GOVERNMENT OF
WESTERN AUSTRALIA

Sustaining Western Australia's Agricultural, Horticultural and Pastoral Soils

Western Australian Soil Health Strategy

Discussion Paper

Soil and Land Conservation Council
of Western Australia

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Cover image

This picturesque aerial rural landscape in the Gordon River Catchment, Frankland area of southern Western Australia, is vulnerable to several threats to soil function including acidification, erosion, nutrient imbalances, compaction, and carbon loss.

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Foreword

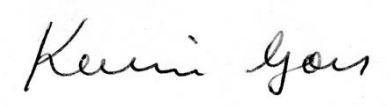
The Western Australian Government, through the Hon. Alannah MacTiernan Minister for Agriculture and Food and the Department of Primary Industries and Regional Development (DPIRD), is committed to developing a Soil Health Strategy to help advance our state's vital agricultural and pastoral industries.

The Minister has given the Soil and Land Conservation Council the responsibility for preparing and overseeing implementation of a Soil Health Strategy for Western Australia. The development of any strategy can only be achieved through a shared understanding and collaboration with landholders. This discussion paper provides an opportunity for stakeholders in the agricultural, horticultural and pastoral industries to shape the development of this Soil Health Strategy.

Stewardship of the soil and land resources on which agricultural and pastoral pursuits depend is critically important. However, questions need to be asked about what constitutes a healthy soil, what risks there are to long-term soil productivity, and what practices are needed to sustain agricultural growth and minimise land degradation. The relatively new term 'soil health' is open to interpretation, ranging from practices proposed by regenerative agriculture advocates to widespread practices such as no-till and stubble retention.

This discussion paper defines soil health through the prism of the physical, chemical, and biological components of the soil ecosystem and the services this ecosystem provides, and invites discussion on a number of principles, topics, and possible actions aimed at sustaining soil and land resources.

Preparation of this discussion paper has drawn on earlier detailed work by DPIRD and the former Soils Ministerial Advisory Committee. The Department's scientific and technical depth, its role in assessing and reporting on soil and land condition, and its regulatory role through the Commissioner of Soil and Land Conservation, has informed this paper and will support the final strategy.



Kevin Goss

Chair

Soil and Land Conservation Council of Western Australia

1. Introduction – a call out to Western Australia

The continued prosperity of our natural environment and our primary industries depends on the health of our soils.

The Western Australian Government recognises that our farmers, pastoralists, and land managers are striving for profitable and sustainable agricultural systems and that our agricultural, horticultural, and pastoral sectors share responsibility for addressing threats to their productive agricultural soils. There are many approaches and practices for achieving productive agricultural soils for our state and its future generations, and we need to respond collaboratively if and when circumstances change.

The role of the Soil and Land Conservation Council (SLCC) is to oversee and implement the preparation of a state Soil Health Strategy that will support industry, communities, and government to better value the soil asset as an essential element of the natural capital of Western Australia.

The SLCC suggests that a statewide Soil Health Strategy should provide direction for research, development, extension, and monitoring activities that support ongoing improvements in soil health in terms of soil function and ecosystem services. Such a strategy should:

- support agricultural and other soil health management practices that provide environmental, economic, and social benefits to Western Australia
- help stakeholders understand the overall direction and management of the state's agricultural, horticultural and pastoral soils
- clearly identify the relevant responsibilities of landholders and government to address emerging soil health issues and challenges to prioritise future investment in soil health.

The SLCC seeks to assist all landholders and managers meet future soil management challenges by adopting a broader ecosystem services approach to decision-making concerning soil health.

1.1 Legislative setting

Two legislative Acts apply to soil and land management in Western Australia:

- The *Soil and Land Conservation Act 1945* (SLC Act) sets out the responsibilities of the appointed Commissioner for Soil and Land Conservation, including the monitoring of land and soil condition in Western Australia and providing information to help reduce land degradation and improve soil condition across public and private land.

  The SLC Act is specific to 'land degradation', which is defined as any action or event (e.g. soil erosion; salinity; eutrophication; flooding; removing or destroying natural or introduced vegetation) that may be detrimental to the present and future use of the land.

  The SLCC is an advisory body under the Act that:

  - supports the role of the Commissioner
  - advises the Western Australian Government on measures and strategies to improve the condition of the state's soil and land resources
  - makes recommendations on soil and land conservation policy, programs, and sustainable land use practices
  - promotes current and emerging opportunities beneficial to soil quality and function.
- The *Land Administration Act 1997* (LA Act) provides for the management of state land, including Crown land and pastoral leases, and Crown land reserves, as well as coastal and marine preservation, biodiversity conservation, water production and filtration, recreation, timber production, preservation of natural heritage, climate regulation, air quality, and tourism.

2. Soil health

Soil has physical, chemical, and biological attributes. The relationship and balance between these attributes determines *soil health*.

Broadly, soil health can be defined as a living ecosystem in which there is soil stability, resilience, and lack of stress symptoms, thus providing the capacity to meet a range of ecosystem functions as appropriate to each soil environment. Soil resilience is the ability of a soil to resist or recover its healthy state in response to destabilising influences.

The 'health' of a soil depends on the relative interaction between the organisms within the soil and the soil's physical and chemical attributes. Soil organic matter and microorganisms play a key role in soil health; however, the degree to which these biological attributes influence soil health is less understood than the role of the physical and chemical attributes.

Soil health is also determined by the degree of soil degradation, which includes soil erosion, loss of soil aggregation, reduced organic matter, loss of water infiltration and water-holding capacity, and increased compaction. A decline in soil health and productivity can result from natural processes or human activities.

In the context of agricultural production, a narrower definition of soil health may apply such that the health of the soil is defined by its ability to support agricultural production without becoming degraded or otherwise harming the environment.

Soil scientists refer to the attributes of a healthy soil as being those that:

- maintain the soil's physical structure and are well aggregated to resist degradation (such as from water and wind erosion and soil compaction)
- maintain adequate pore spaces between particles to allow water and air movement
- receive, hold, filter, and release nutrients and water
- stimulate and sustain plant root growth
- maintain and foster or build soil organic matter including a biologically diverse soil life
- support physical, chemical, and biological conditions suitable for agricultural crops and pasture.

No matter which definition is used, good and well-managed soil health is essential to long-term, sustainable agricultural systems.

Soil health and other concepts are more fully defined in Appendix 1.

2.1 Our valuable agricultural soils

Soil is a vital environmental asset that supports a range of ecosystem services including agricultural productivity, climate, clean air and water, and infrastructure stability. Improvements to the health of Western Australian soils will provide long term environmental, economic and social benefits both now and for the future (Figure 1)

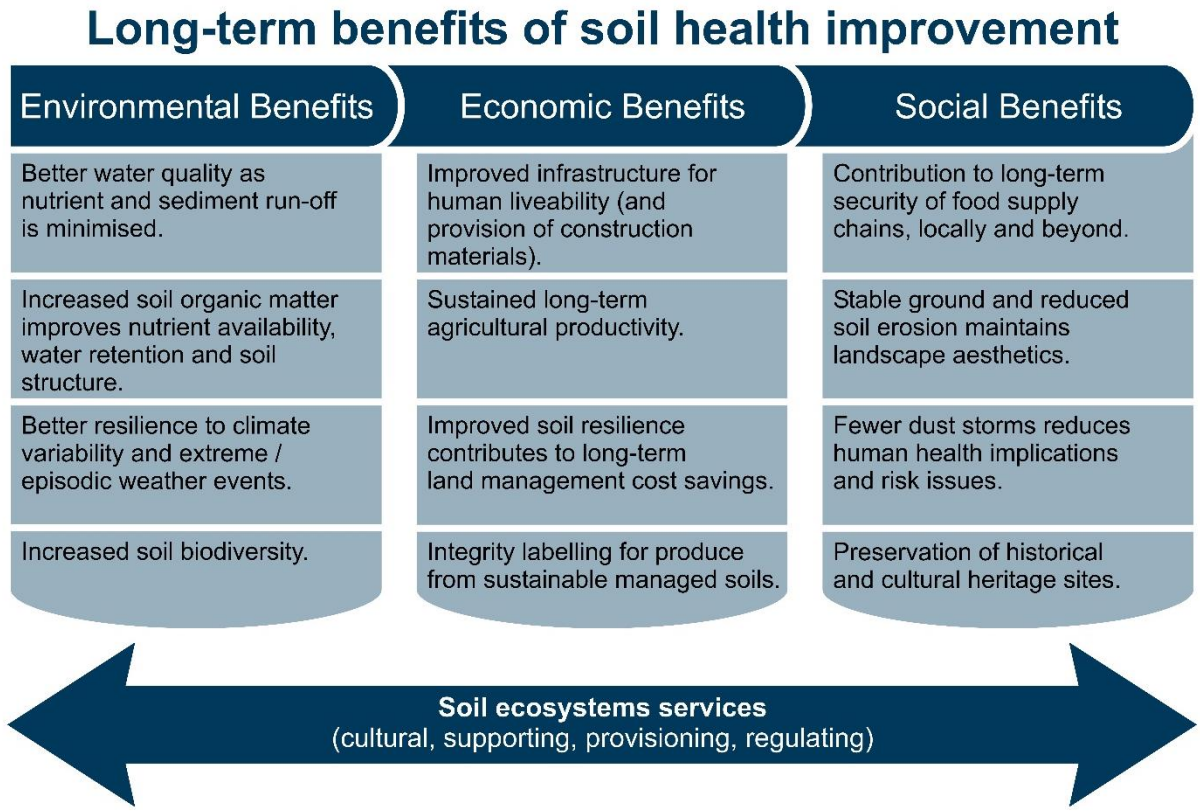


Figure 1: Benefits of long-term and sustained improvements to soil health

Western Australian soils are highly variable with many different soil types occurring across the state. The different properties of soils influence their potential productivity and the degree to which they are inherently susceptible to degradation. In their natural condition Western Australian soils are typically nutrient-deficient and highly variable in both texture and function with many inherently susceptible to erosion and degradation.

For tens of thousands of years, Aboriginal peoples sustainably managed Western Australia's land to provide sufficient food and fibre for their needs. Changes in both domestic and global populations in more recent times have led to more intensive agricultural and pastoral production, with nutrient and other inputs that modify the soil ecosystem introduced with the purpose of generating increased production and improved services.

Today, the Western Australian agrifood industry derives production worth close to $9 billion from the state's soils. Benefits are not restricted to the state, however, as Western Australia exports some 80% of its agricultural production.

The land resources that sustain Western Australia's agriculture and food sector are critical to our rural and regional communities, with this sector directly or indirectly employing 188 000 people (2016–2017) (Department of Agriculture and Food Western Australia [DAFWA] 2018.

2.2 The challenges

Western Australia's agricultural soils are modified ecosystems, which deliver production services such as food and fibre. But the productivity of these modified ecosystems relies on the continuity of the essential underlying ecosystem services.

Generally, modified ecosystems are ecologically more simple and as such have less resilience to external pressures. This can lead to a greater risk of failure or a greater need for increasing artificial inputs to maintain delivery of services over the long term (Walker and Salt 2006). Healthy soils increase the capacity of crops to withstand weather variability, short-term extreme precipitation events, and intraseasonal drought (Al-Kaisi 2016).

Allowing some services (e.g. food production) to take precedence over others (e.g. soil formation or nutrient cycling) may, in time, compromise the functioning and hence the sustainability of the ecosystems that support these services.

Managers of agricultural soils face a number of pressures including:

- increased demands on soils to produce food and other products for an ever-increasing local and global population
- balancing short-term economic sustainability with the long-term benefits of investing in soil health and conservation
- increased regulation in the business of food production, requiring proof of soil or land management sustainability
- high commodity prices, which make short-term gains more attractive than investments that have longer-term pay-offs in terms of soil health and yield stability
- adopting alternative soil management practices that may initially result in lower yields
- practices that can be site-specific and, if adopted, can result in uncertainty and a hesitation to take risks
- changes in climate, which may alter systems and affect soil health.

Land degradation and the loss of high-quality agricultural land is a major ecological and economic concern for Western Australia. The state's soils are intrinsically susceptible to wind and water erosion, acidification and salinisation, waterlogging, compaction, and topsoil water repellence. Frequently these soils are characterised by dispersed sodic subsoils, constrained nutrient availability (or poor nutrient-holding capacity), and generally are low in organic carbon.

Various external challenges can impede the maintenance and management of healthy soils, including exploitative land uses, urban development, invasive pests and diseases, seasonal variability, and a changing climate. All have the capacity to influence or impact the health and condition of Western Australia's soils. Despite these challenges, land users are constantly adapting to changes in conditions and seeking appropriate management strategies to address such challenges.

2.2.1 Land degradation and loss of agricultural soils

Land degradation and loss of agricultural soils can result from various processes including soil erosion by wind or water, acidification, salinisation, waterlogging, compaction, and water repellence. These physical and chemical processes affect the health of the soil and pose significant challenges for land managers.

Soil erosion from wind and water has significant environmental, economic, and social costs across both public and private land, including:

- pollution and eutrophication of water, leading to a decline in water quality of drinking and agricultural water, loss of aquatic life, and loss of recreational amenity
- loss of soil organic matter and carbon storage
- loss of vital soil biology and chemistry necessary to support agricultural and natural biodiversity
- loss of the land's structural integrity (including an increase in the extent of salinity on both public and private land), thus reducing the area available to support native vegetation, infrastructure, and agricultural production
- loss of clean air as a result of dust storms and airborne pollutants
- undermining of infrastructure through the corrosive contamination effects of acid sulfate soils
- loss of overall catchment health - soil erosion compromises most aspects of a functioning healthy ecosystem.

In recent decades, changes to cropping and stubble management practices in Western Australia have reduced the hazard of soil erosion from wind, however, current land-use practices still result in some degree of wind erosion with an estimated opportunity cost of $71 million per year (DAFWA 2013, DAFWA 2017). It is proposed that without an increase in adoption of improved soil management practices, climate variability, including a dryer climate, could increase the hazard of wind erosion (State of the Environment 2016).

Soil acidification is a natural process that is accelerated by agriculture, primarily through the leaching of nitrates from nitrogen fertilisers and/or organic matter. Acidification is increasing in most Western Australian agricultural soils and while agrcilutural lime is used annually by many producers, the extension of this practice and the application rates are well below the amount required to treat existing acidity and ongoing agricultural soil acidification (DAFWA 2013, DAFWA 2017).

Soil compaction is a physical process affecting many soils across the south coast and southern wheatbelt of Western Australia (DAFWA 2013, DAFWA 2017). The average annual opportunity cost of agricultural production lost through soil compaction in the south-west of the state is estimated at $333 million. Compacted soil caused by cropping traffic is particularly severe in the Wheatbelt and is often remedied by costly mechanical treatments (e.g. deep ripping and soil inversion). Changes to land management practices (e.g. stubble retention, green manuring and frequent soil testing) and the retention or build-up of soil organic matter play an important role in maintaining soil structure.

2.2.2 Addressing dryland salinity

DAFWA (2013) estimated that more than one million hectares (>5% of total land in the state) was affected by salt in the south-west agricultural region. The opportunity cost of lost agricultural production attributable to dryland salinity since 2009–2010 was calculated to be $519 million per year (DAFWA 2013, GHD 2019). Without intervention, dryland salinity will continue to be a significant cost and risk to private and public lands.

Reduced rainfall in the south-west in recent years has meant that the degree of risk and intervention required is not easily determined. Monitoring indicates that in some areas the rate of rise in the watertable and the associated risk of salinity has diminished, while in other locations it has increased (Auditor General Western Australia 2018).

DPIRD has commenced new satellite monitoring of the extent of salinity, with an updated risk assessment, which will inform future policy and actions, available in 2021,. In parallel, DPIRD is currently working with agencies and stakeholders on the best ways to improve the effectiveness and efficiency of dryland salinity management measures.

2.2.3 Improving soil health to mitigate climate change

The Western Australian Government believes that improving soil health has several benefits, including contributing to the mitigation of the effects of climate change by reducing greenhouse gas emissions and providing opportunities for the sequestration of carbon. The government is looking at ways to adapt to a changing climate, find more opportunities to reduce greenhouse gas emissions and lay the groundwork for potential participation in Western Australia's emerging carbon offset market. The benefits of improving soil health will fit into the broader Western Australian climate policy currently under development by the Department of Water and Environmental Regulation (DWER 2020).

By global standards, Western Australian soils are comparatively low in soil organic carbon (SOC) (Hoyle et al. 2013). Although there is the potential to store carbon in the soil (mostly as soil organic matter), the challenge is to retain and build the carbon captured for the benefit of soil health. In some areas, the potential exists to sequester more atmospheric carbon dioxide in SOC (Grains Research and Development Corporation 2013). However, studies have shown that, depending on soil type, climate, and land use, many Western Australian soils in low-rainfall environments (less than 500mm per year) have a relatively low capacity to sequester carbon in a stable organic form. Despite this, small increases in SOC over a very large area of the state equate to significant increases in carbon sequestration (Sanderman et al. 2010). Agricultural management systems that actively support maintaining crop and/or pasture biomass for a greater proportion of the year are potentially more likely to result in small gains in SOC (DPIRD 2019). When considering changes in agricultural practice to increase SOC, land managers need good data to benchmark and evaluate the effectiveness of changes or trends in SOC. The limited availability of monitoring data to support the evaluation of changes or trends in SOC remains an immediate challenge across the agricultural, horticultural, and pastoral industries. Measuring and monitoring the levels of SOC in our soils would need to be undertaken under approved and standardised auditing systems.

2.2.4 Reforming rangelands management

The rangelands occupy a vast area of Western Australia, with much of the land under pastoral lease. Vegetation cover and composition are seen as integral to soil health in the rangelands; however, vegetation can be significantly affected by grazing activity (livestock and other indigenous and feral herbivores) (Foran et al. 2019).

Some degree of erosion occurs throughout the rangelands, most notably in the Gascoyne and Murchison, and to a lesser extent in the Kimberley, Pilbara, and Goldfields. The Upper Gascoyne has the highest level of recorded erosion, with 6% of the region experiencing moderate to severe erosion (DAFWA 2017).

Recent climatic and vegetation cover trends indicate that the likelihood of soil erosion by water has increased slightly in parts of the rangelands (DAFWA 2017). The Northern Rangelands are particularly complex to manage, with large land systems ranging across arid lands and pastoral leases, as well as a growing number of irrigated agriculture land developments.

The Western Australian Government is currently revising the *Land Administration Act 1997* and implementing a Pastoral Lands Reform package to support pastoralists in their efforts to drive sustainable development and land management. Improvements in soil health through enhanced land condition monitoring and compliance systems are included in the proposed reforms. The proposed enhanced monitoring system is intended to deliver increased knowledge of the pastoral estates and support improved land condition by encouraging best practices.

2.3 Responding to the challenges

Western Australia has a long history of responding to the unfolding complex and multiple challenges of soil degradation, agricultural soil health, and natural resource management. However, a lack of focus and coordination, together with changing priorities and approaches, has meant that at times the responses have been reactive rather than proactive.

The importance of long-term soil health is a feature of the government's determination to revise the 1945 SLC Act and revive and reform the SLCC. It is critical that the challenges to improving soil health at the property level are matched by appropriate changes and support by industry, community, and government.

Improving the health of Western Australian soils will be assisted by improving information systems, regulation, extension, and administration. Investment and support should include:

- undertaking industry and community driven soil research that is applicable to local conditions
- innovating, and developing new technologies
- improving access to research, innovation and development of new technologies for all Western Australian agricultural and pastoral land managers
- matching land use to land capability, particularly in areas of new agricultural development (e.g. northern Western Australia)
- developing technical specialists to support regional rural communities
- completing High Quality Agricultural Land mapping of the state to support land-use planning decisions
- encouraging agricultural soil analysis, which includes physical, chemical, and biological aspects of soil health
- investing in knowledge capital and career development of Western Australian researchers
- tailoring appropriate regulation, policy, and systems to meet changing environmental and community expectations.

2.4 State Soil Health Strategy development

The development of the state's Soil Health Strategy was first initiated through the 2018–2019 Soils Ministerial Advisory Committee (Soils MAC).

Soils MAC was established to consider the possibility of reviving the SLCC and to determine if there was a need for a state soil health strategy. Soils MAC members with specialist expertise were drawn from Western Australian universities, industry groups, natural resource management (NRM) organisations, and grower organisations. With the support of DPIRD, Soils MAC oversaw a literature review and a targeted consultation process. In November 2019, the newly re-formed SLCC assumed responsibility for developing the state's Soil Health Strategy, acknowledging the sound foundation carried out by Soils MAC.

The SLCC expects to develop the state's Soil Health Strategy in two stages:

- Stage 1 – Release a SLCC Soil Health Discussion Paper (this document), with the purpose of engaging with a broad range of stakeholders to determine goals and principles and prioritise key actions.
- Stage 2 – Release a draft Soil Health Strategy for wider consultation, then make revisions based on input from stakeholders and the public before releasing the final strategy.

3. Developing a direction for soil health

The draft vision for the proposed strategy was developed by government representatives and participants in the Soils MAC Strategy Reference Group.

> ***Western Australians will receive the benefit of healthy and diverse soil ecosystems now and into the future, supporting a healthy environment, agricultural production, and infrastructure protection.***

3.1 Principles to drive change

The key principle of shared responsibility between landholders and government to mitigate land degradation and sustain soils for future use is set out in the SLC Act.

The following guiding principles are suggested for developing a state-level strategic approach to both maintain and manage healthy soils in Western Australia:

- Healthy soils contribute to food security, environmental sustainability, and climate change mitigation and adaptation.
- Soil function priorities and goals should incorporate an ecosystem services approach that applies to all landscapes in Western Australia.
- Soil health management is intrinsically related to good groundcover management and maintenance of sufficient biodiversity within the broader landscape.
- Soil and land degradation mitigation practices should be actionable and cost effective, drawing on new and existing technologies and future opportunities that can improve land and soil health.
- The role of government includes policy development, research and innovation, extension of soil management information, maintenance of soil data and maps, and the monitoring of the state of soil health.

3.2 Strategic themes

Implementation of a Soil Health Strategy will require developing and prioritising goals, determining objectives, and reaching consensus on actions that will be resourced by industry, community, and government.

Three themes have been identified as key matters for consideration. While this discussion paper is only relevant to the Western Australian soil health strategy, these three themes are complementary to current national priorities for improving soil condition across Australia's agricultural landscape (Department of Agriculture, Fisheries and Forestry 2014, McKenzie et al. 2017, National Advocate for Soil Health 2017).

1. **Research and Application:**

   Directions for research and development, extension, and monitoring activities that support new technologies and practices, which can provide ongoing improvement in soil health in terms of soil function and ecosystem services throughout Western Australia.

Scientific investigation underpins our understanding of a range of important soil health values and soil conditions. Supporting farmers and pastoralists in developing new cost-effective technologies that improve soil health management is vitally important in ensuring soils continue to provide the essential ecosystem services that underpin our ecological and agricultural systems (Pannel et al. 2006).

Further, as new land developments are considered in northern Western Australia, an opportunity exists to implement improved planning and systems for soil health longevity and sustainability.

Areas for discussion include but are not restricted to:

- protecting and improving soil health in agricultural, horticultural, and pastoral landscapes through research, innovation, and adopting practices and new technologies that address current known threats to soils and improve soil resilience
- developing soil health technical expertise amongst public and private sector service providers and technical specialists
- improving the knowledge and understanding of soil (quality and ecosystem) services required to build an evidence base that will directly support landholders through state and regional soil health programs
- identifying how and at what intervals monitoring, mapping, and reporting of condition trends in Western Australian soils and land should occur
- identifying best practice on- and off-site soil testing that will support evidence-based decision-making and characterise soil health and risks
- identifying key indicators or surrogates (i.e. soil condition benchmark targets) that effectively and pragmatically characterise soil health and risks to various regional priority environmental assets
- developing and implementing repeatable and reliable methods for monitoring soil biology changes (temporal and spatial for surface soils), which include stable soil biology targets and spatial quantification of soil-derived ecosystem services

- property planning, which in the rangelands includes developing strategies to support herbaceous perennial cover and animal welfare during prolonged dry periods
- developing guidelines to assess the risk of land degradation from new agricultural land development, particularly in northern Western Australia.

2. **Carbon sequestration:**

   Increasing soil organic matter and carbon sequestration in agricultural and pastoral soils through practices adapted to local environmental, social, and economic conditions.

Organic carbon influences chemical, physical, and biological soil properties and functions. Stored SOC plays a pivotal role in generating or supporting essential soil ecosystem services. Soil cultivation, land clearing, and overgrazing contribute to a loss of soil carbon. Adopting management practices that increase the accumulation and stability of organic matter can improve SOC storage and enhance other ecosystem services such as soil stability, water-holding capacity, nutrient cycling, biodiversity, agricultural production, and soil fertility.

Integral to any approach to promote carbon sequestering practices in managed soils are reliable, accurate, and cost-effective means to quantify soil carbon stock changes and forecast soil carbon responses to different management, climate, and soil conditions (Paustian et al. 2019). Climate change is claimed to be one of the more important drivers of land and soil resource condition change (IPCC 2019).

Spatial modelling of monitored SOC is considered essential to inform government and industry on the soil health benefits of SOC. Currently there is no such modelling in Western Australia. Strategies to address this could include:

- co-investment and strong partnerships between industry, community, and government to assess the role of SOC in climate adaptation
- research into the efficacy of soil carbon sequestration from higher densities of perennial pastures and developing the means to achieve this
- research and development into rebuilding complex and diverse vegetation in suitable landscapes.

3. **Soil Governance:**

   Developing effective and innovative policies to guide soil governance (statutory planning, legislation, regulation, and clear and accountable decision-making) by state and local governments that support the sustainable management of soil health and protect high-quality agricultural land and soil resources.

To date, the argument for intervening in soil management has focused on the threat that degraded soils pose to other assets. However, a soil health strategy would focus on soil as a primary asset that provides many valuable services.

Recognising soil as a valuable asset will help planners, investors, program managers, and land managers determine priorities by:

- developing transparent and robust mechanisms to set priorities and better support on-ground soil health actions
- building community capacity and support for innovative landholders as leaders of environmental stewardship
- sharing knowledge and building partnerships with grower and industry groups
- promoting accredited professional development programs for soil scientists
- extending high quality land mapping across designated priority areas and the remainder of the South West Land Division of Western Australia
- developing and extending education programs to target the wider community. Such programs will address the crucial role played by farmers, horticulturalists, and pastoralists in providing food security, climate change adaptation and mitigation, essential ecosystem services, and sustainable development
- integrating land degradation management into land-use planning decisions and supporting state and local government policies for tracking cumulative impacts and planning measures to counteract losses
- reviewing and updating the 1945 SLC Act.

4. Submissions to the proposed Soil Health Strategy

Response to this discussion paper is important and we encourage all stakeholders and interested parties to participate.

If you wish to comment, some suggested questions have been set out below. These are general questions and should not be seen as limiting any submission - respondents are encouraged to include any issues deemed relevant.

The comment period will be open between 18 May 2020 and 6 August 2020.

After considering and incorporating (as necessary) stakeholder feedback, the SLCC anticipates releasing a draft strategy for public consultation for an six week period beginning in September 2020, towards the goal of delivering the final Soil Health Strategy for the Minister's consideration in November 2020.

Comments can be submitted to the Soil and Land Conservation Council:

Email: SLCC@dpird.wa.gov.au

Mail: Department of Primary Industries and Regional Development – State Soil Health Strategy, Locked Bag 4, Bentley Delivery Centre WA 6983.

Your legal rights and responsibilities

When making a submission, respondents are consenting to their submission being part of a public document. The respondent's name will be published, however, to protect the respondent's privacy, the address will be withheld. If the respondent does not consent to the submission being treated as part of a public document, the submission should be either clearly marked as 'confidential', or specific information considered to be confidential should be identified with an accompanying explanation.

Note: Even if DPIRD treats your submission as confidential, it may still be disclosed in accordance with the requirements of the *Freedom of Information Act 1992* (WA), or any other applicable law. Before publishing a submission, DPIRD reserves the right to delete any content that could be regarded as vilifying (as per the *Equal Opportunity Act 1984* (WA)), derogatory, or defamatory to an individual or organisation.

Personal information may be used during the decision-making process and may be used to contact a respondent if clarification is needed for any comments. Personal information may be shared (along with submitted comments) with other government portfolios for use in this decision-making process.

Respondents who have questions about this process should make contact via the addresses above.

4.1 Questions

1. *In your opinion, will the proposal for developing a soil health strategy support the maintenance and management of healthy soils in Western Australia?*
2. *In your opinion, what are the top three actions that industry, government, and the research and education community could take to protect and conserve soil health over the long term?*
3. *What, if any, trends have you noticed in agricultural soil management practices over the past 10 years?*
4. *In your opinion, what are best practices for maintaining and managing soil health?*
5. *How can government and soil specialists best help agriculturalists, horticulturalists, and pastoralists adopt best practice for the management and/or improvement of soil health?*
6. *What specific types of information and/or tools are needed to help governments (local and state), landholders, Natural Resource Management (NRM) groups and farm or conservation organisations make decisions about managing Western Australia's soils and landscapes?*
7. *What tools are needed to assess and monitor soil health and soil and land conservation in Western Australia?*
8. *Beyond what is currently available, are there research topics and/or education and training programs that could be established to provide knowledge and personnel that will help improve the health of soils in Western Australia?*
9. *What are the best ways to make information available to the Western Australian community to support the maintenance of healthy soils and land conservation?*
10. *Do you have any other comments?*

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Appendix 1: Glossary of terms

Soil health

Owing to the complexity of soil, the term ‘soil health’ is difficult to define. However, in broad terms, soil health can be described as an ecosystem in which there is soil stability, resilience, and lack of stress symptoms. Although soil health is displayed as a balance between the physical, chemical, and biological attributes of soil (Figure 2), there is also a biological integrity of the soil community; that is, a balance between organisms in a soil and between soil organisms and their environment. In this context, it is important to acknowledge that soil, atmosphere, hydrosphere, and biosphere interactions are complex and society does not yet have a complete understanding of these interactions across the system.

To the best of current understanding, soil health can be described as a state of a soil meeting a range of ecosystem functions as appropriate to its environment. The benefit of using the term ‘soil health’ is that it can:

- define soil quality in meaningful terms
- provide a descriptive property of soil quality/condition
- provide a foundation for developing and validating the analytical components of soil health, based on quantifiable chemical, physical, and biological properties that can be used for management and policy decisions.

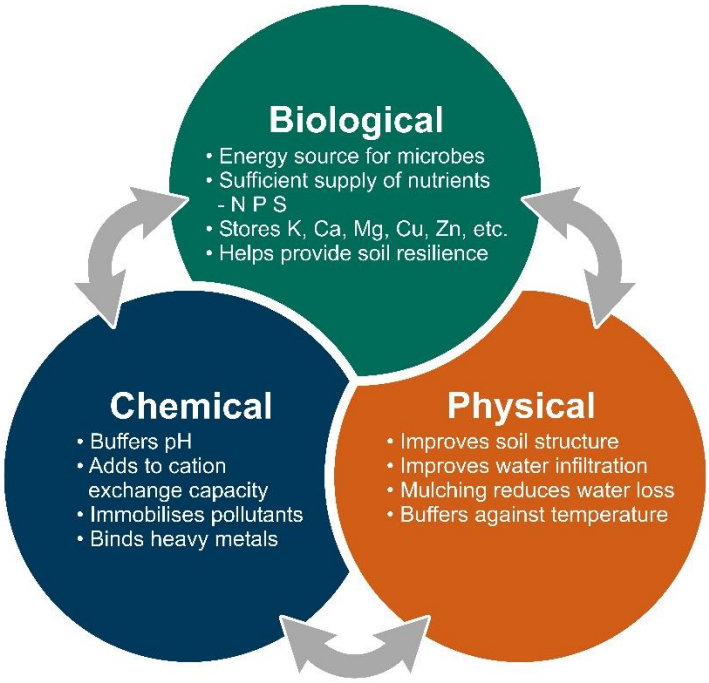

Figure 2: Soil health is a balance between physical, chemical, and biological attributes (adapted from Hoyle et al 2011).

A simple definition of soil health is ‘soils fit for purpose’. In an agricultural setting this would relate to the fitness of the soil to support plant growth without becoming degraded or detrimental to the environment.

Soil degradation

The flipside of soil health is soil degradation. Degradation includes the loss of soil aggregation, reduced organic matter, loss of water infiltration and water-holding capacity, and increased compaction (Fig. 3). All contribute to reducing soil health and productivity, and increasing the potential for erosion.

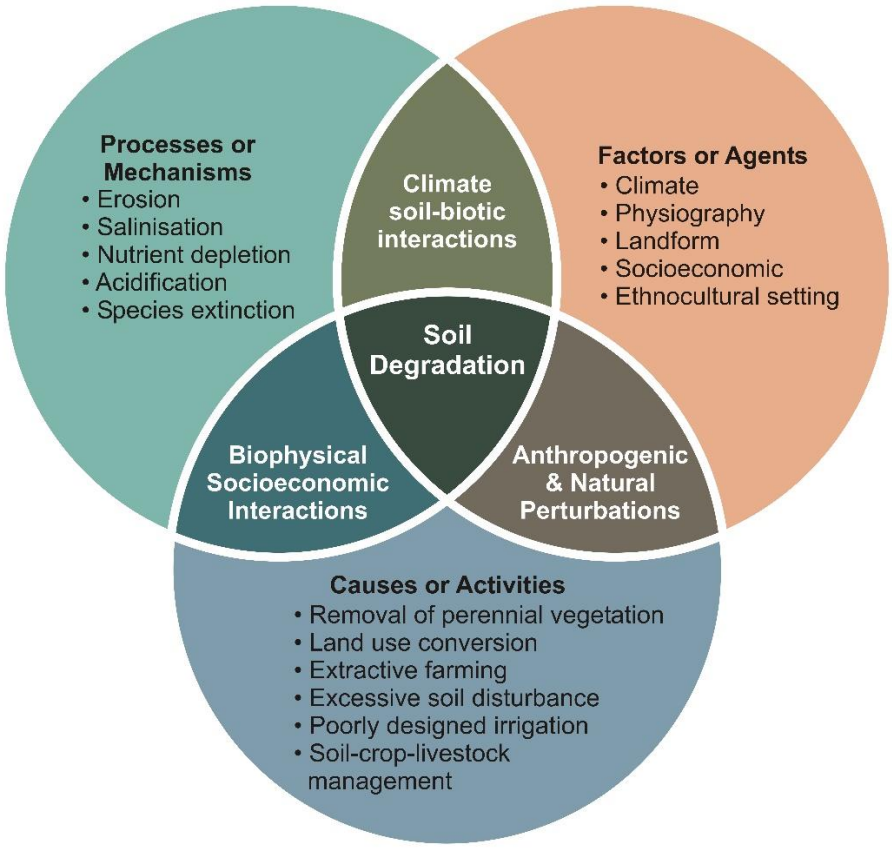

Figure 3: Mechanisms, factors, and causes of soil and land degradation (adapted from Lal 2015).

Soil degradation is strongly exacerbated by the interaction between processes, factors, and causes:

- Processes: the various mechanisms (or types) of soil degradation
- Factors: agents of degradation related to natural or anthropogenic drivers such as climate, physiography, socioeconomic, or ethnocultural parameters
- Causes: specific activities that aggravate the adverse effects of processes and factors, e.g. land-use conversion, excessive soil disturbance, excessive grazing etc.

The Process-Factor-Cause relationship is strongly impacted by site-specific conditions. Therefore, understanding this connection is critical to restoring soil quality and mitigating degradation.

Soil ecosystem services

The term ‘ecosystem service’ emerged in the early 1980s and has recently received increased attention. The term is defined as ‘the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly’.

Table 1 shows a summary of the ecosystem services supplied by soil. It is beyond the scope of this Discussion Paper to address all services, but this summary highlights the fact that whether in the rangelands or agricultural south-west, the ecosystem services supplied by soil provide key opportunities for soil health improvement across geographic regions at any scale.

Table 1: Summary benefits that human populations derive directly or indirectly from soil ecosystem functions (adapted from Greiner et al 2017).

Ecosystem service type (classification)	Soil services supplied
Supporting services	• Soil formation • Retention and delivery of water and nutrients for plants • Carbon sequestration. SOC is the key attribute that influences the soil’s capacity for ecosystem services • Foundation for infrastructure for human habitation and liveability (and provision of construction materials)
Regulating services	• Essential role in regulating atmospheric greenhouse gases and climate - soils are the terrestrial biosphere’s largest reservoir of carbon • Erosion control • Sediment and eutrophication control (toxic algae outbreaks at the end of summer are the result of the slow accumulation over time of phosphorus in the sediments of dams and rivers) • Control of potential pests and pathogens
Provisioning services	• Basis for food and fibre production, fuel (biomaterials), water availability, and of vital importance to recharging water supplies (including flood and drought control) • Source of pharmaceuticals • Remediation of wastes and pollutants • Soil organic matter is necessary to these services because it influences nutrient availability, water availability, and soil structure
Cultural services	• Historical and cultural heritage sites—the preservation of archaeological artefacts, spiritual value, religious sites, and burial grounds
Habitat (biodiversity)	• Stable habitat for organisms, critical for biodiversity and genetic resources (the microbiome).

By improving soil health, the flow of services from the soil system will be maintained and the impact of degradation on natural and built assets will be reduced.

Soil resilience

Soil resilience refers to the ability of a soil to rebound from poor or unsuitable management practices and to resist or recover a healthy state in response to destabilising influences.

A resilient system can absorb disturbance and essentially retain the same function, structure, and feedback. A soil can be resilient to changed conditions, but it may reach a point where it is vulnerable to decline or even collapse because either the rate and scale of change are too great, or because the system reaches a threshold where its essential processes are changed (Department of the Environment, Water, Heritage and the Arts 2009). Typically, a modified soil has less resilience than a natural soil due to the changes in the physical, chemical, and biological attributes. It is important therefore, that we protect or ‘build’ our soils so they can regain the necessary elasticity to resist or recover from change.