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Discussion

Soil Security for Australia

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Abstract: Soil Security is an emerging sustainability science concept with global application for guiding integrated approaches to land management, while balancing ecosystem services, environmental, social, cultural, and economic imperatives. This discussion paper sets the scene for an Australian Soil Security framework as an example of how it might be developed for any country, defining the key issues and justification for Soil Security, as well as detailing implementation requirements and benefits; two examples of beneficial outcomes are provided in terms of facilitating decommoditization of agricultural products and the impact of urban encroachment on productive land. We highlight research gaps, where new knowledge will contribute to well-rounded approaches that reflect differing stakeholder perspectives. We also provide key nomenclature associated with a potential Soil Security framework so that future discussions may use a common language. Through this work we invite scientific and policy discourse with the aim of developing more informed responses to the myriad of competing demands placed on our soil systems.

Keywords: ecosystem services; land management; food security; fibre security; land use; land planning; natural capital; social capital; farming systems

1. Introduction

The Soil Security concept [1] provides the opportunity to develop national frameworks, with the potential for a unified global approach to sustainable and regenerative land-use and management. The Sustainable Development Goals (SDGs) contain mandatory key performance indicators in the form of targets for each of the 193 signature countries, of which Australia is one [2]. Keesstra et al. [3] explains that this presents both a great challenge and opportunity to the science community, including the soil science community, as the SDGs require truly multidisciplinary solutions and soil science directly affects five of the 17 SDGs. Fortunately, the Soil Security concept supersedes traditional single-dimension land capability assessment and provides a framework for multi-dimensional assessment taking into account the balance of social, economic, and natural capital.

This soil security concept is motivated by sustainable development and is driven by the need to: secure food and fiber production that is not only productive, but profitable; preserve our biodiversity; and contribute to our water and climate sustainability. All of these drivers are critical to human health and the health of our nation and planet. It is, therefore, an integrated framework identifying the economic value of our soils for multiple uses and provides a systematic way of guiding land-use and management decisions well beyond our current compartmentalized systems. This discussion paper aims to demonstrate how the Soil Security concept can aid Australia, or any other country, to simultaneously manage its natural assets for the betterment of our domestic society, while also striving to meet global SDG requirements.

The Soil Security concept is perhaps uniquely attractive due to its holistic, multi-dimensional view and the fact it can be driven by users (e.g., land managers). By contrast, single viewpoint and top-down regulatory-only approaches seem incapable of tackling contemporary challenges at the nexus of land-use conflict, and balancing socio-economic drivers with soil and landscape health [4–7]. Importantly, the Soil Security concept provides a market-based approach to land assessment and management that has the capacity to identify niche markets though *decommoditization*, whereby agricultural commodities are inextricably linked to healthy land, ecosystem function, and responsible production practices, which deliver enhanced value at the point of origin. In such an approach, the driver for the adoption of good land management is the ability to state the quality of land management, prove this, and attach it to the product provenance, or ecosystem service assessments. This drives a commodity towards becoming a "*decommodity*", attracting a premium, and simultaneously providing a driver and mechanism for maintenance and improvement of land management and ecosystem health.

In essence, the Soil Security concept allows simultaneous management of production and environmental systems, with the potential to better inform public investment in ecosystem services, as the private investment will be market-driven. This has important advantages for governance bodies and regulators, as Soil Security has capacity to motivate a range of actors from individual land managers to political organizations, which is a truly unique modis operandi for any land management system. A fact of environmental governance is that the issues requiring attention always outweigh the budget provided to address them. Therefore, the first question when implementing new environmental policy—asked overtly or not—will always relate to the cost of policy development and implementation in relation to the perceived benefit. We will demonstrate how a Soil Security approach can provide greater transparency to government decision making around the investment of public money into environmental land management, while offsetting the burden on governments through private industry investment.

This discussion paper contains a number of key terms with specific meanings, which have been identified in italics and defined within Section 2. The main objective of this paper is to outline a framework for implementing Soil Security in the Australian context, although our approach should be universally applicable. Such a framework provides a template from which other nations could commence their own planning—starting from a vacuum is often a barrier to sensible policy creation. However, we hope that this preliminary framework could form the basis of a unified global approach.

2. Defining a Common Language

In moving towards a Soil Security framework for Australia, and more broadly at the global scale, it will be important that terms are used with precise meaning. The purpose of this section is to define the precise definition of the terms used within this paper to ensure that the core message is clearly interpreted. While the majority of these terms are in current use, we have needed to define specific terms for this work.

Australia's Natural Capital—Refers to an overarching account of the function and value of our nation's ecosystems services, including from soils (e.g., the capacity of the soil to store carbon, provide riparian filtration, and support biodiversity). Natural capital [8] places a value on natural resources such that they can inform decision-making processes; value is in terms of the ecosystem function, and

service this delivers, as well as economic value. In some cases, the ecosystem services value will be of more importance than the economic value. For specific definition of capital within the Soil Security concept, see "*Soil Security Dimensions: Capital*" below.

Best-Management Practices; Best Land-Management Practices—Methods or techniques found to be effective and practical in achieving a production objective within the context of sustainable natural resource management (i.e., avoiding soil loss or degradation, preventing or minimizing pollution), while making optimum use of the economic, social, and natural resources. A singular, national-scale best-management practice scheme cannot exist, due to the soil variation, highly complex and differing environments, and climate, as well as different land uses. Therefore, best-management practices need to be regionally tailored and industry specific. Additionally, best-management practices do not seek to optimize factors, or objectives, as individual aspects, but rather balance whole production system and wider ecosystem objectives. In this context, suboptimal performance may result in some system aspects to allow performance optimization of the holistic sustainable system in perpetuity.

Decommodity; Decommoditization—in agriculture refers to the identification and segregation of products (crops and animals) at the source and through transport and supply chains to consumers. This facilitates greater traceability of product provenance that is clearly linked to quality control, as well as the story and metrics of production. Decommoditization will inevitably be linked to the social license for agricultural organizations to operate, increasingly demand by consumers. The principal reasons to transfer commodities to decommodities are to gain consumer confidence (around product quality, integrity, and method of production) and thereby achieve a premium in a discerning market. High-value wine is the classical example; see [9] for further discussion on *decommoditization* and agricultural markets.

Ecosystem Services (reproduced from [10])—are the benefits provided to humans through the transformations of resources (or natural assets, including land, water, vegetation, and atmosphere) into a flow of essential goods and services, e.g., clean air, water, and food. Some ecosystem services, such as the regulation and stabilization of climate, water flow, and the movement of nutrients have been even less visible until recent times, when disturbance to these systems has exacerbated climate change, soil erosion or eutrophication. Like all complex systems, ecosystems can appear to be working well until they suddenly collapse, as the supporting base may have eroded without obvious warning symptoms.

National Account; National Account for Soil—encompasses the concept of soil having capital value within production systems, and the broader ecological systems these exist within. The national account is, in essence, a bank balance providing the current balance of soil capital. Most importantly, the *National Account for Soils* would provide the trajectories against that balance in a regionally specific manner, meaning that Australia can account for its soils at any point in time and forecast future projections. The Soil Security concept provides the means for accounting, while the *National Soil Capability Statement* provides a measure of this account against the current vulnerabilities, providing the soil management plans that would help the nation achieve enhanced Soil Security, and the associated production benefits this brings (See *Soil Capability Statement*).

National Soil Capability Statement—Soils, like any asset, have vulnerabilities to their value. In the case of soils, the condition (see *Soil Security Dimensions: Condition*) and capability (see *Soil Security Dimensions: Capability*) determine the production capacity (economic, natural, and social), which in turn affects the capital value. Soils will have current and potential capabilities, which need to be accounted for (see *National Account for Soil*), as well as vulnerabilities to these capabilities, which further infers that resilience to these is an important factor that requires addressing. The national capability statement details soil capability on a regionally specific basis, nationally, and details the resilience of these soils to the identified vulnerabilities. These vulnerabilities might include erosion, salinity, climate change, urban encroachment, etc.

Soil Security—Rather than a single-dimensional land assessment approach, such as land capability mapping (largely considering only soil and landscape biophysical features) [11], the Soil Security concept incudes consideration of other allied soil facets, including societal connections, education,

policy, legislation, current land use, the requirement for conservation, condition, and the economic and natural value of our soils. Soil Security does not simply identify discrete soils, rather it aims to quantify additional pressures which could result in soil becoming unsustainable or insecure. Quantification provides a framework for realizing the potential for improved productivity, function, and ecosystem services. In this way, Soil Security is much more than soil health, or soil quality, which are encapsulated within "Soil Security dimensions: Condition." See [1,12,13] for detailed reading on Soil Security as a globally important framework.

Soil Security Dimensions (Reproduced from [14]):

Capability—What can this soil do? i.e., Focusing on what the soil can be 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 [11]. This has historically been applied in Tasmania, for example, as a seven-class land capability assessment [15], assessing soil attributes, landscape position, parent material, and climate.
Condition—Can the soil do this? 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.
Capital—Placing a value on "things" ensures contribution of said things to decision making processes 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. Economic capital is considered as the potential earnings a soil landscape could deliver for a particular land use or enterprise.
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 Australia, similar to 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.
Connectivity—Epitomized by "Those who know care, and those who care lobby", 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, by all stakeholders, not just by the land manager. Although difficult to quantify for many land uses, in this case it is focused on the knowledge of the land manager in regard 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.

3. Background Leading to the Need for Soil Security

In reading this paper, it is important to note that Soil Security is not intended to be a framework for locking up soil (i.e., protection through legislation), but instead a framework designed to empower and reward good soil stewardship through a variety of approaches, the most important of which may be soil-product *decommoditization*. The concept of *decommoditization*, and how this can be realistically achieved, is explained below in Section 6.1. In brief, the Soil Security framework utilizes the heightened, and inevitable, global demand for traceability ("provenance") of food and fiber produce. Traceability is clearly linked to quality control, but it will inevitably be linked to the social license for agricultural organizations to operate that consumers increasingly demand [16], as well as the provision of ecosystem services, which are becoming a component of the Australian agricultural social license to operate.

Therefore, rather than a protection-through-legislation regulatory approach, the Soil Security concept provides an empowerment framework where the end-user (e.g., landholder), society in general, and Government benefit from prudent implementation. Given the complexities of land management, and the breadth of actors influenced by land management decisions—all people, current and future generations—an empowerment approach is direly needed to shift the management culture towards a shared societal responsibility reflecting the actors involved.

Australia's greatest natural asset is its soil. Soil accounts for 80% of Australia's natural assets with an estimated value of $3860 billion [17]. Some 45% of the nation's soil is used for agricultural production, with 84% of this used for grazing, 8% for cropping and the remaining for forestry and other practices [18], resulting in an annual output of $37 billion [19]. This is a share of 2.7% of all national industry, employing over 320,000 people. Major banks now recognize the need to integrate natural capital, including soils, into their risk assessments [20].

There is increasing demand being put on the soil resource, such as being able to produce more food with less and at the same time to sequester carbon to mitigate climate change. This is driven by the need to ensure reliable, clean, and nutritious food for national markets, along with the longer-term vision of Australia providing for the 70% rise in food demand internationally, and food diversification globally [11]. Adding to this is the need to restore the productive capacity of degraded soil. While there is continuing improvement, the loss of soil capability through acidification, salinity, structural decline, and erosion remains a threat, especially related to arable and grazing land management. This equates to a global requirement to produce twice the output of the so-called "green revolution", in half the time (i.e., by 2050). To achieve this, Australia requires new and empowering market-based approaches to soil resource management. This is what a Soil Security framework offers.

An emerging issue is the loss of agriculturally useful soil due to the fact of urbanization, with urban and peri-urban usage encroaching into agricultural green-fields and flood plains around our regional cities, and resulting in the loss of high-production horticultural soil around our capital cities [21]. There is a growing need to consider the optimal use of soil (in association with other key resources such as water) in and around cities to ensure its security and maximize its potential, as the current soil resource will already struggle to meet the global production demand without minimizing the available land.

Globally soil contains ≈25% of terrestrial biodiversity [22]. Soil has a significant role in supporting and protecting our biodiversity through its contribution to the National Reserve System and providing a sanctuary for soil biodiversity. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) estimate that more than 25% of Australia's aboveground biological carbon stock (i.e., 20 million hectares) exists in protected areas [23]. More recently, the "soil carbon 4 per mille" initiative of the Paris Climate Accord led from France has focused the attention on developing soil carbon stocks. For Australia, it is estimated that 25 GT is stored in the top 30 cm of soil [24], supported by a healthy soil biome.

Australia is the fifth largest country by size, covering some 5% of the world's land area. The capital value of the world's soil stock is equal to $325 trillion, suggesting that Australia's contribution is $16 trillion. The annual value of ecosystem services contributed by soil is estimated at $11.4 trillion, suggesting that soil provides $570 billion to Australia's ecosystem services annually [25].

Australia is regarded as having a highly educated and advanced land-holder population, which would help facilitate best soil management practices. Nevertheless, there is always a need around the ongoing soil and land literacy of these land-holders [26,27] who are, in a sense, the proxies for the whole population in the care of much of our productive soil resource. Perhaps more importantly, there is a clear disconnect with the clear majority of the population and the land-holders, and in turn the soil. Food is produced anonymously to the consumer. However, there is a small, but growing, demand by consumers for information on how and where their food is produced. This growing connection has the potential to link consumers back to the soil through the concept of "provenance". Such connection will be vital in driving Chinese import of provenance identified agricultural products; in recent history, small-scale *decommoditization* has resulted from Chinese markets seeking premium Australian products.

Technologically, this is becoming more feasible through digital agriculture. Younger generations of Australians are developing a strong social conscience, identifying that domestic social license to operate will be a key economic driver of provenance-based markets. In the future, we imagine the general population will be concerned about best-management practice and the ecosystems services this management promotes, for soil via the production of food and its associate social license.

The continued development of remote and proximal sensing technologies has increased the opportunity to routinely assess the soil's capability and condition at both regional and local scales. The use of these technologies is also increasing in Australia's agriculture sector, through precision agriculture and robotic innovations. This is coupled with the increasing innovations and adoption in digital soil mapping (DSM), united with digital soil assessment (DSA) [28], that is increasing the opportunity for recognizing and enabling best management practices.

In order to address the issues discussed above, there is need for sustainable development that secures food and fiber production, preserves biodiversity, and contributes to water and climate sustainability, all of which contribute to human health and the health of the nation. The Soil Security concept provides the foundation from which to construct such a framework. Soil Security, as a multidimensional concept, is underpinned by the need to assess and manage our soil determined by its capability and asks the question, "what can this soil do?". Soils differ in their resilience and react to pressures differently, meaning that spatial variability in the capability to address a given issue/s must be expected, mapped, and understood. This can be reported as a National Capability statement. Similarly, the condition of the soil against its capability must also be spatially understood to map production capacity, where production can be defined as economic, environmental (natural assets), and social. Both at local and regional scales, the continued monitoring of the soil's condition will provide the information needed to ensure sustainable use of the soil in line with adoption of best-management practices.

The concept also incorporates the need to value soil's contribution to other ecosystem services in addition to production, i.e., its capital, contributing to a statement of Australia's Natural Capital. This is all affected by people's connectivity to soil or knowing and valuing soil as one of Australia's greatest assets. The need to develop governance, i.e., codification, both in the public and private sectors to ensure appropriate use and management of soil is also recognized in the Soil Security concept. The five dimensions of capability, condition, capital, connectivity, and codification ensure a holistic approach to securing soil by encompassing the biophysical, social, and economic dimensions. A proof of concept has been implemented in the state of Tasmania as a first approximation of Soil Security demonstrating the feasibility of the approach [14].

4. Role of Scientific Professions in Achieving Soil Security

The implementation of a national land management framework based upon the Soil Security concept will require concerted effort from scientific organizations, working in tandem with State and Federal Government, and their counterparts, as well as all stakeholders of soils. Within Australia, and globally, professional scientific societies and peak bodies have been given less credence in political decision making than is likely prudent. There appears to be a global shift away from science informing (i.e., evidence-driven) policy development, and in shaping society [29,30]. It will, therefore, be important that professional societies and peak bodies are integrated in the development of a Soil Security framework. We consider this here from the perspective of the Australian professional society for soil science: Soil Science Australia (https://www.soilscienceaustralia.org.au/). It would be prudent for other countries to consider this from their own professional body perspective.

The role of Soil Science Australia is to act as the scientific advocate for Australia's soil resource; to recognize its capability and condition and to advise government on concepts and methods that can facilitate good public policy for the security of our soil. We note here that professional societies are much more than introspective groups for the discussion of their technical detail; they are the wealth of knowledge available for consult, usually operate as not-for-profit, as well as being independent and

impartial to the political process. It is for these reasons that the onus is on professional societies to also remain proactive in their lobbying and advocacy roles. We believe that these attributes also contribute significantly to brokering trust between society, industry, and Government [30], which is integral to the success of a new management framework.

In the implementation of any framework that requires natural asset audit and assessment of condition, there must be suitably qualified auditors/assessors, whereby there is also transparency in the certification of this. Within the Australian context, Soil Science Australia has developed, and continues to support, the professional standards of practice in soil science. The Certified Professional Soil Scientist (CPSS) accreditation is the hallmark of professional confidence in expertise and is importantly independent from and impartial to Government and industry. Technical organizations, societies, and peak bodies will, and must, play an important role in the social credibility of certification.

Soil Science Australia works closely with the National Committee on Soil and Terrain (NCST, http://www.clw.csiro.au/aclep/contacts.htm), which is the Government peak body for soil and land evaluation, consisting of Commonwealth, State, and Territory Government representation. The NCST oversees the development of consistent national soil scientific, survey, and data standards and fosters collaborative capacity-building and information sharing among member organizations. However, responsibility for soil information inventories, land-use policy, and regulation resides with State and Territory governments. The fact that Australia does not have an existing dedicated body for reporting on the soil resource, but has such bodies for major water systems, vegetation, meteorology, and geological/mining resources (e.g., Murray Darling Basin Authority, Parks Australia, Bureau of Meteorology, Geoscience Australia), is a clear indicator of the requirement for concerted soil resource management. An impartial and independent body is required, and while SSA and NCST must be key stakeholders in the development of this, professional bodies spanning the full spectrum of industry and ecological function that soils underpin will need to be stakeholders also. Soil Science Australia, or any other peak body and/or technical organization/society, will need the support of all levels of government together with soil and land management professionals to help achieve the policy goal of Soil Security.

5. Soil Health and Soil Quality in Relation to Soil Security

There is a current focus on "soil health" and "soil quality" in Australian agricultural and environmental industry. These terms are similar, and often used synonymously, but do have some nuances. In general, both terms describe that soil exists on a continuum in terms of being somewhere between good and bad. Soil health and quality approaches seek indicators that are measurable to subsequently report in a quantitative manner as to how good/bad a soil is in relation to the numerous indicators, providing a means to understand production capability and what might be done to improve it. Soil Security is more encompassing than soil health or quality, whereby soil health/quality are essentially equivalent to the soil condition criteria of the Soil Security concept (1/5 criteria).

It is noted that soil health and soil quality both have various levels of merit. Soil health creates the correct perception that soil has a living component, and can become "sick" just like ourselves as humans, providing a very intuitive understanding of soil health [26,27]. However, soil health can often also lead to excessive focus on the biological aspects of soils, creating ignorance in the chemical and physical attributes. Soil quality is normally used to overcome this issue, but the term quality is a subjective one, in that quality to one individual is not quality to another. Sojka and Upchurch [31] state that the definition of soil quality remains elusive and value laden, with the usage often having developed arbitrary policy overtones. This perhaps explains why Bünemann et al. [32] find that evaluation of soil quality with explicit relation to soil threats, functions and ecosystem services are rarely implemented, and where implemented have unclear interpretation schemes, limiting the adoption of soil quality schemes by landholders and policy alike.

Furthermore, there is an important point that must be made when considering a given soil and whether it may be healthy or of good quality; i.e., a soil might be healthy, but not a good quality soil in terms of relativity to other soil qualities. This indicates that the *capability* dimension is missing from the soil health discussion and appears to confound the use of soil quality in the same discussion. While our intent is not to commence a debate around terminology, we contend a new term is required to walk away from the split paradigm of soil health and soil quality. Furthermore, that soil needs to be considered in terms of its productivity as a function of soil *condition* on a continuum of soil *capability*, where *capability* refers to its ability to meet a given global issue.

6. Benefits and Case Studies

In this section we provide three examples of how Soil Security could be used to better manage the land resource in terms of agricultural profitability, society confidence in land management, as well as determination of land-use suitability at the urban and agricultural fringe. While there are, of course, many other benefits of a Soil Security framework, these case studies serve to demonstrate the possible breadth and ability to enhance the experience of all actors.

6.1. Soil Security and Agricultural Decommoditization: Incentivising Agriculture

Decommoditization in agriculture refers to the segregation of products (crops and animals) at the source and their transport through supply chains to consumers. The principal reason is to gain consumer confidence (around product quality, integrity, and method of production) and thereby achieve a premium in a discerning market. High-value wine is the classical example. The proposition is that with sensor and digital technologies this can be achieved at scale for all products. It requires new systems and the education of consumers.

So, where does soil come in? With a "decommodity" one, can think of a consignment moving through a supply chain from producer to consumer. The consignment consists of the "product" along with information about the product. When the consumer searches with the intent to purchase, "product + information" is found, whereby the information provides consumer confidence in the product quality, but also the sustainability of its production (i.e., ecosystem service value, such as for carbon credit/offset schemes). The information contributes to the consignment value, and is attached to the consignment, by say blockchain technology, consisting of:

(1) Compositional information on the product itself; minimal quality criteria (protein content, contaminants); and more generally, compositional characteristics that could indicate place of production (provenance, terroir) (e.g., stable isotope composition, DNA/metagenomics information—such information will largely reflect the soil environment).
(2) Information on the method of production (a compilation of digital information from digital farms records on how the crop or animal was grown, e.g., for a crop—sowing dates, fertilisers, herbicides applications, harvest date, irrigation, etc.). Part of the *decommoditization* dividend comes from "Certified" or *best practice* approaches. For soil, best practice would suggest growing crops or animals on soil that is highly suitable for that purpose and in a manner that is sustainable—the capability dimension of Soil Security. This allows the creation of metrics for emerging ecosystem services markets such as biodiversity offsets and carbon trading.
(3) Information on the state of the environment where the crop or animal was grown (this is a time-stamped or longitudinal record of the state of the environment at the place of production—this would include a number of environmental entities, but vegetation and soil would the key ones. A key part of the *decommoditization* dividend comes from evidence of sustainability—a stable or non-declining environment. For soil this is the *condition* dimension, and would be measured by properties such as soil carbon, pH, microbial diversity, bulk density, salinity, etc. Additionally, this information could provide localized information on the ancillary ecosystem services provided

by the environment in which the crop or animal is grown—the ecosystem services—this is the capital dimension of Soil Security.

So, we see immediately that *decommoditization*, which is a way of assuring quality and sustainability of agricultural products and thereby attracting a financial premium, connects growers and consumers and utilizes a number of the dimensions of Soil Security. Through this approach consumers can evaluate soil condition, capability, and capital and the linking of consumers to producers. All of this is encapsulated in a digitally enabled market-based mechanism which can increase confidence for consumers, producers, business, and governments. Soil Security is a key part of agricultural *decommoditization* and also is likely to be achieved via this mechanism. There is a market-based mechanism for achieving Soil Security.

As an example, Australia is currently highly reliant on a live export market in terms of meat as a commodity. However, live export to Europe is not feasible due to distances and restrictions on live export. The Soil Security framework, with concerted industry, government and peak-body effort, could realize a significant European market for Australian meat that is provenance driven. It is entirely possible through a market-based Soil Security approach that the meat industry could develop a sustainable and gourmet niche market to Europe, where ecosystem service contribution (*soil capital*) and sustainable practices are the value-add that realizes *decommoditization*. This would bolster the Australian industry through the creation of new markets, while augmenting existing markets simultaneously (e.g., Chinese demand for quality assurance and genuine product).

6.2. Soil Security and Social License to Operate: Educating the Consumer

Across the board, Australian society's trust in key institutions—media, business, government, and NGOs—has fallen to levels only four points above the least trusting country in the world [30], which has led to the perception that a social license to operate within agriculture is considered as a negative concept [16]. When social license to operate is driven by mistrust, a divisive culture emerges and license becomes subject to "guilty until proven innocent", which only serves to further disconnect society from agriculture. We argue that this disconnect between the general population and the agricultural industry can be overcome through the Soil Security concept. Building on *decommoditization* as an incentive to adopt best-management practices, a social license to operate can be utilized to educate the general populace over time as to what *best management* actually entails. The same blockchain technology that brings provenance information to consumers is also an educational tool for the true value of ecosystem services.

Soil Security as a framework can be used to increase the *connectivity* between urban and country regions through demonstration that agriculture is a part of society, and that social license to operate is a positive concern for both the consumer and the agricultural practitioner. Indeed, Lush [33] argues that society is already determining the right to farm and that new approaches are required to diminish the growing gap between the general population and the agricultural industry; further stating that this approach must focus on upskilling producers to lead with shared values, in order to build trust within society. Unfortunately, Lush [33], a strategic communication specialist, subsequently argues that this is a communication issue and that more information and science will fail to overcome the gap. We would argue that through a framework where *connectivity* is a core consideration, communication, along with further information and accessible science, is required to transition social license to operate from a negative to positive perception with shared values. Soil Security provides a new approach that serves to upskill and educate through participation in day-to-day business for both the consumer and the producer.

Connectivity is perhaps one of the most important dimensions of Soil Security in terms of the success of a Soil Security framework. The disconnection between consumption and production requires further attention within society, but also within defining a land management framework. Social *capital* is not something that is quantified as a currency, meaning its inclusion is not straight forward. The richness of social networks between consumers and producers might be a useful proxy, where

changes in this could be driven by ad hoc networked learning approaches [34]. Irrespective of how this is measured, it is apparent that future work should focus more strongly on this dimension for Soil Security to be truly harnessed as a consumer education framework.

6.3. Soil Security as a Superior Land Planning Framework

One of the biggest threats to food and fiber security within Australia, and globally, is removal of productive land from contribution, due to the fact of infrastructure and urban development, colloquially referred to as "urban creep". The analogy of "urban creep" into productive land, in relation to the concepts of soil health/quality, allows better understanding of the interrelation of soil health and soil quality terms, and how soil condition provides a metric with more clarity. Focusing on just soil health or soil quality and their indicators does not directly address urban creep into primary production land. If a soil is healthy/high quality, or the reverse, this ranking does not formally affect the ability to make decisions about urban development; building an urban precinct on it, for example. Within the Australian political structure, the framework for considering the development is removed from both the environmental and agricultural frameworks. This disrupts sound and transparent planning.

Considering the instance where such an urban precinct is built, it will have some effect on the quantum of land used for primary production. The question then is: "If the urban precinct was built on poorer health/lower quality land would this have less of an effect for Australia as a whole, than if it were built on healthy/high-quality land?" The short answer is yes. Covering productive land with urban development places pressure on the remaining productive land to either produce more or expand into less productive regions. To quantify this somewhat, 1.0 m^2 of high-productivity coastal land (e.g., Hunter Valley, New South Wales) is roughly equivalent to 260 m^2 worth of land in less productive regions (e.g., Dubbo, NSW)—these calculations were made using dry sheep equivalent without consideration to cropping/horticulture (high-value production) capabilities, so the real figure for lost land and increased pressure would likely be greater; this is a conservative measure). This means for every 1.0 ha of productive land lost, up to 260 ha of land would need to be introduced to replace this lost land. With a rapidly diminishing capability to farm new land, this actually equates to increasingly immense pressure on current production systems.

In this analogy, knowing whether the soil is healthy or of high quality does not allow us to make land-use decisions in a systematic fashion. It might inform such decisions, but not within a single framework. The Soil Security concept provides the framework with which to make these decisions well informed, not just on the productive land in the region, but on a larger scale and across more aspects (e.g., ecosystem services and socio-economic imperatives). The soil health and quality intentions are captured within "*soil condition*" and then expanded on through the framework to directly inform such issues as urban creep via quantifying the natural capital of the land within a single framework.

A Soil Security framework allows Australia's food- and fiber-producing land to be protected from undue minimization through urban encroachment, but it is not done at the expense of urban development. It allows the most strategic land for urban development to be simultaneously identified in the same assessment that strategic agricultural land is identified. That is, Soil Security provides governments with a framework that simultaneously rewards land stewardship via *decommoditization*, improving ecosystem services through this incentivized improved land management, strategically identifying urban development locations, and better defining where public money needs to be spent on managing natural resource services.

7. Research Gaps

In presenting Soil Security as a framework for Australian adoption, a number of areas requiring further research have been identified. It is extremely important to note that a research continuum can coexist on a parallel timeline to the implementation of a Soil Security framework. That is, the fact that there are research gaps need not hold up the investigation and development of a Soil Security framework for Australia, nor any other country.

There is a need to build, consolidate, and disseminate knowledge in the areas of:

- *Connectivity*. The connectivity dimension is potentially the most important dimension for the Soil security framework to be successfully implemented, as it provides the education, market motivation, and social license to operate. There needs to be an authentic and valued discourse in order for Soil Security to succeed. How to instigate this in a measured manner, as well as be able to account for it in at least a semi-quantitative manner, will be required to map Soil Security.
- The ability to capture social capital within the framework presents some immediate challenges, as it is not appropriate to quantify it in terms of units of social capital. Within the concept of the social license to operate, it may be that this is sufficient as a measure of the social capital from a *codification* point of view, but it will fail to capture the true value of a well implemented Soil Security framework.
- Digital soil mapping and assessment of soil condition at a resolution that is effective for a *national account* requires further thought and specified design. This resolution must also be effective across scales (farm, regional, national). There are major national and global initiative in digital soil mapping [35], but the availability of data to achieve the *national* account resolution will remain as a limitation irrespective of these initiatives. Kidd et al. [14] and Yang et al. [36] have demonstrated the implementation of the dimensions of the Soil Security framework within Tasmania (Australia) and China, respectively. These works highlight that the framework is implementable, but also that further case studies are a requirement in refining the process and creating the data sharing culture it requires to achieve the resolution across scales (farm, regional, national). This is both a simultaneous implementation and research requirement.
- Valuing ecosystem services and natural capital on a multi-land-use basis will remain a challenge. In addition, while the Soil Security framework provides a means by which to better rationalize this, the question of how we can design production landscapes to deliver multiple benefits and sustain natural capital remains. Therefore, there is a simultaneous requirement to commence initiation of the Soil Security framework to aid in valuing ecosystem services and natural capital, while considering the research question of how to design such production landscapes.
- The regenerative agriculture movement is gaining momentum within Australian agricultural communities, but is often criticized for lacking a scientific framework as its basis (e.g., [37,38]). In many ways, the perceived tenets of regenerative agriculture could be captured within the Soil Security framework, as they loosely describe aspects that would be captured within the five dimensions of Soil Security. Therefore, the research gap here is one of reframing the discourse surrounding regenerative agricultural communities, as well as seeking to develop regenerative agriculture approaches that could be measured in terms of a Soil Security framework. This might provide a significant step in shrinking the chasm between regenerative and conventional agriculture industries.

Soil Security, and the issues it encompasses, is a transdisciplinary approach that acknowledges it is simultaneously between, across, and beyond each individual discipline that might be required to research and implement it. On this basis, no one research discipline, nor institution, is capable of doing Soil Security the justice it would require; a concerted effort is required. Vitally, social sciences would be required in the consideration of all dimensions within the Soil Security framework. Ensuring that quantitative, qualitative, fundamental, and applied research, and their disciplines are involved, will build stronger schemes, expediting awareness raising and potentially realizing previously untapped financial resources.

8. Recommendations

To utilize the Soil Security concept as a national management framework, the following recommendations are made, forming the contextual basis of the subsequent discussion:

- Development of an agreed quantitative spatio-temporal framework for each dimension which is mindful of the potential to be able to estimate the indicator variables locally and over time. The work of Kidd et al. [14] was the first attempt at this—but clearly more detail is required.
- Development and reporting of a National Soil Capability Statement at a resolution that is effective across scales (farm, regional, national) to underpin a National Account for Soil;
- Adoption of evaluation strategies and indicators of the continuum of soil condition to inform best soil management at local spatial and temporal scales; highlighting areas of particular vulnerability or poor condition;
- Reporting the value of the soil asset through developing a statement of Australia's Natural Capital;
- Developing a National Account for Soil that recognizes the value that soil contributes to the financial and business sectors;
- Increasing society's connectivity with the soil by recognizing it as one of Australia's greatest national assets;
- Creating incentives for private industry and landholders to provide their local soil sampling and analysis information—achieved through public–private partnerships;
- Creating a set of agreed regionally and soil-specific best land-management practices;
- Developing incentives that reward or provide tax credits for individuals or firms that adopt best-management practice to secure their soil.

9. Consultation on the Policy Approach

As the intention of this paper is not just to describe Soil Security, but to present the justification for it as a national framework within Australia, and informing global adoption, it is prudent to document here the level of scrutiny that has led to writing the paper. The narrative, justification, and suggested way forward has been developed after extensive consultation on the Soil Security concept at a global level. Global Soil Security Symposia were held in Texas (2015), Paris (2016), and Sydney (2018). The first two symposia provided rigorous discussion of the Soil Security concept, leading to refinement over several years with contribution from some of the world's best scientists and leading global stakeholder organizations. The December symposium in Sydney provided a unique and open platform for government, scientists, and stakeholders to further develop an Australian framework through consultation. As a result of this Sydney (2018) symposium, we have further developed the narrative and captured it here such that it can influence policy development and hold a demonstrated weight in this influence.

10. Implementation of the Policy

There would be no immediate significant financial costs to implementation, which is a clear motivator for exploring the implementation of a Soil Security Framework for Australia. The first phase of developing a Soil Security framework would involve a consultation and communication process. Immediate stakeholder engagement in scoping the framework is required, while promotion to more removed stakeholders in the general public will simultaneously be required. The second phase would require further development of a framework, subsequently leading into phase three, which would be the implementation process.

The lead up to implementation requires:

(1) A working group for an agreed assessment framework;
(2) An agreed group of stakeholders, which must include State and Federal Government instrumentalities; and
(3) Catchment—and activity (land-use)—based pilot studies of the assessment framework in each state.

Actual implementation in phase three, requires:

(1) A market-driven approach: A key driver for the Soil Security concept will be to determine, in a manner that facilitates quantification, how it integrates with industry, and to demonstrate that adoption of it serves to simultaneously reward good management (based on soil-specific criteria), while promoting *decommoditization* and the creation of new markets. Without this, it does not incentivize stakeholder engagement and empowerment at the agricultural interface;
(2) The ability of Governments to priorities public investment against private investment offsets: Soil Security will allow the Australian government to identify where public investment is needed, and where it can be reduced/withdrawn, due to the private investment addressing flow on effects to ecosystem services. There is an associated need to determine the flow on links and to develop a manner of quantifying these within capital development. It is important to remember that *Australia's National Capital* value is not simply economic, indeed it is a function of ecosystem services (natural and social capital).
(3) A cultural shift in the value of ecosystem services: whereby the natural capital value can be determined and social capital is able to be included in the value scheme. This will likely require significant investment in education campaigns at all levels, including the general public.
(4) For this to be a truly user-driven framework, it will be important to demonstrate that the framework must be based on trust and transparency. Trust is the currency of agriculture—a decision is not made unless the landholder trusts the source of the information or the body providing the option (the alternative is implementation by enforced regulation, which we know does not work). We suggest that there is a need for an independent and impartial organization that has ready access to the key peak bodies. Importantly, it must be removed from funding, research, corporate industry, and government structures.

11. Conclusions

The Soil Security concept offers a framework for sustainable development of the soil resource for the benefit of all human society in the maintenance of ecosystem and planetary function. It is required to be implemented over large areas—nation states seem to meet both area and governance criteria. Soil security can both be a public- and private-sector activity, not simply a regulatory framework. It is more about incentives than restrictions or penalties. Work is clearly needed to develop the multi-dimensional quantitative assessment framework, and to set-up stakeholder groups allied to each of the dimensions. Australia is pursuing this idea, as is the Republic of Korea. Other countries, states, regions, local government areas or private businesses may find the approach of new and continuing benefit.

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