following paper outlines one of potentially several approaches for mapping the dimensions of Soil Security. The methodology described is a relevant in a Tasmanian context, in terms of the available data resources, soils, governance and land uses; this approach could be applied elsewhere, but would require adaptation depending upon regional conditions and available data. The aims of this paper are;

To demonstrate the feasibility of spatially quantifying the concept of Soil Security using a Tasmanian case-study.

2. Methods

2.1. The basic methodological roadmap for this study includes

1. Selection of Tasmania and appropriate soil and land use data.
2. Separation of data into three major land and soil use types; Agriculture, Forestry and Conservation.
3. Application of parametric ratings, empirical functions and relevant jurisdictive information to each land use type to determine a spatial measure of each Soil Security Dimension.
4. Combination of each Soil Security Dimension into an overall map of Soil Security for Tasmania.
5. Consideration of mapping inferences, strengths and weaknesses of the approach, and how the approach could be further refined for application elsewhere.

2.2. Study area

Tasmania, the southern-most and island state of Australia (−42.08°S, 146.59°E) has a cool-temperate climate, with mean annual rainfall averaging > 1800 mm year^{-1} in the west, to < 450 mm year^{-1} in the central Midlands (Australian Bureau of Meteorology, 2014). Area is 68,401 km^2, with a diverse range of soils and landscapes and associated native flora and fauna. Tasmania's most productive soils are derived from Tertiary basalt on the north-west coast and the north-east