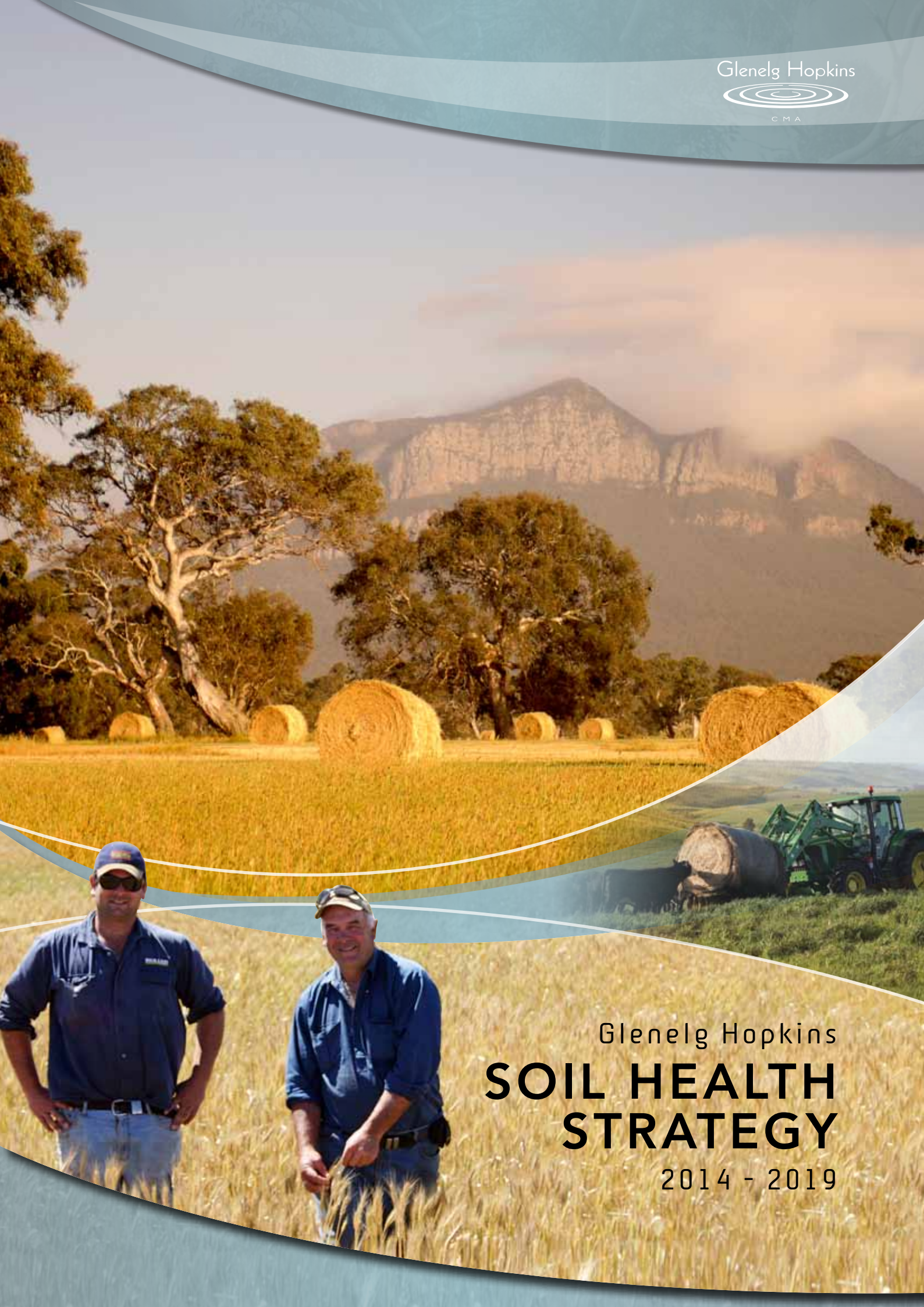
Glenelg Hopkins
CMA



Glenelg Hopkins

SOIL HEALTH STRATEGY

2014 - 2019

CONTENTS

Acknowledgements

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Front Cover: Agriculture is a dominant feature of the Glenelg Hopkins region, with around 74% of the catchment used for dryland agriculture. Photo: Southern Grampians Shire Council.

CHAIR'S FOREWORD

As a long-term resident with over 25 years regional farming experience, I am proud to present the Glenelg Hopkins Soil Health Strategy. The Strategy has been developed by Glenelg Hopkins CMA on behalf of the community with input from community groups, key Government agencies and industry partners.

The Strategy provides a framework for government investment in the management of soil on private and public land in the Glenelg Hopkins region. It seeks to increase community awareness of the benefits of healthy soil, increase community capacity to manage soil sustainably and support land managers in adopting farm practices that can improve both production and soil condition.

The Strategy aligns with the Glenelg Hopkins Regional Catchment Strategy 2013-19 which provides a framework for integrated management of land, water and biodiversity for the region. This Strategy will replace the Glenelg Hopkins Soil Health Strategy 2009-14 and Glenelg Hopkins Salinity Plan 2005-08.

Drawing on a range of important national and state government legislation, policies and documents, the Strategy presents an approach that recognises the community benefits of services provided by soil and the value of soil as the foundation of agricultural production.

Data from government and industry sources demonstrates the importance of agriculture to the regional, Victorian and national economy. Generating a gross commodity value of almost $1.6 billion in 2011-12, the region is ranked 6th of Natural Resource Management regions nationally for agricultural production and 3rd in Victoria.

The Strategy presents a strong argument for government investment to increase community awareness of soil as a natural resource at risk and the capacity to manage production within the natural or improved soil capability.

The Strategy provides a five year program that will support land managers to adopt farm practices that can achieve long-term benefits in both production and soil condition.

As the foundation of productive agriculture, healthy soils are critical to our region's economic prosperity. The document is designed to be a practical guide for cooperative action by government, industry and community to improve our soils into the future.

Mike Wagg
Chairperson

ABOUT THE STRATEGY

PURPOSE

The Glenelg Hopkins Soil Health Strategy supports the Glenelg Hopkins Regional Catchment Strategy (RCS), which establishes a 50-year vision for the Glenelg Hopkins catchment of: "Achieving a healthy and sustainable relationship between the natural environment and the community's use of land and water resources." In moving towards this vision, people of this region aim to create healthy catchments where the integrity of soils, water and biodiversity is maintained or enhanced in the face of a changing climate.

It is a vision which can only be attained through strong regional partnerships with our community and the primary producers who manage about 80% of the land in our region.

The goals of this Strategy are to:

- protect and improve soil health by addressing current known threats to soils and improving soil resilience;
- promote the value and importance of soil health and services;
- maximise the efficiency and effectiveness of government investment in soil health for environmental and production benefits; and
- build government, industry and community partnerships to manage for soil health.

The four goals of the Strategy all contribute to improving regional land use and management; and improving soil condition, which in turn, benefits production and improves the quality of ecosystem services (e.g. water quality) delivered from agricultural lands to the broader community.

The Strategy sets a course towards more sustainable management of soils within the region and provides a roadmap for regional soil health investment over the next five years. It will be used to guide investment in soil health across both public and private land. The Strategy is written within an integrated catchment management context, and aims to provide a framework that encourages and supports collaboration between stakeholders to protect and improve soil health.

The Strategy recognises that individual land managers, on both urban and rural properties, are best placed to make and implement soil improvement actions. It seeks to increase community awareness of the environmental benefits of soil as a natural resource and to increase regional capacity to manage soil sustainably. It also recognises that agriculture is a complex industry and there is a diversity of pathways to achieve soil improvement outcomes; and that management practices to achieve environmental outcomes on private land are often best adopted if production benefits are highlighted.

INCORPORATING THE REGIONAL SALINITY MANAGEMENT PLAN

There is a requirement under the *Catchment and Land Protection Act 1994* (Victoria) Statement of Obligations (SOO) for the CMA to develop and coordinate the implementation of a Regional Salinity Management Plan or its equivalent in accordance with the Regional Catchment Strategy and any relevant State policy, framework, plan or guideline.[1]

The Glenelg Hopkins Soil Health Strategy incorporates the Regional Salinity Management Plan. Specific actions that form the basis of the Regional Salinity Management Plan are identified in the implementation section of this document (*Table 7*). An overview of the regional status of dryland salinity and the management approach adopted for the Glenelg Hopkins region is provided in Appendix 1. The regional approach to managing dryland salinity aligns with the Victorian Government's plan for managing dryland salinity in Victoria, which uses an asset based approach for managing dryland salinity and establishes a salinity provinces framework for guiding investment.

> "Achieving a healthy and sustainable relationship between the natural environment and the community's use of land and water resources".

HOW WAS THE STRATEGY DEVELOPED?

This is the region's second Soil Health Strategy. Updating the existing Soil Health Strategy (2009-2014) and Salinity Plan was identified as an action in the Glenelg Hopkins RCS.

The review and renewal of this document has been guided by:

- the objectives and measures contained in the Glenelg Hopkins RCS;
- relevant Australian and Victorian Government policies, strategies and program objectives, that relate to soil health as outlined in the strategic relationships section.

The Glenelg Hopkins Soil Health Strategy will help facilitate the achievement of RCS soil and land, and community participation objectives and measures through a range of initiatives that are identified in the accompanying implementation plan. Improving soil health will help maintain the flow of services from the soil system, and reduce the impact of threats to natural and built assets. Priority regional environmental assets are identified in the Glenelg Hopkins RCS and include specific environmental assets such as waterways, estuaries and vegetation communities.

The Strategy was developed by Glenelg Hopkins CMA in partnership with many regional organisations, agencies, community groups and individuals. A number of agency and community workshops were undertaken in 2012 as part of RCS development. Where applicable, the outcomes of these workshops have been used to inform development of the Strategy. An overview of the Soil Health Strategy consultation process is provided below.

CONSULTATION PROCESS

The Glenelg Hopkins CMA Community Advisory Groups provide advice to the CMA on the development of regional strategies and plans as well as emerging community concerns and issues, and threats that impact Natural Resource Management (NRM) assets across the region. The Glenelg Hopkins Biodiversity and Land Health Advisory Group provided advice on the development of the draft Strategy, associated actions and measures through a series of workshops. The Advisory Group includes representatives from the community and NRM partner agencies such as the Department of Environment and Primary Industries (DEPI) and Parks Victoria.

Key agencies and partners were also consulted during preparation of the draft, including Australian Government representatives, DEPI and soil specialists to provide expert knowledge and ensure alignment with Australian Government and statewide initiatives. The document was made available for public comment from 3 May 2014 to 2 June 2014.

Below left: Canola field. Photo: Ararat Rural City Council.

Below right: Friends of Yatmerone revegetate Yatmerone wetland with Conservation Volunteers Australia. Photo: Mary Johnson.

Opposite: In 2011 Glenelg Hopkins carried 928,242 cattle, the largest number of any CMA region in Victoria. Photo: Hopkins River Beef.

HOW WILL THE SOIL HEALTH STRATEGY LEAD TO ACTION?

Improvements in soil management and condition at a catchment scale can only be achieved through the actions of an informed community. The Strategy seeks to increase community awareness of the environmental benefits of soil as a natural resource and to increase regional capacity to manage soil sustainably.

The Strategy contains a range of initiatives targeted at increasing the uptake of sustainable land management practices.

The Strategy includes measures that are designed to reduce the impact of threatening processes on natural assets that have been identified as regionally significant.

Specific processes that have been identified for priority attention include:

- inadequate ground cover in erosion susceptible areas;
- soil structure decline;
- movement of sediment and nutrient into rivers, lakes and estuaries;
- soil contaminants, such as salt and acids; and
- sodic soils that are prone to water erosion and are highly erosive.

With around 81% of the catchment used for primary production, healthy soils are critical to the region's future prosperity and are fundamental to increased production of agricultural commodities and the sustainability of farming communities. Regional programs delivered as part of this Strategy will involve government agencies, industry and community groups in key agricultural sectors to meet the needs of farmers with a focus on improving soil condition on agricultural land.

The Strategy supports agricultural sustainability and improved productivity through measures that are targeted at:

- increasing awareness and use of sustainable practices by farmers, land managers and local industry;
- building the capacity of farmers to make and implement land management decisions to improve soil condition;
- raising awareness of methods that can be used to maintain or increase production in a sustainable way, through the use of on-farm trials and demonstrations; and
- supporting initiatives that encourage the use of innovative practices for improved natural resource management.

Partnerships with community, individuals and organisations within the region are the foundation for effective delivery of this Strategy. As a supporting Strategy to the RCS, it provides a framework for investing in and prioritising on-ground works and projects within the region. It will continue to build on the success of earlier work within the catchment and the contribution made by landholders and community groups.

Below left: Improved agricultural production will be supported through regional programs. Photo: Southern Grampians Shire.

Below right: The Strategy will assist farmers in sharing ideas to improve their soils. Photo: Southern Grampians Shire.

STRATEGIC RELATIONSHIPS

The Victorian government's broad directions for the management of soils are defined in the *Catchment and Land Protection Act 1994* and some high level goals for soil management are captured in the document *Soil Health Strategy: Protecting Soil Health for Environmental Values on Public & Private Land.*[2]

The State strategy seeks to support work conducted by CMAs in planning and managing soil health, provide a framework for regional and local planning and delivery of soil health initiatives and set priorities that promote more effective and efficient soil research, development and extension projects.

This regional strategy has been developed to align with the State Strategy and the Glenelg Hopkins RCS. It has also been guided by the 2013 *Victorian Dryland Salinity Update* which was developed to guide CMAs and other National Resource Management (NRM) practitioners in their management of dryland salinity.

Opportunities for alignment of NRM related elements of industry peak body strategies, such as the *Dairy Industry Sustainability Framework*, were also considered (e.g. nutrient management).

Figure 1 shows the relationship between the Glenelg Hopkins RCS, the Soil Health Strategy, and Australian and State Government legislation, strategies and policies.

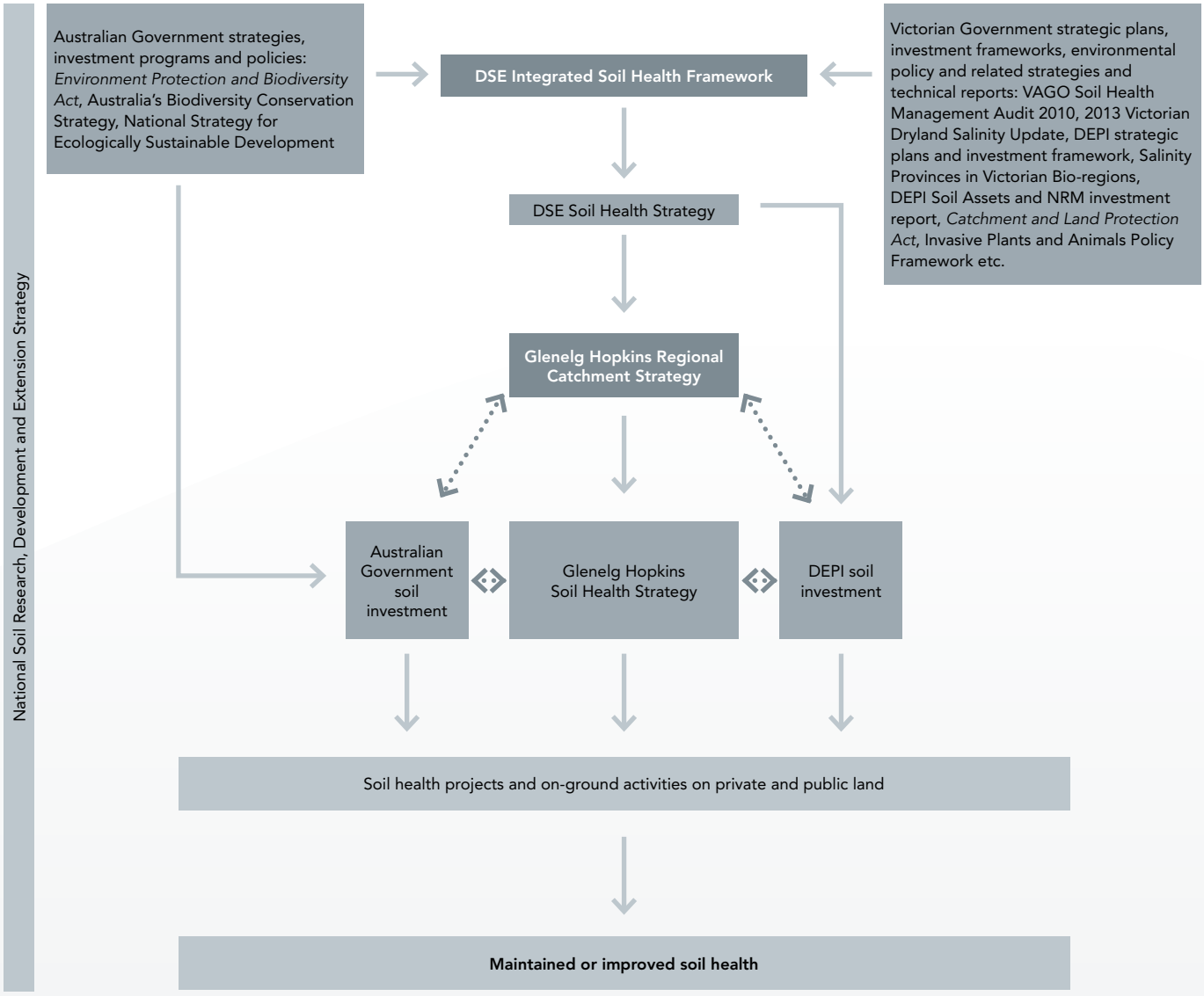


Figure 1: Strategic relationships.

AN ECOSYSTEM SERVICES APPROACH

Soil health can be defined as "the condition of the soil in relation to its inherent or potential capability, to sustain biological productivity, maintain environmental quality, and promote plant and animal health".[3]

Healthy soils are vital to the region's primary industries and provide a range of ecosystem services that "maintain fertility by cycling nutrients and decomposing wastes, provide a habitat for a vast array of organisms and support terrestrial ecosystems that are responsible for providing clean air and water as well as a regulated climate".[4] *Table 1* provides a summary of key ecosystem services (and disservices) provided by soils.

Table 1: Summary of ecosystem services and disservices provided by soils. Adapted from DSE Soil Health Strategy.[5]

Ecosystem services	Description
Supporting	
Soil formation	Soil formation through weathering and redistribution
Provisioning	
Provision of marketable goods	Food, skins, fibre, timber
Habitat provision/genetic resource maintenance	Habitat for soil biota and repository of genetic material
Soil structure stabilisation	Retention of soil
Regulation	
Gas regulation	Consumption/emission of atmospheric gases
Water quality regulation	Water filtration/purification
Water yield and flow regulation	Water storage and distribution
Carbon sequestration	Net carbon stored in soil
Remediation of wastes and pollutants	Breakdown, immobilisation or detoxification of excess or harmful organic and inorganic materials
Disease and pest regulation	Control of pests and pathogens

Ecosystem disservices	Description
Salinisation	Increase in salt content to levels that decrease services
Acidification	Increase in H+ ion concentration that disrupts provision of soil services and accelerates disservices
Wind erosion	Loss of soil by wind erosion to harmful levels
Water erosion	Loss of soil by water erosion to harmful levels
Organic matter/biota decline	Decrease in soil organic matter that disrupts provision of soil services
Soil structure decline	Breakdown in soil aggregation or dispersion that disrupts provision of soil services
Landslides	The movement of a mass of rock, debris or earth down a slope
Acid sulfate soils	Any soil that contains sulfidic or sulfuric material
Soil contaminants	One or more certain substances added to soil exceeding background levels which may be a risk to human health or the environment
Eutrophication (hypertrophication), caused by nutrient loss	Nutrient loading of waterways
Waterlogging in high rainfall regions	Low permeability clay soils and sub-soils are prone to saturation. Areas of clay soil and poor landscape drainage can experience waterlogging and natural flooding during periods of extended winter rainfall

Investment in soil health is informed by Victorian government policy which has evolved over time in relation to different drivers and philosophies. For example, the former DPI historically had a strong emphasis on supporting productive agriculture and "…various issues rose and fell in prominence over time (i.e. trace element deficiencies (1950s), acidification and waterlogging (1980s), soil structure (1990s), subsoil constraints (2000s), [and] soil organic matter (2010s)"; while the former Department of Sustainability and Environment (DSE) (and its predecessor the Soil Conservation Authority) have traditionally had more of an emphasis on land degradation and soil protection.[6] Soil erosion was a key focus in the 1950s (Soil Conservation Authority); and this emphasis moved to dryland salinity in the 1990s.[7]

The historic threat-based approach has meant that "there has been inadequate attention given to understanding the broader benefits of protecting soils".[8] In response, management approaches have shifted from a focus on addressing specific problems and issues, to managing soils as a complex system that produces services that benefit the wider community (i.e. an ecosystem service approach).[9]

This Strategy adopts an ecosystem services approach. It targets areas of soil health that have been identified for priority attention at a regional scale where they risk degrading high priority natural assets (including soils). An assets focus "allows planners to prioritise efforts and investment where they will have the greatest impact…".[10]

ECOSYSTEM SERVICES AND AGRICULTURAL LAND

Ecosystem services can be defined as the benefits provided to humans from nature.[11] The 'ecosystem services approach' provides a framework for considering the whole ecosystem in decision making and is a way of looking at the way the natural environment works as a system.[12] Ecosystems include agricultural landscapes, which are particularly significant in the context of the Glenelg Hopkins region due to the high proportion of the catchment used for agriculture.

For land managers, ecosystem services can represent increased soil structure, moisture retention, nutrient cycling and activity of beneficial soil organisms; functions that support the growth of healthy pasture, crops, livestock and people. Improving the quality of ecosystem services on agricultural land (e.g. improved habitat provision and soil structure) may provide economic benefits to farmers, such as improved habitat for beneficial organisms which can reduce pest management costs.

Actions taken by farmers on agricultural landscapes can have "a significant impact on the quality of ecosystem services delivered to the community".[13] For example, farm fertiliser practices can have a large impact on water quality, and nutrients lost to lakes can increase algal blooms, which in turn, can cost the community through increased requirements for water treatment; impacts on recreation and tourism opportunities (and associated economic losses); negative impacts on stream biota (e.g. fish kills); and reduced amenity.[14]

There is good scientific evidence that "land management practices adopted by farmers have a direct impact on soil condition".[15] This Strategy, therefore, has a strong emphasis on increased adoption of sustainable land management practices; as the management practices that farmers choose can have a major impact on soil condition.[16] Improved soil condition can benefit production; as well as the quality of ecosystem services delivered from agricultural lands to the broader community (e.g. water quality, regulation of atmospheric gases, water flows).[17]

Increasing the quantity and/or quality of ecosystem services provided by soil benefits not only farmers but, all people[18] - a key rationale for government investment in soil health on private land.[19] Possible reasons for government investment in soil health could include "when a decline or increase in soil health on a property leads to a decline or increase in ecosystem function, primary production or amenity values outside of the property boundary".[20]

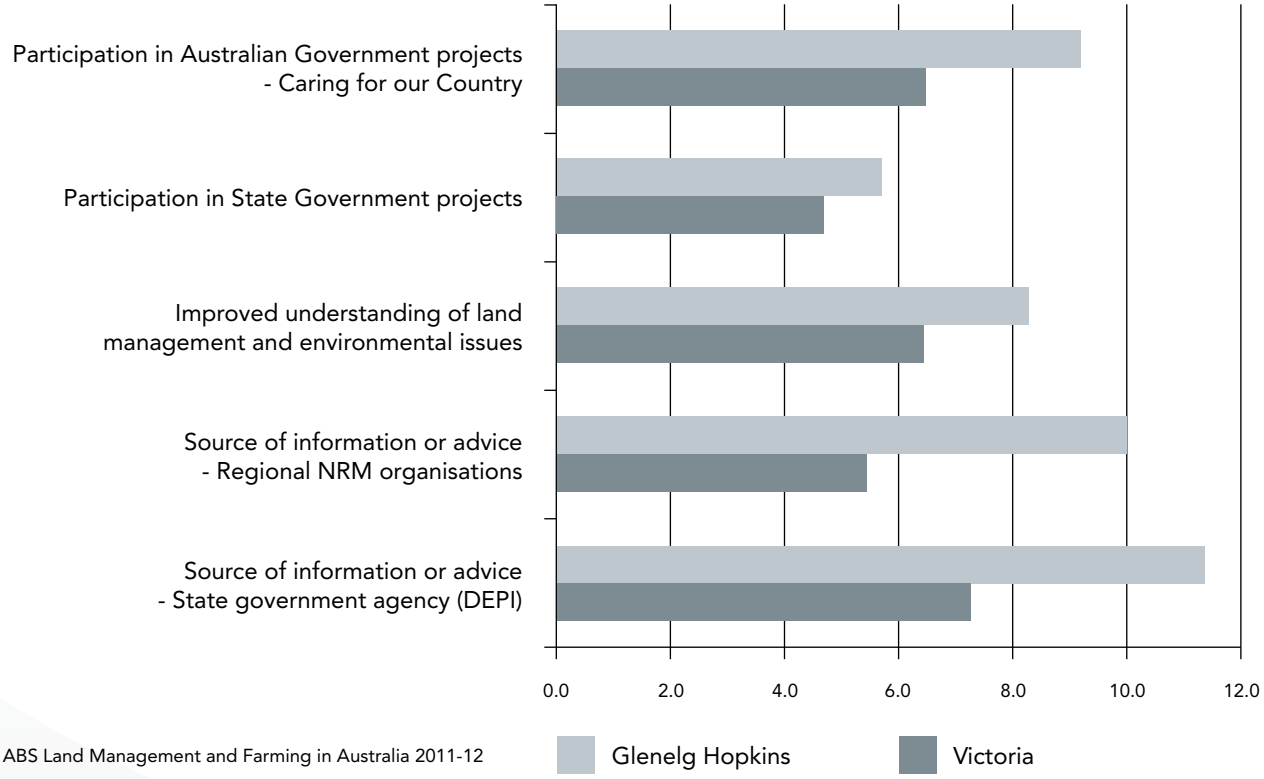
Below: Dairy farming is common in the south of the catchment. Photo: WestVic Dairy.

KEY ACHIEVEMENTS TO DATE

There have been many key soil health projects and programs that have been delivered by land managers, community groups, government agencies and non-government (industry) organisations in the Glenelg Hopkins region. Much of this on-ground work wouldn't have been possible without strong regional partnerships and the support of regional farmers and Landcare groups. A selection of key regional soil health projects and programs that have been delivered in the Glenelg Hopkins region is shown in Figure 3.

The Glenelg Hopkins region was found to have high participation rates in both Australian and Victorian government projects in a 2011-12 Australian Bureau of Statistics survey of 33,000 of Australia's 135,000 agricultural businesses (Figure 2), reflecting the strength of regional partnerships. It also had a higher proportion of farming businesses using Glenelg Hopkins CMA as a source of information and advice compared to the State average for regional NRM organisations.

The proportion of regional farmers that had indicated an improved understanding of land management and environmental issues was also high, when compared to the State average. The Strategy aims to build on these achievements.



Source: ABS Land Management and Farming in Australia 2011-12

Figure 2: Farm management responses to 2011-12 ARMS survey showing response as percentage of businesses surveyed for Victoria and Glenelg Hopkins CMA region.

CASE STUDY

LANDCARE IN THE GLENELG HOPKINS REGION

Overview

The region has a long and proud history with the Landcare movement; and in 2011, celebrated 25 years of Landcare in the Glenelg Hopkins region. Pioneering Tree Groups, the Potter Farmland Plan project and early soil conservation work are examples of the land stewardship ethic in this region.

Community based NRM organisations such as Landcare play a significant role in improving and maintaining large areas of our region's natural assets, with the region supporting over 100 Landcare and community based NRM groups. For 25 years Landcare has grown and evolved into a large and resilient community of volunteers.

Our region is renowned for its active and diverse community, which displays an entrepreneurial "can-do" spirit. This spirit is no more clearly exemplified than through those people involved in Landcare.

Landcare groups and community based NRM organisations will play an important role in the implementation of the Soil Health Strategy, particularly in terms of:

- *increasing participation by regional communities and groups in natural resource management activities;*
- *exchanging knowledge and information on sustainable land management practices; and*
- *participation in on-ground partnership projects that are targeted at addressing threats to soil health at a landscape scale.*

Below (L-R): The region conducts an annual Regional Landcare Gathering to exchange knowledge and ideas. It provides an opportunity to share experiences, learn from peers and celebrate achievements. The 3rd annual South West Landcare Gathering was hosted by the Panyyabyr Landcare group near Dunkeld. The gathering involved over 60 Landcare members and support staff from around the catchment. Photos: Glenelg Hopkins CMA.

LANDCARE

From the 1950's community volunteer groups worked with the SCA to improve land degraded by soil erosion and salinity. As links between dryland salinity and rising water tables become better understood in the 1980's Farm Tree Groups formed to revegetate the landscape. In 1985 the Victorian Government recognised land degradation threatened future agricultural production and community-based action was the best way to tackle these concerns.

Landcare was established in1986 with the goal to balance environmental and production use of land. Landcare groups and principles coupled with property management planning *(see PFP below)* were readily adopted by the regional community. Landcare activities as diverse as tree planting, erosion control works, dung beetle release, hosting of community education events have enabled broad-scale improvements that have transformed farming and the landscape.

This page includes a small number of examples.

DEPI

Delivered by DEPI, the Glenelg Hopkins Land Health program provided regional farmers with a farm extension service that promoted production, profit and environmental conservation. Achievements include:

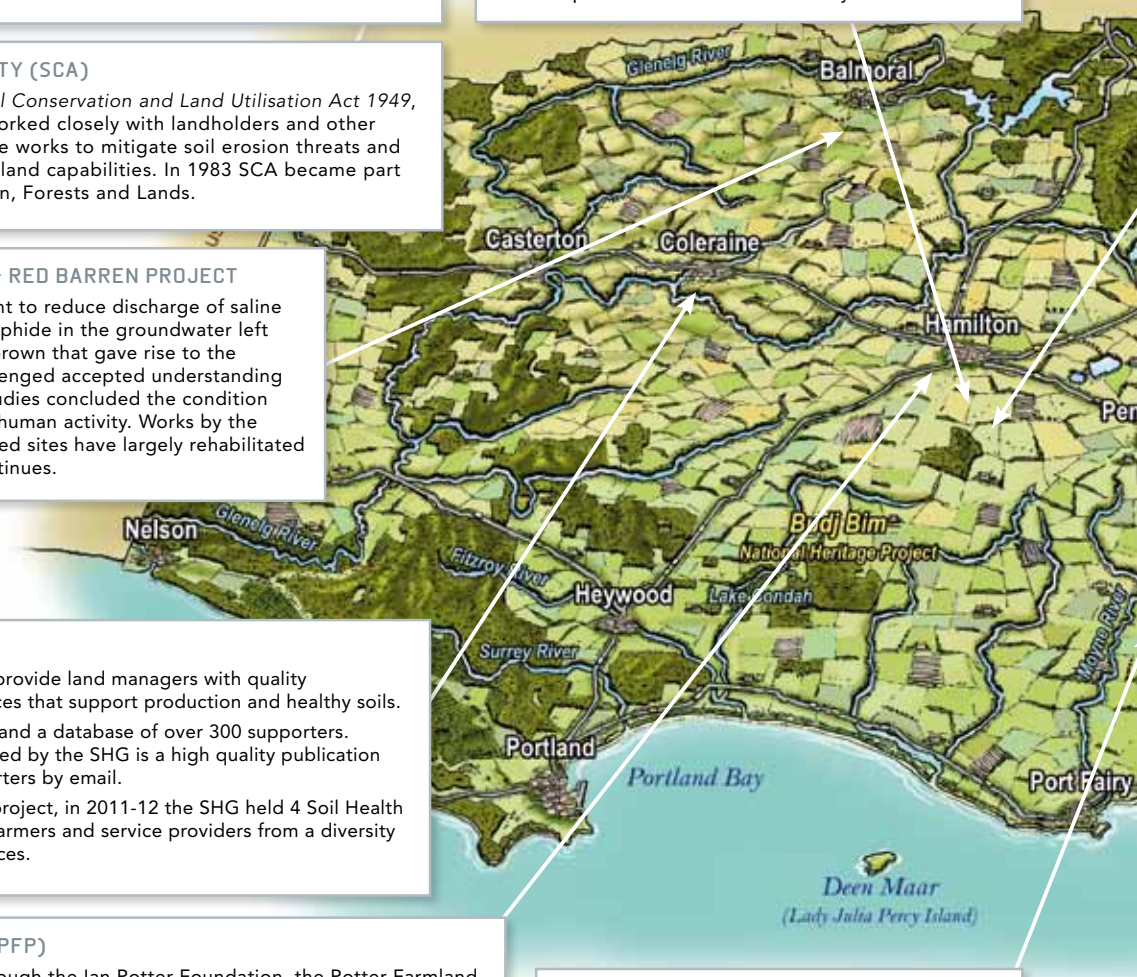
- 2009-10 – Thirty-six events were held to increase capacity of community groups to contribute to NRM
- 2010-11 – Sixty-two agreements for on-ground works were established and 335 farmers received technical advice that enhanced their farm business
- 2011-12 – Land management of 104,415ha was improved with farm plans
- 2012-13 – Indigenous revegetation of 88 ha for improved habitat for biodiversity.

SOIL CONSERVATION AUTHORITY (SCA)

Constituted in 1950 under the *Soil Conservation and Land Utilisation Act 1949*, the Soil Conservation Authority worked closely with landholders and other government agencies to undertake works to mitigate soil erosion threats and advise on land uses that matched land capabilities. In 1983 SCA became part of the Department of Conservation, Forests and Lands.

BALMORAL LANDCARE GROUP - RED BARREN PROJECT

Initiated in 1988, the project sought to reduce discharge of saline groundwater. Dissolved ferrous-sulphide in the groundwater left affected soils barren and reddish brown that gave rise to the project's name. Observations challenged accepted understanding of dryland salinity mechanisms. Studies concluded the condition was natural rather than a result of human activity. Works by the Balmoral Landcare Group of affected sites have largely rehabilitated affected land though seepage continues.



SOIL HEALTH GROUP (SHG)

Formed in 2009 the SHG works to provide land managers with quality information on a diversity of practices that support production and healthy soils.

In 2014, the SHG had 52 members and a database of over 300 supporters. The Healthy Soils Magazine produced by the SHG is a high quality publication distributed to members and supporters by email.

A community partner in the RRSA project, in 2011-12 the SHG held 4 Soil Health events that brought together 265 farmers and service providers from a diversity of agricultural industries and practices.

POTTER FARMLAND PROJECT (PFP)

Launched in 1984 with funding through the Ian Potter Foundation, the Potter Farmland Plan established 15 demonstration farms in three localities near Hamilton. Families followed a structured process to plan their farm business, integrating production, soil conservation, biodiversity and water use. PFP become the forerunner for the DEPI farm planning courses that continues to be delivered by DEPI as FarmPlan21.

SALINITY MONITORING

Dryland salinity is estimated to affect 27,435ha in the Glenelg Hopkins CMA region. 115 bores are monitored for salinity by DPI or community and 4 surface water sites.

VICTORIAN INVESTMENT FRAMEWORK (VIF) – LAND HEALTH

From 2009-10, the 4-year Victorian Government funded VIF Land Health program was implemented in partnership with DEPI. Public investment totalled $4,758,925 over this period. In the final year (2012-13) the Glenelg Hopkins region received the highest funding allocation in Victoria reflecting the strength of this regional partnership.

WESTVIC DAIRY

From 2006 WestVic Dairy Farm Focus groups provided farmers with opportunities to learn and work together to improve their farms to achieve economic and NRM benefits. A key partner in the RRSA project, WestVic Dairy held 16 workshops and five field days increasing knowledge of 398 farmers in soil acidification and nutrient best management practice. One hundred and fifty-six farmers completed training and adopted practices to reduce soil acidification risks over 32,983ha - making significant savings from more efficient, prescriptive fertiliser applications.

The WestVic Dairy partnership, with DEPI support, was critical in meeting practice adoption targets for the RRSA project.

Figure 3: Some key soil health projects and programs that have been delivered by land managers, community groups, government and non-government organisations in the Glenelg Hopkins region.

VICTORIAN NO-TILL FARMERS ASSOCIATION (VNTFA)

Partnership established with the National Landcare Program in 2013-14. VNTFA established four Mentor Groups to assist farmers moving to no-till cropping.

EVERGRAZE - HAMILTON PROOF SITE

The DEPI Hamilton Proof Site supported EverGraze research into selection and management of pasture against soil types, rainfall, livestock enterprise needs and management requirements. Experiment findings have been widely communicated to regional farmers through field days, workshops, fact sheets and the EverGraze website.

ARARAT HILLS MULTIPLE OUTCOME PROJECT (MOP)

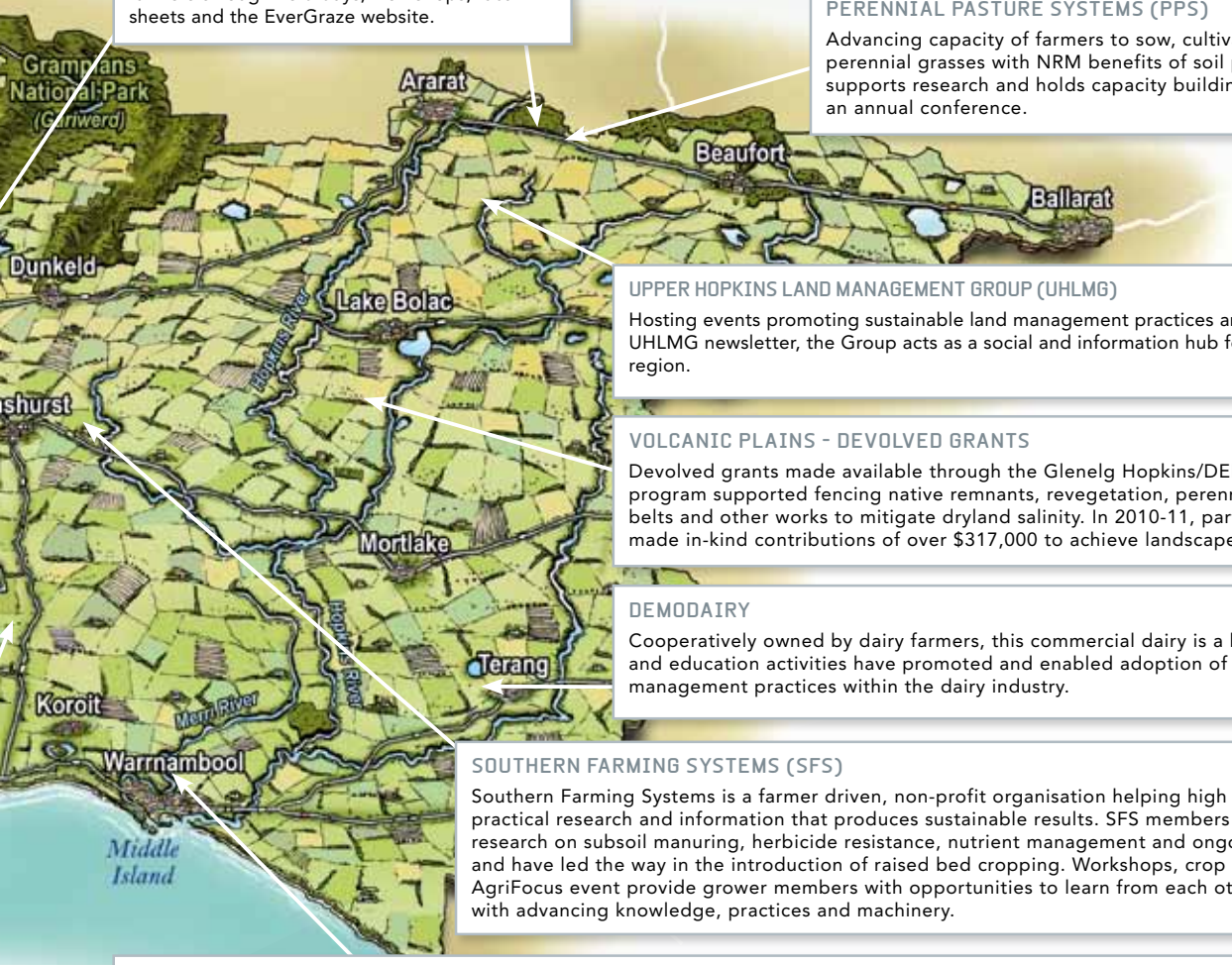
Established in 2005, the Ararat Hills MOP led the way in planning for an integrated approach to catchment management. In recognition that natural assets face multiple threats, the MOP was designed to coordinate separate programs (like river health, biodiversity, salinity and soils, pest management and Landcare) to achieve landscape change. In providing opportunity for collaborative action, the MOP achieved lasting environmental, social and production benefits for the communities of the Ararat Hills.

EVERGRAZE - DEFERRED GRAZING

Research into natural regeneration of native grasses on the Western Upland steep hill country provided farmers with increased pasture while reducing erosion, ground water recharge and dryland salinity risks.

PERENNIAL PASTURE SYSTEMS (PPS)

Advancing capacity of farmers to sow, cultivate and profit from perennial grasses with NRM benefits of soil protection. PPS supports research and holds capacity building events including an annual conference.



UPPER HOPKINS LAND MANAGEMENT GROUP (UHLMG)

Hosting events promoting sustainable land management practices and publication of the UHLMG newsletter, the Group acts as a social and information hub for the upper Hopkins region.

VOLCANIC PLAINS - DEVOLVED GRANTS

Devolved grants made available through the Glenelg Hopkins/DEPI Land Health program supported fencing native remnants, revegetation, perennial pastures, shelter belts and other works to mitigate dryland salinity. In 2010-11, participating farmers made in-kind contributions of over $317,000 to achieve landscape improvements.

DEMODAIRY

Cooperatively owned by dairy farmers, this commercial dairy is a hub for research and education activities have promoted and enabled adoption of sustainable land management practices within the dairy industry.

SOUTHERN FARMING SYSTEMS (SFS)

Southern Farming Systems is a farmer driven, non-profit organisation helping high rainfall farmers with practical research and information that produces sustainable results. SFS members have supported research on subsoil manuring, herbicide resistance, nutrient management and ongoing cultivar trials and have led the way in the introduction of raised bed cropping. Workshops, crop walks and the annual AgriFocus event provide grower members with opportunities to learn from each other and keep pace with advancing knowledge, practices and machinery.

SOUTH WEST SOILS CONFERENCE (SWSC)

An exemplary partnership between Glenelg Hopkins CMA, Corangamite CMA, Heytesbury District Landcare Network and Basalt to Bay Landcare Network. The inaugural SWSC 2012 was followed by an equally successful 2013 event.

CARING FOR OUR COUNTRY - REDUCING THE RISK OF SOIL ACIDIFICATION (RRSA)

With Australian Government investment of $1,434,000 over 4-years from 2009-10, Glenelg Hopkins CMA worked with three industry partners and nine community groups to hold 55 workshops and seven field days with 1,743 people attending. Farming practices to improve soil health and production were adopted by 224 farmers over 39,765ha, well in excess of project targets.

ENVIRONMENTAL BEST MANAGEMENT PRACTICE (EBMP)

Developed in 2000-01 through a DPI, Glenelg Hopkins CMA, Corangamite CMA partnership with support of regional landowners, EBMP provided farmers with a practical Environmental Management System to guide land management decisions. EBMP set out a structured self-assessment process that enabled farmers to benchmark current condition of their farm and business and identify, schedule and budget improvement actions. The resulting action plan enabled land managers to systematically address the limitations in their operations and realise opportunities. Originally delivered through funded, community based facilitators and DPI, 200 land managers completed the self-assessment process in the Glenelg Hopkins CMA region in the first year (2002) with this number rising to 700 by 2005.

Disclaimer: The map shown in this figure pictorially represents the Glenelg Hopkins Region. It is not intended to accurately reflect land use.

REGIONAL OVERVIEW

PEOPLE, PLACES AND ECONOMIC PROFILE

The Glenelg Hopkins region lies south of the Great Dividing Range in Victoria's south west. The region is renowned for its scenic beauty, dramatic coastline and rich biodiversity. It covers approximately 26,910 sq km, extending from Ballarat in the east to the South Australian border in the west, and from the southern coast of Victoria to the townships of Harrow and Ararat in the north (Figure 4).

There are four basins that occur within the region: Glenelg, Hopkins, Portland Coast and Millicent Coast. The boundaries of the region include marine and coastal waters out to the state limit of three nautical miles. The region is characterised by flat volcanic plains in the south, while the Grampians, Dundas Tablelands, and Central Highlands are dominant in the north.

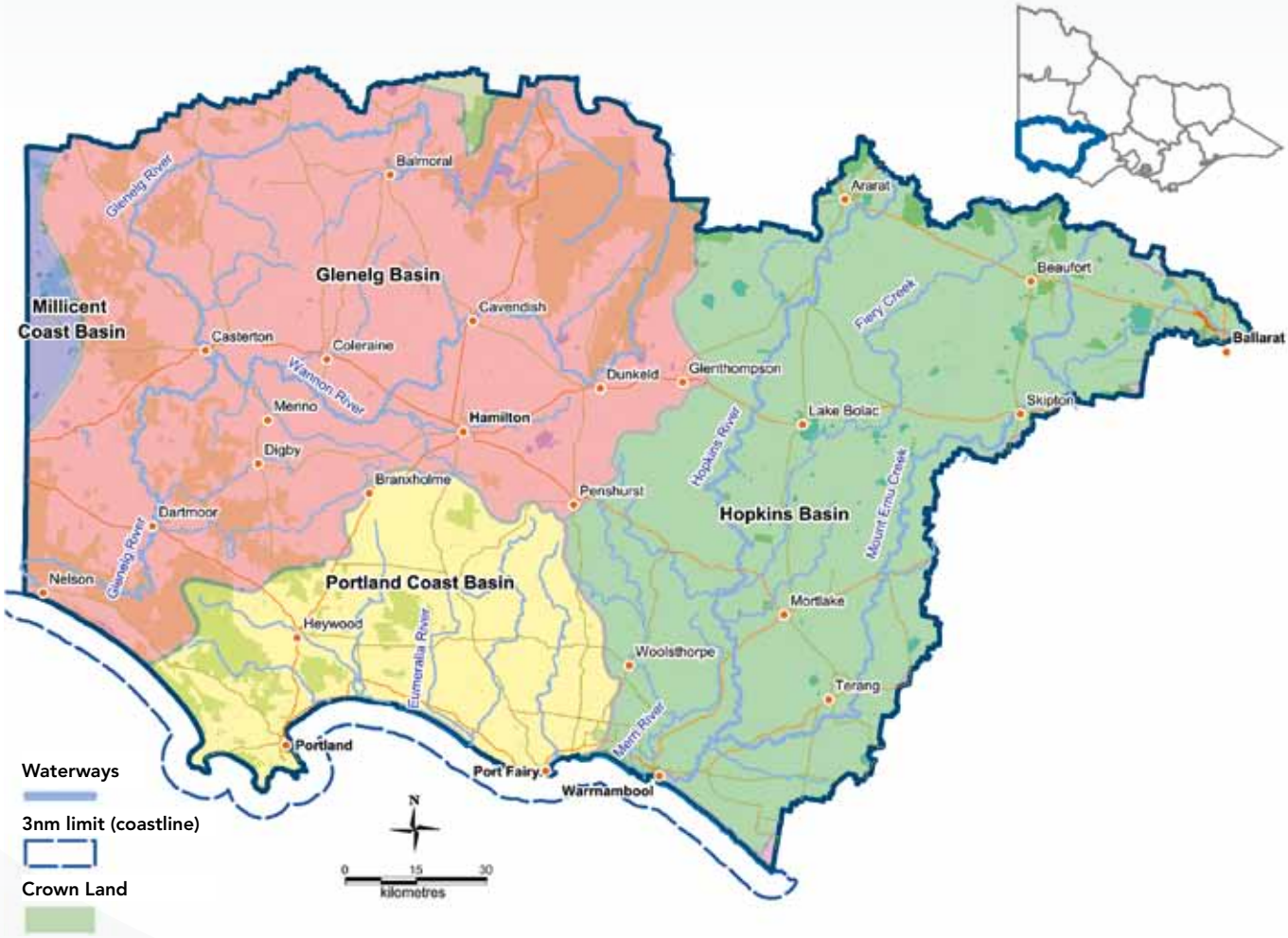


Figure 4: Basins of the Glenelg Hopkins Catchment Management Region.

The region supports a permanent population of 130,000 with year-round tourism adding significantly to this number. Major cities and towns include Warrnambool, Hamilton, Portland, Ballarat, Ararat, Casterton, Port Fairy and Beaufort. More than 33,000 of the region's residents reside in Warrnambool, and strong population growth is forecast for this area.

The Glenelg Hopkins region has a rich resource base that supports a diverse and growing industry. The main economic drivers are agriculture, fisheries, retail, manufacturing, health and community services, education and construction. Agriculture, forestry and fishing are the major employers, providing nearly 25% of total employment. The area contains some of the most productive land in Victoria and is noted for its contribution to the gross value of Australian agricultural production.

The Glenelg Hopkins region contains a number of natural features that are of national and international significance, including the heritage listed Glenelg River, several wetlands that are listed on the Directory of Important Wetlands Australia, the Budj Bim National Heritage Landscape, Grampians National Park, two of Australia's 15 biodiversity hotspots and a diverse range of flora and fauna.

> "The area contains some of the most productive land in Victoria and is noted for its contribution to the gross value of Australian agricultural production".

INDIGENOUS LAND MANAGEMENT

Indigenous peoples' relationship to country is based on a long tradition of custodianship, utilisation and cultural significance. While Indigenous Australians were nomadic across much of Australia, the abundance of freshwater, plants and wildlife in south west Victoria enabled clans to build dwellings, complex fishing systems and live in permanent settlements. Today, Traditional Owner groups and Indigenous communities continue to play a central role in regional land management. For example, the Gunditj Mirring Traditional Owner Corporation manage significant parcels of land of high environmental, historical and cultural value, such as Mt Eccles and Lake Condah, which form part of the Budj Bim National Heritage Landscape.

Traditional Owner and Indigenous community groups also own and manage areas of private land for agricultural production. Indigenous culture and stewardship remain fundamental to their management responsibilities on these areas of land. Indigenous people work to achieve sustainable agricultural, environmental and economic outcomes through their land management practices. This Strategy recognises the important role of Indigenous land ownership and management, and the value that traditional ecological knowledge has in contributing to the long-term management of natural resources within the region.

Below: The region has a strong history of wool production. Photo: Southern Grampians Shire.

PHYSICAL GEOGRAPHY

CLIMATE

The climate of the Glenelg Hopkins region is characterised by warm dry summers and cool, wet winters. The Southern Ocean has a moderating influence on temperatures and promotes higher rainfall along the coast. Areas to the north of the catchment experience a wider temperature range across the seasons and lower average rainfall than elsewhere due to the effects of the Western Uplands and Grampians (Gariwerd).

Annual average rainfall decreases from north to south with 588mm at Ararat, 686mm at Hamilton and 825mm at Portland and also varies from east to west from 500mm per year near Lake Bolac to more than 910mm per year near Heywood. Temperatures are less variable closer to the coast, with warmer winters and cooler summers. At a catchment level, the average annual temperature ranges from a maximum of 19.9°C to a minimum of 8.3°C (mean).

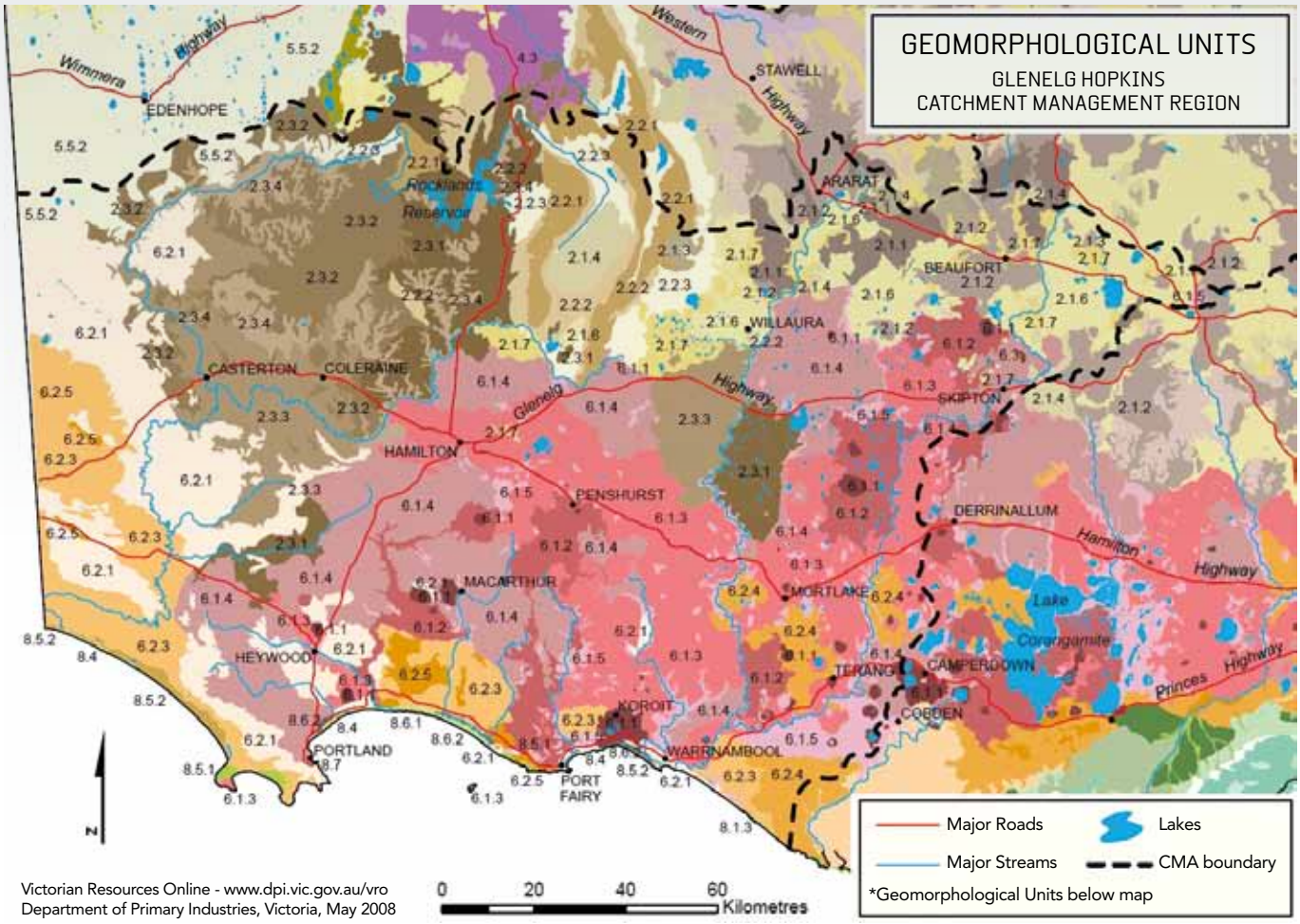
GEOMORPHOLOGY AND SOILS

The Glenelg Hopkins regional landscape is geologically diverse. Two recent periods of volcanism shaped much of the landscape. Beginning two to four million years ago, lava flows formed the extensive plains, wetlands and U-shaped river valleys that are characteristic of parts of the region. More recent volcanic activity, culminating as recently as seven thousand years ago, created the iconic scoria cones and stony rises visible across the southern part of the landscape. More ancient uplift of sedimentary deposits and erosion formed the Grampians, Dundas Tablelands and Central Victorian Uplands.

The catchment contains 49 different soil types that vary in texture, structure, fertility and drainage characteristics. Spatial distribution is complex and soil types include: red, yellow, brown and grey duplex soils, grey cracking clays, lateritic/stony profiles and rock outcrops. This large variation is due to different ages, geology of the parent material and weathering processes active over their period of formation. The resulting soils vary in suitability and capability for agricultural production and susceptibility to processes that would degrade soil health. More than 80% of the region's soils have chemical or physical limitations affecting agricultural management for sustainable productivity and maximum recharge control.[21] Limitations include nutrient deficiency, acidic top-soils, shallow soil profiles and poor soil structure. A map of geomorphological units of the Glenelg Hopkins region is shown in Figure 5. Detailed descriptions of each unit are available at 'Victorian Resources Online'.[22]

Below left: Sodic subsoils of Western Uplands (GMU 2.3.3) are at high risk of gully erosion. Photo: Glenelg Hopkins CMA.

Below right: Rolling hills and the iconic red gum are a common feature around Coleraine. Photo: Southern Grampians Shire.



Geomorphological Units

Western Uplands (WU)

- 2.1.1 Ridges, escarpments, mountains on non-granitic Palaeozoic rocks
- 2.1.2 Hills, valley slopes and plains on non-granitic Palaeozoic rocks
- 2.1.3 Ridges, escarpments, mountains on granitic Palaeozoic rocks
- 2.1.4 Hills, valley slopes and plains on granitic Palaeozoic rocks
- 2.1.6 Eruption points and volcanic plains
- 2.1.7 Dissected uplands: Terraces and floodplains
- 2.2.1 Grampians complex: Cuesta landscapes
- 2.2.2 Grampians complex: Sandstone hills
- 2.2.3 Grampians complex: Valleys, alluvial terraces and floodplains
- 2.3.1 Tablelands: Low relief, low drainage density
- 2.3.2 Tablelands: High relief, low drainage density
- 2.3.3 Tablelands: High relief, high drainage density
- 2.3.4 Tablelands: Terraces and floodplains

Northern Riverine Plains (RP)

- 4.3 Alluvial Fans and Aprons

North Western Dunefields and Plains (DP)

- 5.5.2 Low ridge tops with remnant aeolian sands and oriented swales with lakes and lunettes

Western Plains (WP)

- 6.1.1 Volcanic derived eruption points: maars scoria cones and lava shields, including associated ash and scoria deposits
- 6.1.2 Volcanic derived stony rises
- 6.1.3 Volcanic derived plains with poorly developed drainage and shallow regolith
- 6.1.4 Volcanic derived plains with well developed drainage and deep regrowth
- 6.1.5 Volcanic derived terraces, floodplains and lakes, swamps and lunettes and their deposits
- 6.2.1 Sedimentary derived plains with ridges
- 6.2.3 Sedimentary derived karst plains with depressions
- 6.2.4 Sedimentary derived plains and plains with low rises
- 6.2.5 Sedimentary derived terraces and floodplains, and coastal plains
- 6.3 Hills and Low Hills

Coast (C)

- 8.1.3 Active Cliffs: Subaerial dominant processes; with shore platform
- 8.4 Coastal Barriers
- 8.5.1 Transgressive dunes: Cliff top stranded
- 8.5.2 Transgressive dunes: Sea level
- 8.6.1 Low coasts: Tidal
- 8.6.2 Low coasts: Lagoonal
- 8.7 Engineered Coast

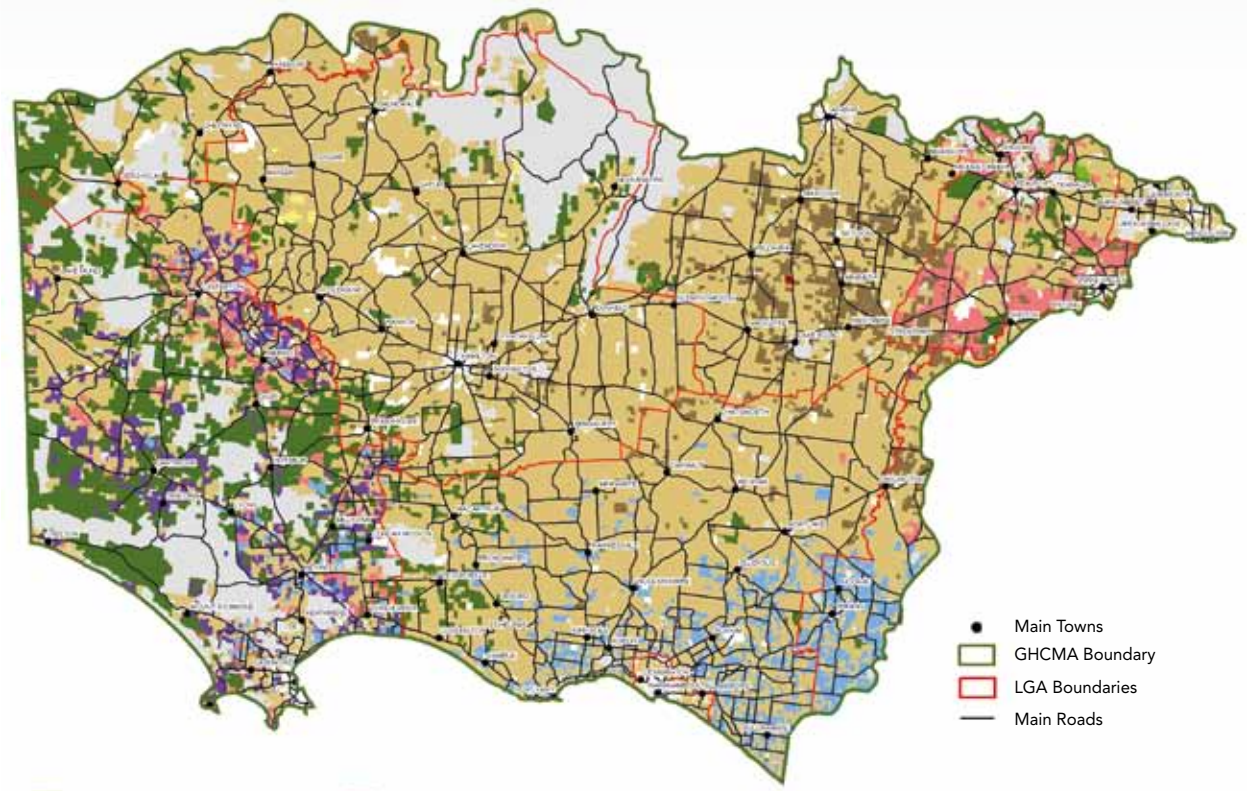
Figure 5: Geomorphological units (GMU's) – Glenelg Hopkins Catchment Management Region.

LAND USE

The Glenelg Hopkins region is best known for the production of wool and prime lambs, beef production and dairy. Substantial changes in land use have occurred in south western Victoria since the early 1990s from broadacre grazing to cropping, dairy and blue gum plantations. The use of raised beds techniques has enabled cropping to be adapted to the historically high rainfall zones. The area under cropping increased dramatically from the 1990s to 2010, with an average of approximately 12,000 ha per year of grazing pastures converted to cropping.[24] The transition over this period is partially due to declining wool prices.[25]

The support for forestry through Managed Investment Schemes commencing in 1998 generated a small increase in area under softwood plantation and a large expansion of land used for hardwood (blue gum) production.[26] Some harvested areas of blue gum plantations are not being placed under a second rotation. Returning these areas to pasture or cropping remains a challenge, due to the potential high costs involved.

A high level map of regional land use is shown in Figure 5. The map is indicative and based on 2010 land use data. The map reveals most farms are mixed operations.



This map displays tertiary level Primary Production land use categories.
Primary Production is one of nine main categories in the Australian Property Classification Code system, please refer to http://www.dse.vic.gov.au/property-titles-and-maps?a=95185 and VBP 2014 Specification Guidelines, Appendix B.

Source: DEPI 2014.

Figure 6: Land use – Glenelg Hopkins Catchment Management Region.

THE IMPORTANCE OF AGRICULTURE TO THE REGION'S ECONOMY

The Glenelg Hopkins region is recognised as having some of the most fertile and productive soils in Australia.[27] Consequently, the economic impact of declining soil health and associated ecosystem services extends well beyond the region. Plant growth is a good indicator of soil productivity.

Figure 7 shows the relative productivity on private land across Victoria, using a relative measure of biomass determined through the Ecological Vegetation Index (EVI) (a measure of primary production). Relative productivity is high for much of the Glenelg Hopkins region, compared to elsewhere in the State.

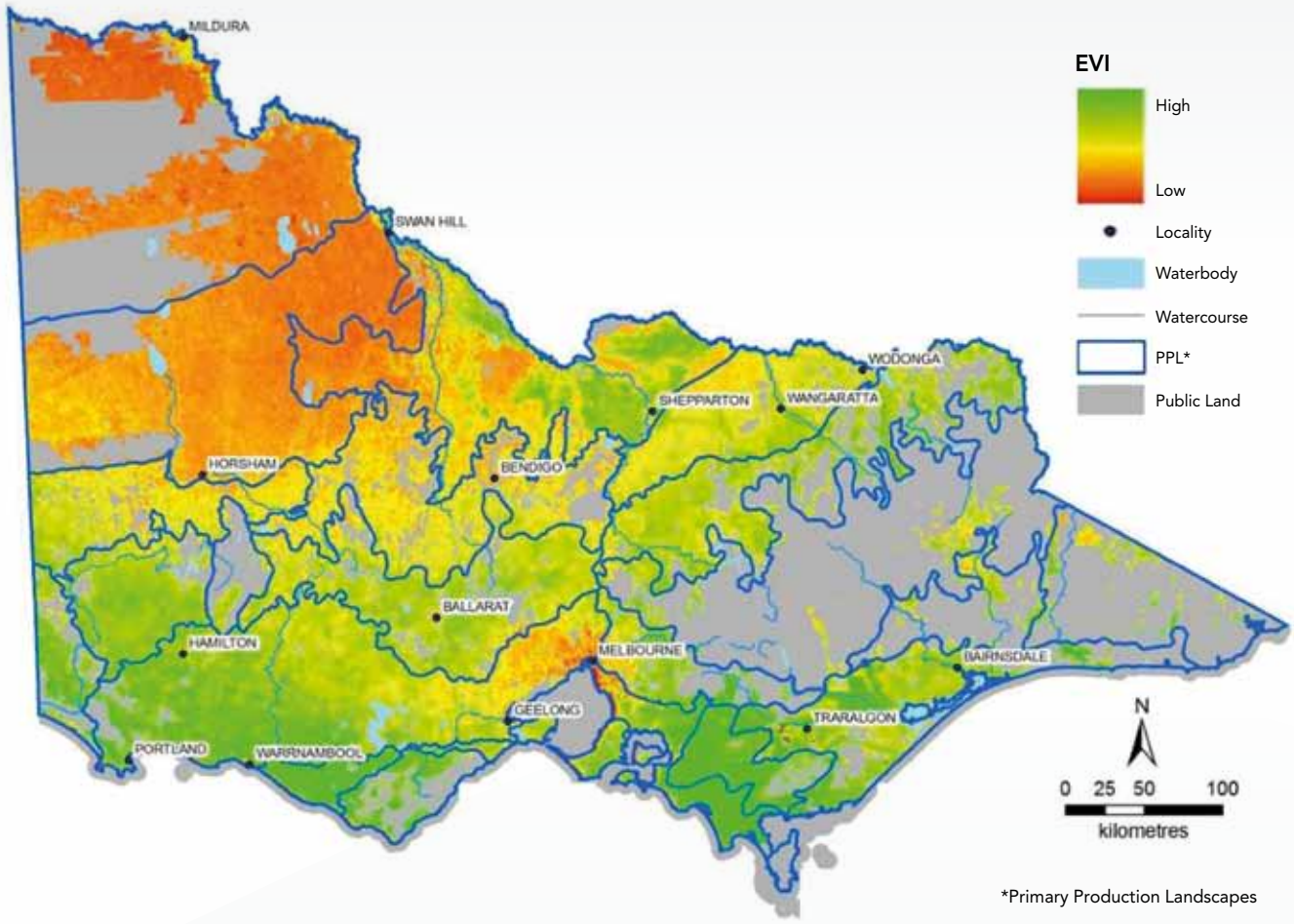


Figure 7: Private land relative productivity – Victoria, based on averaged 2001 to 2009 EVI data.[28]

With more than 80% of the Glenelg Hopkins catchment management region dedicated to agricultural production, the protection and enhancement of the region's soil is clearly linked to regional prosperity; and fundamental to ongoing sustainable food and fibre production.

The region is one of Australia's major agricultural areas; and was rated as the 6th highest agricultural production region in Australia in 2011-12, producing agricultural commodities with a gross value of $1,578 million.[29] The region is the largest producer of wool nationally and in 2011-12, produced wool with a gross value of $239.4 million.[30] It was also the largest producer of sheep, lamb and wool commodities nationally during this period ($663.1 million).[31]

The expanding regional dairy industry was the second highest milk producing NRM region nationally in 2011-12, producing milk with a gross commodity value of $423.8 million. As at 30 June 2011 the region carried both the highest number of cattle (928,242)[32] and sheep (5,485,804)[33] of the 10 NRM regions in Victoria. The region was ranked 10th nationally for numbers of cattle and 2nd for numbers of sheep in 2011; and was the 9th highest producing NRM region nationally by gross commodity value for cattle and calves in 2011-12 ($276.5 million).

A breakdown of the gross value of agricultural commodities produced by Victorian NRM regions in 2011-12 is provided in *Table 3*.

Table 2: Contribution of Victorian NRM regions to the gross value of agricultural commodities 2011-12.

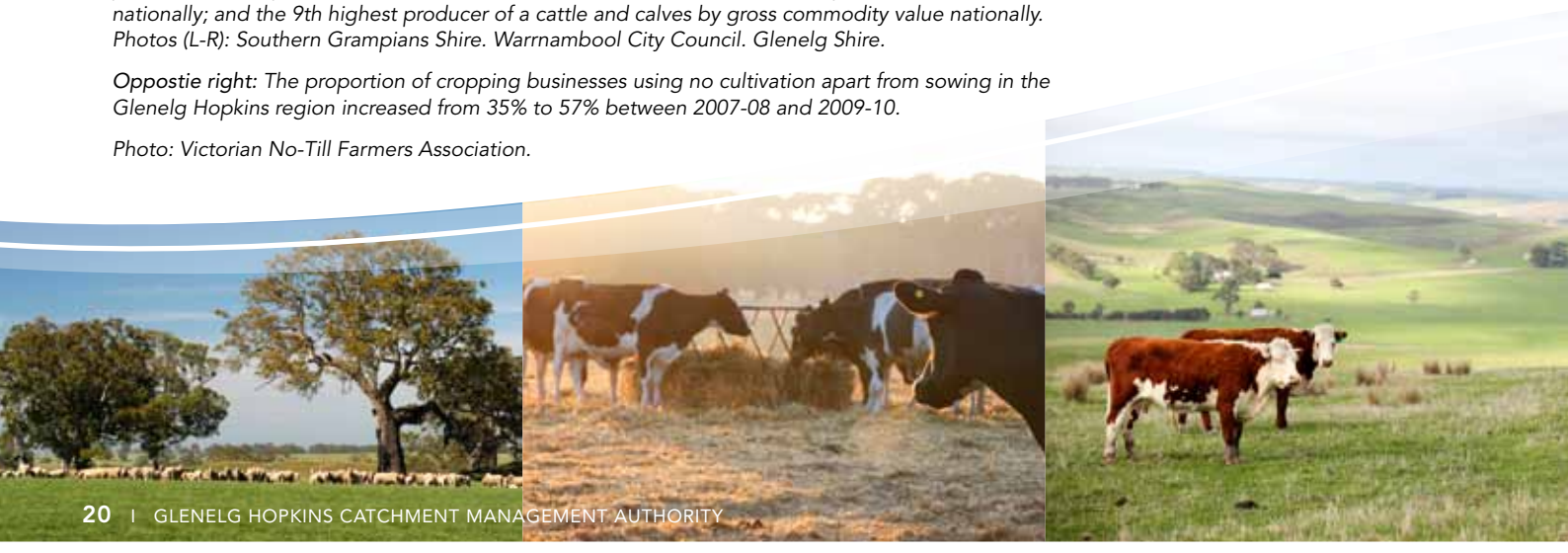
	Gross value of agricultural commodities 2011-12 ($m)						
	Broadcare crops	Horticulture	Cattle and calves	Sheep, lamb and wool	Other livestock	Dairy - Whole milk	Total Gross value ($m)
Corangamite	107.6	84.9	135.9	158.7	170.5	360.6	1,018.1
East Gippsland	7.8	89.9	42.1	21.9	2.0	29.9	193.5
Glenelg Hopkins	**179.7**	**17.1**	**276.5**	**663.1**	**18.4**	**423.8**	**1,578.7**
Goulburn Broken	223.6	477.1	198.1	217.0	76.7	417.6	1,610.1
Mallee	532.1	569.7	7.2	55.5	2.8	-	1,167.3
North Central	475.7	302.5	129.7	310.8	160.5	265.6	1,644.7
North East	53.4	55.8	129.0	40.3	4.6	78.9	361.9
Port Phillip & Westernport	25.1	811.8	114.0	27.9	379.9	150.0	1,508.6
West Gippsland	46.3	176.2	273.8	59.8	41.6	793.8	1,391.4
Wimmera	496.4	60.3	16.6	250.5	25.0	2.0	850.7
Victoria	2,146.7	2,645.2	1,322.9	1,805.4	881.9	2,522.1	11,324.0

Source: Australian Bureau of Statistics, Value of Agricultural Commodities 2011-12

Below: In 2011-12, the Glenelg Hopkins natural resource management region was the largest producer of sheep, lamb and wool commodities nationally; 2nd highest milk producing region nationally; and the 9th highest producer of a cattle and calves by gross commodity value nationally. Photos (L-R): Southern Grampians Shire. Warrnambool City Council. Glenelg Shire.

Oppostie right: The proportion of cropping businesses using no cultivation apart from sowing in the Glenelg Hopkins region increased from 35% to 57% between 2007-08 and 2009-10.

Photo: Victorian No-Till Farmers Association.



CHALLENGES AND OPPORTUNITIES

CLIMATE CHANGE

If current trends continue, global surface temperature change is predicted to exceed 2°C by the end of the century and will continue beyond 2100.[34] Australian annual average daily mean temperatures showed little change from 1910 to 1950 but have progressively warmed since, increasing by 0.9 °C from 1910 to 2011.[35] Above a rise of 2°C, the risks to human societies are considered unacceptably high.[36]

From 1998 to 2007, average annual temperatures in the Glenelg Hopkins region were 0.2°C warmer than the 30 year (1961 to 1990) average. Between 1998 and 2007 the region's average rainfall was 10% below the 1961 to 1990 average.[37]

Climate change modelling and projections indicate that the region can expect increasingly hotter and drier conditions. Average annual temperatures are projected to rise by between 0.5 and 1.1 degrees by 2030. Winter rainfall is likely to decrease, and summer rainfall increase with an overall decrease in rainfall of up to 7% by 2030. The intensity of extreme rainfall events is likely to increase. Natural variability in rainfall across the region may mask overall trends for decades to come (particularly in summer).[38]

Future projections indicate an overall hotter and drier climate for the Glenelg Hopkins region.[39] Without major adaptations, agriculture may struggle even to maintain current production levels, let alone strive for increases to meet the needs of an expanding population.[40]

> "If current trends continue, global surface temperature change is predicted to exceed 2°C by the end of the century and will continue beyond 2100".

CLIMATE CHANGE AND SOILS

Climate change is predicted to lead to increases in drought, bushfires and storms, which will impact primary production and natural ecosystems. Agriculture and forestry are likely to be impacted through impacts on water availability, land health and agricultural yields. Future land use patterns may also have to alter in order to adapt to climate change.[41] Soil erosion is likely to be exacerbated by the projected increases in intense rainfall events where those rains fall on dry, denuded soils.[42]

The Strategy recognises that adaptation to a changing climate is a priority challenge for society and agriculture in the coming decades.

Further information on potential climate change impacts on soils and agriculture for the Glenelg Hopkins region is provided in Appendix 2.

PROVIDING FOR A WORLD POPULATION

It is predicted that the world population will reach 9.7 billion people by 2050,[43] an increase of 2.6 billion compared to today. By 2050 world food consumption is expected to be 75% higher than in 2007 with almost half the demand coming from China.[44]

The south west region of Victoria was identified in the 2012 National Food Plan Green Paper as one of the regions in Australia that contributes most to the gross value of agricultural commodities.[45] The Glenelg Hopkins region is well placed to make a major contribution to increasing Australia's agricultural productivity and is among the leading NRM regions nationally in terms of gross value of agricultural commodities produced for several key sectors (e.g. dairy, sheep lambs and wool, beef). The achievement of increasing agricultural outputs with reduced inputs will demand new thinking and innovation in agricultural land management practices. Increasing the uptake of best practice soil management is likely to be an important factor in achieving this goal.

CURRENT CONDITION

ASSESSMENT OF TRENDS IN SOIL CONDITION

The health of soil can be inferred by comparing "soil condition against a reference or natural condition" (e.g. using measurements from undisturbed sites, modelling and published literature).[46] The National Natural Resource Management Monitoring and Evaluation Framework (2003) identified four soil processes (soil acidification, soil organic carbon, and erosion by wind and water) as having highest value as indicators of soil condition. These were selected on the basis of advanced understanding of the underlying biophysical processes, robust simulation models, availability of datasets and capacity for tracking and forecasting changes in soil condition based on these indicators.[47]

Assessment of trends in condition for soil in Victoria is problematic. The Victorian Catchment Management Council noted in its 2012 *Catchment Condition and Management Report* that there "has been no assessment of soil health undertaken at a Statewide level".[48]

It also noted that:

"There are no benchmarks of soil health for different soil types in Victoria. Unless soil condition can be related to a benchmark value, soil health cannot be properly evaluated. While the development of a soil health index has been proposed, its components have not been identified".[49]

The Victorian Catchment Management Council has recommended the development of a Soil Health Index.[50] DEPI is currently compiling data from field research and previous soil surveys into the Victorian Soil Information System, which is expected to help support the development of soil health indicators.[51]

The quality and currency of soil health data sets in Victoria is also patchy.[52] For example, there is currently no comprehensive, statewide map of soil salinity in Victoria, and there has been no new data at a Statewide level on rates of soil acidification since the release of the 2007 catchment condition report.[53]

Below: Visual Soil Assessment workshop, Coleraine. Photo: Glenelg Hopkins CMA.

REGIONAL STATUS

A summary of the condition of soil at a regional level, using indicators such as dryland salinity and acidification, is provided in *Table 4*. In most cases, there is no baseline 'reference' condition for each indicator which makes it difficult to assess changes in soil condition from a natural state, and to determine a subsequent soil health rating.

A more detailed summary of the status of soil ecosystem disservices is provided in Appendix 1, including broad scale inherent susceptibility maps for threats such as salinity and acidification where available. These maps indicate inherent susceptibility to land degradation based on soil type, land form and other natural factors, rather than actual incidences.[54]

Table 3: Regionally significant ecosystem disservices.

Ecosystem Disservices	Summary
Dryland salinity	Primary salinity is a natural feature of the catchment illustrated by the labelling of streams as salty and brackish by early settlers. Secondary salinity arises from altered hydrological characteristics of cleared landscapes developed in response to land use changes and clearing of vegetation cover for agricultural development.[55] Salinity has been estimated to affect more than 27,000ha of the region.[56] It impacts the region's agricultural production, water quality, river health, biodiversity, and infrastructure.
Soil acidification	Soil acidification is a naturally occurring process that occurs very gradually in undisturbed ecosystems. It can be accelerated by vegetation clearing and agriculture.[57] Most of the Glenelg Hopkins region has a high, inherent susceptibility to soil acidification, with an estimated 74% of agricultural soils in the region strongly acidic. There is a risk of further soil acidification in parts of the region under agriculture, particularly in areas receiving more than 500mm of annual rainfall. The Glenelg Hopkins region has been identified in the 2013 Victorian State of the Environment Report as one of the Victorian NRM regions most at risk of soil acidification.
Wind and water erosion	Soil susceptibility to erosion is increased by adoption of farming practices that expose soil. Long-term outcomes of continued erosion can be seen in sediment deposits in the river systems, particularly in the Glenelg Basin. Extensive sheet, tunnel, gully and stream bank erosion has led to large volumes of sand being trapped in the Glenelg River and its tributaries.[58] Approximately 18% of the catchment has been estimated as having a high to very high inherent susceptibility to sheet and rill erosion and around 12% for gully and tunnel erosion.[59] Coastal erosion is evident along the Portland coast and preventative measures have been attempted. The percentage area of the catchment threatened by sheet and rill erosion, and gully and tunnel erosion has been estimated using land cover data for the 2001-2009 period. Around 27% of the catchment was considered to have a moderate to very high threat of sheet and rill erosion during this period, and around 16% for gully and tunnel erosion.[60] Satellite imagery has been used to model areas under threat of wind erosion in Victoria between 2001-2009, considering inherent susceptibility and land use. Around 9% of the catchment was considered to have a moderate to very high threat of wind erosion between 2001 and 2009.[61] Soil landscapes in the west of the catchment in the Glenelg Plain and Dundas Tablelands areas have very high inherent susceptibility to wind erosion; and Discovery Bay and the Nelson Plain area near Portland are particularly prone to wind erosion.[62] Approximately 16% of the catchment has been estimated as having a high to very high inherent susceptibility to wind erosion.[63]
Decline of soil structure	Soil structure controls the movement of water and air through the soil and therefore affects the supply of oxygen and the removal of carbon dioxide from the respiration of roots and soil organisms. 66% of the region is considered highly susceptible to soil structure decline.[64] Agricultural practices that reduce soil biological activity can damage soil structure and lead to compaction, decreased infiltration rates, increased runoff with attendant increased erosion as well as surface ponding and increased waterlogging. Surface crusts and compaction are the direct result of soil structure decline.[65]
Waterlogging	Agricultural practices and animal or vehicle traffic can damage soil structure and lead to increased waterlogging. Historically, waterlogging is extremely widespread on sloping and rolling country, such as on the Dundas Tableland and the basaltic plains.[66] In many areas it is a natural condition of the land, but in other parts it has been exacerbated by clearing of native vegetation. Water logging can be a regular occurrence in higher rainfall, southern areas where dairying is the dominant land use. Grazing on waterlogged soils can lead to pugging. In recent years, lower annual rainfall has reduced the occurrence of grazing.
Loss of soil organic carbon	Soil organic carbon (also soil organic matter) refers to all non-living material in and on the soil that is derived from living organisms. Soil organic carbon is a key indicator of soil health.[67] Soil organic matter is a vital component of healthy soils and has many benefits in terms of soil structure, water holding ability, its support of soil organisms and its release of nutrients. Farming practices that remove ground cover such as overgrazing and tillage (cropping) can lead to a loss of soil organic matter as well as soil structure breakdown and increased erosion. Research in this area has been limited at a catchment level.
Water quality of streams	Degradation and movement of soil through erosive processes (wind and water) can cause soil to degrade water quality threatening waterway health. Along with turbidity and sedimentation, movement of soil can carry urban and agricultural chemicals (nutrients applied above requirements, animal wastes, pesticides and herbicides), salt (salinity) and other pollutants.[68] The Water Quality component of the 2010 ISC3 assessment considered total phosphorus, turbidity, salinity and pH. 21 of the regions 122 reaches were assessed for water quality, with results ranging from poor to excellent.[69]
Subsoil constraints	The most common soils in the Glenelg-Hopkins region are texture contrast soils with a lighter A horizon overlying a dense clay B horizon. Duplex soils such as these give rise to subsoil constraints including waterlogging, nutrient deficiencies, acidity and sodicity and are acknowledged to limit crop yields by restricting water movement and root growth. These subsoil limitations are a natural feature of the soils in the catchment and occur in the Kurosols, Chromosols and Sodosols of the region. The amelioration of subsoil constraints is intended to relieve these limitations by improving structural integrity and allowing plant roots access to water and nutrients at depth in the profile.[70]

LAND MANAGEMENT PRACTICE TRENDS

LAND MANAGEMENT PRACTICES TO IMPROVE SOIL CONDITION

The land management practices that farmers choose can have a significant impact on the condition of Australia's soils.[71] Improved management practices can help slow rates of acidification and soil carbon decline, reduce soil loss through wind and water erosion[72] and improve productivity.

A 2012 report funded by the Australian Government into land management practices, soil condition and ecosystem services[73] found that "... many of the current and emerging approaches to managing soils in Australia appear to be effective, or have the potential to be effective, at addressing the major concerns of declining soil carbon content, increasing pH in some areas, and wind and water erosion." Some conclusions from this report are summarised in *Table 4*.[74]

Table 4: Regionally significant ecosystem disservices.[75]

Land management practices	Type of agriculture	Increases carbon content	Reduces risk of wind erosion	Reduces risk of water erosion	Reduces risk of soil acidification (low pH)
No cultivation/tillage apart from actual sowing	Broadacre cropping	*	✔	✔	*
Stubble left intact	Broadacre cropping	✔	✔	✔	
Reduce fallow	Broadacre cropping	✔	✔	✔	
Soil pH testing	Broadacre cropping, horticulture, dairying, grazing (beef cattle/sheep)	*	*	*	✔
Lime or dolomite applied to reduce soil acidity	Broadacre cropping, horticulture, dairying, grazing (beef cattle/sheep)	*	*	*	✔
Monitoring of ground cover	Dairying, grazing (beef cattle/sheep)	✔	✔	✔	
Use of ground cover management targets	Dairying, grazing (beef cattle/sheep)	✔	✔	✔	
Pasture phase in crop rotations	Broadacre cropping	✔	*	*	
Increasing perennial pastures	Dairying, grazing (beef cattle/sheep)	✔	✔	✔	
Soil nutrient testing	Broadacre cropping, horticulture, dairying, grazing (beef cattle/sheep)	*	*	*	✔

✔ Directly benefits * Indirectly benefits

Significant regional progress has been made in the last four years to increase the rate of adoption of sustainable land management practices. For example, the Australian Government funded *'Reducing the Risk of Soil Acidification Project'*, a major regional partnership project involving Glenelg Hopkins CMA, West Vic Dairy, Southern Farming Systems, the former DPI, Landcare and production groups, helped achieve the following outcomes between 2009-2013:

- some 1,743 farmers and service providers have demonstrated improved knowledge and skills to manage soils to mitigate risks of soil acidification, improve soil condition and optimise use of external inputs; and
- an additional 244 farmers adopted soil management methods to reduce soil acidification risks over an area of 39,765 ha.

MONITORING LAND MANAGEMENT PRACTICES

The Australian Bureau of Statistics (ABS) has tracked trends in practice change using data from the 2007-08 and 2009-10 Agricultural Resource Management Survey (ARMS) which sampled approximately 33,000 of Australia's 135,000 agricultural businesses, and ABS agricultural census data from 1995-96, 2000-01 and 2010-11 at a national, state and regional scale.

Areas monitored include stubble management; cropping cultivation systems; ground cover and soil pH management in the dairy industry; and ground cover management in other grazing industries (beef/sheep).

A particular emphasis has been placed on practices that affect the proportion of ground cover retained, due to the influence of this factor on the amount of soil lost through erosion (wind and water), and on biomass which can contribute to soil carbon storage.

The ARMS provides important baseline information for monitoring trends in land management practices within the Glenelg Hopkins region (see Appendix 3). *Table 5* summarises results from the initial 2007-08 ARMS survey. Future ARMS survey results that are released during the life of this Strategy will provide a measure of practice change at a regional level; and help inform regional planning for on-ground projects that seek to increase the uptake of sustainable land management practices.

Table 5: Agricultural land management practice - 2007-08 ARMS data.

Industry sector	Farmers	Practice		Using practice*	Potential audience or area for change
Broadacre cropping	3,048	Residue management (area of stubble 285,087 ha)	Farmers retaining crop residues^	492	2,556
			Area of residues retained (ha)	117,420 ha	167,667 ha
		Cultivation intensity – (area prepared for cropping 327,035 ha)	Farmers using no cultivation/tillage	1,052	1,996
			Area of crops not cultivated except for sowing (ha)	226,786 ha	100,249 ha
		Managing soil acidity	Farmers testing soil pH^	1,080	1,968
			Farmers applying lime or dolomite†	1,027	2,021
		Managing soil nutrients	Farmers undertaking nutrient testing^^	1,063	1,985
Grazing	3,395	Maintaining ground cover	Farmers monitoring ground cover levels	2,092	1,303
			Farmers setting ground cover targets	1,190	2,205
		Managing soil acidity	Farmers testing soil pH^	869	2,526
			Farmers applying lime or dolomite†	910	2,485
		Managing soil nutrients	Farmers undertaking nutrient testing	857	2,538
Dairy	626	Maintaining ground cover	Farmers setting ground cover targets^	268	358
		Managing soil acidity	Farmers testing soil pH^	359	267
			Farmers applying lime or dolomite†	236	390
		Managing soil nutrients	Farmers undertaking nutrient testing	353	273
Horticulture	101	Managing soil acidity	Farmers undertaking pH testing	22	79
			Farmers applying lime or dolomite†	27	74
		Managing soil nutrients	Farmers undertaking nutrient testing	22	79

Source: Department of Agriculture 2014.

* Values without annotation have Relative Standard Error (RSE) less than 10%.
^ RSE 10% to less than 25%, should be used with caution.
† Not all agricultural businesses will benefit from applying lime.

Maps have been prepared at a national scale by researchers and stage agency experts to show indicative areas where improved land management practices are likely to have the biggest impact in reducing wind and water erosion and soil acidification risk, and increasing soil organic matter (Appendix 4).

The area in Victorian NRM regions where changing land management practices are expected to benefit soil condition was estimated as part of Caring for Our Country Phase 1 (*Table 6*). These figures highlight the potential benefits of increased adoption of sustainable land management practices at a regional level.

Table 6: Area in Victorian NRM regions where changing land management practices are expected to benefit soil condition.

NRM region	Area of NRM region (Ha)	Area of agriculture (Ha)	Estimated agricultural area (Ha) with high water erosion rates (>5t/ha/yr)	Estimated area (Ha) where managing pH will provide high benefits	Estimated area (Ha) where managing carbon will provide high benefits	Estimated area (Ha) where managing wind erosion will have high benefits*
Corangamite	1,324,000	907,000	2,000	354,100	409,000	0
East Gippsland	2,068,600	509,600	9,800	94,100	32,500	0
Glenelg Hopkins	**2,671,900**	**2,010,000**	**600**	**1,119,700**	**846,700**	**0**
Goulburn Broken	2,408,900	1,499,700	41,900	904,300	367,000	408,400
Mallee	3,930,500	2,183,000	0	20,100	1,589,100	3,926,100
North Central	2,965,100	2,380,500	10,300	599,700	1,341,300	1,503,500
North East	1,979,800	626,500	107,100	461,500	214,900	0
Port Phillip and Westernport	1,265,900	590,200	12,900	282,900	251,100	0
West Gippsland	1,698,700	883,000	10,100	496,600	315,300	0
Wimmera	2,347,400	1,866,300	8,100	342,200	1,224,600	686,400

Source: Department of Agriculture. * Water erosion is percentage of agricultural area; all others are percentage of total area of NRM region.
Note: no water erosion data is available for most of pastoral zone.

The ARMS data provides baseline information for measuring change in sustainable land management practices at a regional level. The data demonstrates that good progress is being made in many practice areas within the Glenelg Hopkins region. This is particularly evident for management practices such as reducing tillage in cropping systems.

The data suggests that a large number of regional dairy and cattle/sheep businesses are monitoring ground cover, which helps prevent top soil loss through wind and water erosion. The research also highlights that there is an opportunity to undertake further work in encouraging dairying and grazing businesses to establish and manage ground cover targets.

Below: Cropping is common in the north of the catchment.
Photo: Southern Grampians Shire.

CASE STUDY

REGIONAL SUSTAINABLE AGRICULTURE PROGRAM 2013 - 2018

Funding
Australian Government: $3,221,100 over 5 years

Overview

The Regional Sustainable Agriculture Program builds the capacity of regional farmers to make and implement land management decisions that will improve soil condition, increase production and protect the natural resource base.

Activities are delivered as parallel and integrated programs, through three projects:

- *Sustainable Agriculture*
- *Indigenous Partnerships for Improved Natural Resource Management*
- *Regional Landcare Facilitator*

The projects are designed to meet the needs of key agricultural groups and enterprises. Activities are delivered through collaborative partnerships with industry, government agencies and community-based organisations including production groups, Traditional Owners and Landcare.

Outcome

Increase productivity and improve the quality of ecosystem services delivered to the broader community.

Salt crust on saline groundwater discharge site. Photo: DEPI.

Project Partners

Glenelg Hopkins CMA, DEPI, WestVic Dairy, Victorian No-Till Farmers Association, Landcare and production groups.

Output Targets

By 30 June 2018:

- *145 farming entities have adopted more sustainable land management practices*
- *36,000 hectares under more sustainable land management practices*
- *24 farming entities have trialled innovative land management practices*
- *920 land managers have improved capacity to manage natural resources for ecosystem services*
- *630 farming entities have improved capacity to manage natural resources for ecosystem services*
- *36 regional community members have increased capacity and confidence to be regional leaders*
- *72 regional communities or groups have increased engagement in NRM activities.*

Funding

Australian Government: $2,100,475.

SUSTAINABLE AGRICULTURE

Overview

Building on the 2009-13 Australian Government funded project 'Reducing the risk of Soil Acidification', the Project provides activities that support adoption of sustainable land management practices and innovation across a range of agricultural enterprises.

The project is delivered as four sub-projects. Three align with key agricultural enterprises - broadacre grazing, cropping and dairy - to be delivered in partnership with leading industry organisations and government agencies. The fourth supports community based initiatives to investigate innovative farming practices through dependable information sources and on-farm demonstrations.

Opportunities are provided for farmers undertaking change to gain and provide peer support opportunities, build confidence and increase capacity as regional leaders.

CASE STUDY CONTINUED...

INDIGENOUS PARTNERSHIPS FOR IMPROVED NRM

Overview

Delivered in partnership with Traditional Owner groups and Indigenous communities, the project engages Indigenous land managers and young Indigenous Australians to achieve sustainable land management and NRM outcomes.

Working collaboratively with five Traditional Owner groups the project will build the capacity of participants to undertake NRM and sustainable land management activities. Traditional Owner groups will be equipped with the knowledge and skills to collect, record and appropriately archive Indigenous ecological knowledge. It will include the delivery of a Junior Ranger Program in Schools by Traditional Owners.

The Project benefits from the experience of 2009-13 Australian Government funded projects 'Yarns on Farms', 'Indigenous Ecological Knowledge and 'Indigenous Communities Facilitation', enabling opportunities for Indigenous Ecological Knowledge to inform contemporary farming practices through a two way exchange of knowledge and experience.

Project Partners

Glenelg Hopkins CMA, Traditional Owners groups and Indigenous communities.

Output Targets

By 30 June 2018:

- *3 information exchange & awareness raising events*
- *3 training and capacity building events*
- *1 Junior Ranger program delivered in schools*
- *120 Indigenous people with increased capacity and improved confidence to participate in NRM activities*
- *12 Indigenous land managers with increased knowledge and skills to manage natural resources.*

Funding

Australian Government: $345,625.

REGIONAL LANDCARE FACILITATOR

Overview

The Regional Landcare Facilitator (RLF) is an 'enabling' role supporting Landcare and production groups to adopt sustainable farm and land management practices. The RLF works with individual land managers, community groups (Landcare, production and industry) to promote sustainable agricultural practices to farmers. Within this role, the RLF fosters connections between the community, industry and government agencies that lead to collaborative, productive partnerships. The RLF assists community groups seek funds and resources to undertake capacity building activities.

Project Partners

Glenelg Hopkins CMA, Landcare, industry and production groups.

Output Targets

By 30 June 2018:

- *10 farming entities have trialled innovative land management practices*
- *150 land managers and farming entities have improved capacity to manage natural resources*
- *20 regional community members have increased capacity and confidence to be regional leaders*
- *50 regional communities or groups have increased engagement in NRM activities*
- *500 community members have increased awareness and understanding of NRM.*

Funding

Australian Government: $775,000.

Above: Chetwyn Landcare Group Visual Soil Assessment workshop. Photo: DEPI.

Left: Launch of the Budj Bim landscape field guide. Photo: Glenelg Hopkins CMA.

THE STRATEGY FOR PROTECTING AND IMPROVING SOIL HEALTH

The Glenelg Hopkins region was found to have high participation rates in both Australian and Victorian Government projects in a 2011-12 Australian Bureau of Statistics survey of 33,000 of Australia's 135,000 agricultural businesses (Figure 2), reflecting the strength of regional partnerships. It also had a higher proportion of farming businesses using Glenelg Hopkins CMA as a source of information and advice compared to the State average for regional NRM organisations.

The proportion of regional farmers that had indicated an improved understanding of land management and environmental issues was also high, when compared to the State average. The Strategy aims to build on these achievements.

The Soil Health Strategy for the Glenelg Hopkins region focusses on the health of the soil asset and the ecosystem services that soils provide; and increasing community awareness and understanding of the value and importance of soil health. The Strategy provides a regional framework for encouraging collaboration and partnerships between landholders, community groups, industry organisations, farm service providers and government agencies to achieve common goals. Actions build on the success of earlier work within the catchment and seek to maximise the efficiency and effectiveness of government investment in soil health for production and environmental benefits.

The goals of the Soil Health Strategy support the 50-year vision for the Glenelg Hopkins catchment of:

> "Achieving a healthy and sustainable relationship between the natural environment and the community's use of land and water resources."

The issues identified for priority attention at a regional scale that are impacting high priority natural assets (including high priority soils) are:

- Inadequate ground cover in erosion susceptible areas (e.g. cropping areas). This can lead to a decline in agricultural productivity as a result of soil and nutrient loss through wind and water erosion. Erosion can also impact air and water quality.
- Soil structure decline. Although a natural process and influenced by soil type and slope, soil structure decline can be accelerated by human activities such as some cropping activities, soil compaction (e.g. farm machinery and livestock), and vegetation clearing.[76] This can lead to compaction, decreased infiltration rates, increased runoff with attendant increased erosion as well as surface ponding and increased waterlogging.
- Movement of sediment and nutrient into rivers, lakes and estuaries. This can compromise the health of these waterways and lead to eutrophication and triggering of algal blooms.
- Soil contaminants, such as salt and acids. Salt affected soils can lead to decreased agricultural productivity and increased leaching of salt into waterways.
- Sodic soils that are prone to water erosion and are highly erosive. This can impact agricultural land, infrastructure and vegetation.

The goals for the Strategy are:

1. Protect and improve soil health by addressing current known threats to soils and improving soil resilience.
2. Promote the value and importance of soil health and services.
3. Maximise the efficiency and effectiveness of government investment in soil health for environmental and production benefits.
4. Build government, industry and community partnerships to management for soil health.

The following sustainable practice targets have been established to facilitate increased regional uptake of sustainable land management practices and help guide on-ground efforts over the next five years:

- increase the number of farming entities using sustainable land management practices by 140 over an area of 35,000ha;
- increase the percentage of regional farming businesses above 2009-10 Agricultural Resource Management Survey (ARMS) levels that monitor ground cover levels and have established minimum ground cover level targets for dairying and broadacre grazing industries (sheep and beef);
- increase the percentage of regional cropping businesses above 2009-10 ARMS levels that use one-pass cropping systems; and
- increase the percentage of regional agricultural businesses above 2007-08 ARMS levels using sustainable land management practice categories defined in *Table 5*.

These are based on what is considered appropriate and achievable based on land management practices measured in the region in the ARMS surveys described in *Table 5*.

A key objective of this Strategy is to increase the number of grazing operations setting and monitoring ground cover targets. DEPI will work with individual farmers and production groups to realise ground cover targets through the conduct of training programs such as FarmPlan21 and EverGraze. These initiatives are expected to contribute to an increase in the area and diversity of deep-rooted perennial pasture across the region.

Emphasis has been placed on adoption of management practices that reduce the risk of soil acidification and erosion, and increase levels of soil carbon due to the impact of these factors on the majority of processes that are expected to generate ecosystem services; and the benefits flowing from them.

IMPLEMENTATION OF THE STRATEGY

Implementation of actions in this Strategy are expected to contribute to an increase in the number of regional cropping entities using minimum tillage systems, an increase in the number of farmers retaining crop residues for fallow period ground cover, and an increase in the number of farmers minimising soil disturbance at sowing. The establishment of farmer mentor programs will be encouraged to help support the roll-out of these initiatives; along with traditional extension programs.

Partnership opportunities with industry organisations such as Southern Farming Systems, WestVic Dairy and Victorian No-Till Farmers Association in sustainable agriculture initiatives will be investigated to strengthen the potential for on-ground adoption of sustainable land management practices (e.g. controlled traffic systems, minimum tillage systems, and nutrient management initiatives).

Actions in the Strategy will continue to support tailored training events, farm trials and demonstration of innovative practices to increase the capacity and confidence of land managers to make and implement land management decisions to improve soil condition and increase production in a sustainable way.

Strategy actions seek to increase the number of farming businesses monitoring soil acidity and undertaking soil tests to inform nutrient management decisions. WestVic Dairy will work with dairy processors to increase the number of farmers adopting nutrient best management practices. DEPI soil health training courses provide land managers with the opportunity to increase knowledge and understanding of soil, including soil test interpretation and making informed nutrient management decisions based on soil test results. Increased monitoring of soil acidity through testing will enable farmers to better manage soil acidity through application of mineral carbonates (e.g. lime and dolomite).

Work undertaken by WestVic Dairy during the life of this Strategy will increase the number of dairy farmers producing farm nutrient maps and nutrient management plans for their farms. This work will support farmers in better targeting nutrient applications to meet the specific needs of their soil. The resulting nutrient use efficiencies reduces the risk of soil acidification and the risk of movement of water soluble nutrients into waterways, which can lead to eutrophication and algal blooms.

Management of salinity is a priority in the Strategy. Grazing management to achieve minimum ground cover targets on perennial pastures remains the primary salinity mitigating action. Deep-rooted grasses accessing soil moisture will aid in reducing salinity risks by reducing groundwater recharge opportunity and the utilisation of soil moisture in discharge zones. Areas of overlap between high value natural assets and high priority salinity provinces will be targeted for salinity mitigation actions.

Empowerment of groups and individuals is achieved through the continued support of community driven activities. Groups (production and Landcare) will be supported to hold events to fill knowledge gaps and facilitate discussion.

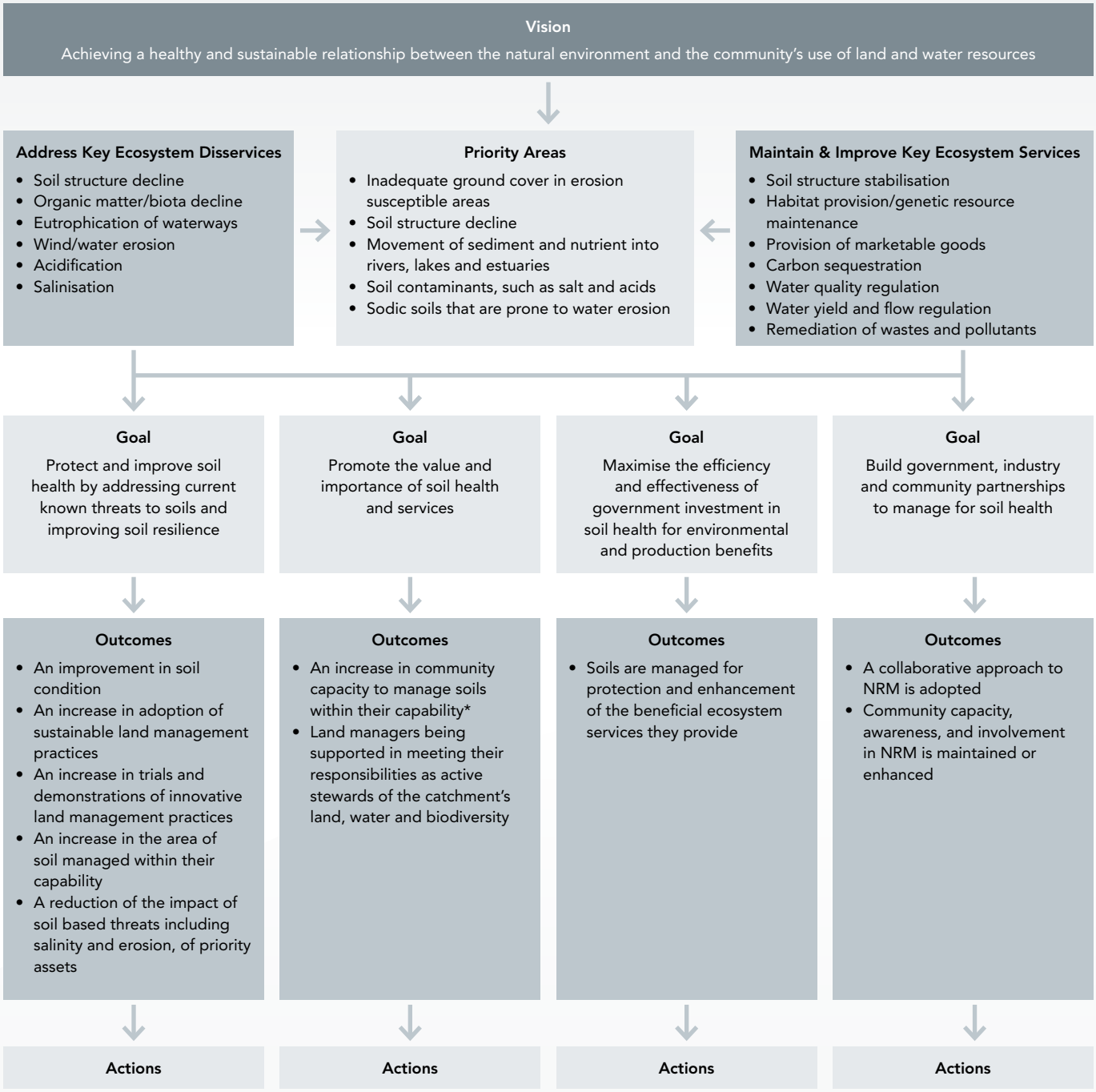
"Work undertaken by WestVic Dairy during the life of this Strategy will increase the number of dairy farmers producing farm nutrient maps and nutrient management plans for their farms".

Below left: Fencing and revegetation of river banks benefits the farm and river health.

Below right: Shelter belts protect stock, provide habitat and reduce erosion and salinity risks.
Photos: Glenelg Hopkins CMA.

PROGRAM LOGIC FOR SOIL HEALTH MANAGEMENT

A high-level program logic for the Strategy is shown in Figure 8. It shows the regional vision, goals and key areas of focus for this Strategy.



* Outcomes are achieved across multiple goals

Figure 8: Program Logic – Glenelg Hopkins Soil Health Strategy.

Detailed actions and associated measures are shown in *Table 8*.

Table 7 shows how each Strategy goal contributes to the achievement of RCS objectives (outcomes).

Table 7: Soil Health Strategy goals and RCS objectives

Soil Health Strategy goal	Summary
Protect and improve soil health by addressing current known threats to soils and improving soil resilience	• An improvement in soil condition as measured by key indicators by 2032 (10.1) • An increase in the area of soils managed within their capacity (10.2) • By 2033 reduce the impact of soil based threats, including salinity and erosion, on waterways and wetlands, as measured by improved ISC and IWC scores (10.3)
Promote the value and importance of soil health and services	• Support land managers in meeting their responsibilities as active stewards of the catchment's land, water and biodiversity (2.3)
Maximise the efficiency and effectiveness of government investment in soil health for environmental benefits	• By 2032 soils are managed for protection and enhancement of the beneficial ecosystem services they provide (10.4)
Build government, industry and community partnerships to manage for soil health	• Facilitate a collaborative approach to NRM (2.2) • Maintain and enhance community capacity, awareness and involvement in natural resource management within the region (2.1)

IMPLEMENTATION PLAN

Table 8: Implementation Plan

No.	Action	Measure[§]	Lead agency	Proposed delivery partners
1	**Goal - Protect and improve soil health by addressing current known threats to soils and improving soil resilience**			
1.1	Increase the uptake of sustainable land management practices within the Glenelg Hopkins region[#]	• Increase the number farming entities using sustainable land management practices by 140 over an area of 35,000ha • Increase the percentage of regional farming businesses above 2009-10 ARMS levels that monitor ground cover levels and have established minimum ground cover level targets for cropping, dairying and grazing industries • Increase the percentage of regional cropping businesses above 2009-10 ARMS levels that use one-pass cropping systems • Increase the percentage of regional businesses above 2007-08 ARMS levels using sustainable land management practice categories defined in *Table 5*	CMA	DEPI
1.2	Maintain ground cover levels above regional ground cover targets to mitigate dryland salinity risks, reduce soil and nutrient loss, through wind and water erosion, and improve air and water quality[#]	• By 2019, 10,000ha of additional grazing land is monitored and managed to achieve ground cover targets of at least 70% during the summer season • By 2019, 20,000ha of additional cropping land is monitored and managed to achieve ground cover targets of at least 50% through crop residue retention	CMA	DEPI
1.3	Manage soil acidification to help improve productivity and limit future loss of productive land through subsoil acidification	• Maintain or increase the percentage of regional farming businesses above 2009-10 Agricultural Resource Management Survey levels undertaking pH testing	CMA	DEPI, Industry Groups
1.4	Manage nutrient addition to soils to help improve productivity, reduce losses into waterways and slow rates of soil acidification	• Maintain or increase the percentage of regional farming businesses above 2009-10 Agricultural Resource Management Survey levels undertaking nutrient testing	CMA	DEPI, Industry Groups
		• 60% of regional dairy businesses using Nutrient Management Plans	WestVic Dairy	CMA, DEPI

No.	Action	Measure[§]	Lead agency	Proposed delivery partners
1.5	Support projects that are targeted at improving the condition of soils currently at risk where they impact high value assets[#]	• Proportion of CMA led regional soil health projects implemented in priority areas identified in Glenelg Hopkins Regional Catchment Strategy; and in areas of high relative productivity potential • Hectares of land fenced to protect high value waterways at risk of bank instability, as identified in the Glenelg Hopkins Waterway Strategy 2014-2022	CMA	DEPI, Community Groups
1.6	Support trials or demonstrations of regionally innovative practices to increase farming system resilience to impacts of a changing climate within a whole farm context	• 20 farming entities supported	CMA	Community Groups
1.7	Continue monitoring of surface water salinity targets as set for Glenelg Hopkins Salinity Plan 2005-2008[#]	For 90% of the time: • Station No. 236202 Hopkins River at Wickliffe measures 15,000 EC or less • Station No. 236209 Hopkins River at Hopkins Falls measures 7,000 EC or less • Station No. 238202 Glenelg River at Sandford measures 6,500 EC or less • Station No. 238228 Wannon River at Henty measures 6,000 EC or less	DEPI	CMA
2	**Goal - Promote the value and importance of soil health and services**			
2.1	Investigate benchmarks for key indicators of healthy soils[+]	• Regional support for initiatives that contribute to the development of a Statewide Soil Health Index	DEPI	CMA
2.2	Support research to ameliorate sub-soil constraints to improve soil condition and agricultural production	• 1 sub-soil amelioration research project supported	DEPI	CMA, DEPI, Industry Groups, Community Groups
2.3	Support research to reduce contribution of agricultural soils to greenhouse gas emissions	• 1 priority greenhouse gas reduction (nitrogen use efficiency) research project supported by 2019	CMA	DEPI/other Victorian CMAs
2.4	Investigate opportunities for soil capability mapping under different land management practices[+]	• Regional support for initiatives that contribute to consistent, method of land capability evaluation methodology for Statewide adoption	CMA	DEPI/LGA
2.5	Establish demonstration farms showing regionally innovative practices to improve soil health and increase productivity	• 4 on-farm demonstration sites established	DEPI, Industry Groups, Community Groups	CMA
2.6	Continue development and communication of land capability information to guideland use change decisions[+]	• 2 Local Government Authorities have completed and/or updated land capability mapping to inform planning and land use decisions	LGA	CMA/DEPI
2.7	Identify opportunities for land capability overlays and planning controls[+]	• 4 opportunities realised to collaborate with regional partners for land capability, overlays and planning controls by 2019	DEPI	CMA
2.8	Identify soils at risk under certain management regimes[+]	• Improved management decisions on 2,300ha of agricultural land where significant land use change is occurring	DEPI	CMA, Industry Groups
2.9	Promote increased levels of awareness and adoption of land management methods to maintain or improve the health and productivity of soil[+]	• Increase the number of farming entities using sustainable land management practices by 140 over an area of 35,000ha to increase productivity and improve the quality of ecosystem services delivered to the broader community from their land, while building their resilience to climate change • Improve the productive potential of 40,000ha of agricultural land	CMA	DPI, Industry Groups

No.	Action	Measure[§]	Lead agency	Proposed delivery partners
2.10	Undertake education programs that promote soil as a finite, valuable resource and ecosystem services provided by soils[+]	• 630 farming entities and 920 land managers with improved knowledge and skills to manage natural resources and deliver ecosystem services • 200 farm entities have improved capacity to manage natural resources for improved delivery of ecosystem services to the community	CMA	DEPI, Industry Groups
2.11	Raise awareness of fundamentals of soil carbon composition, function and sequestration opportunities	• 150 additional farming entities adopt land management practices that provide opportunities for carbon sequestration within a whole farm context	CMA	DEPI, Industry Groups
3	**Goal - Maximise the efficiency and effectiveness of government investment in soil health for environmental and production benefits**			
3.1	Work with Glenelg Hopkins CMA and agencies to support water quality improvement, reduce sediment and salt loads and minimise catchment-related impacts on the parks[#]	• Development of Integrated Catchment Action Plans in priority areas identified in Glenelg Hopkins Waterway Strategy 2014-2022	CMA	DEPI, Parks Victoria
3.2	Liaise with agencies, industry groups and the community to develop integrated land and soil health programs[#]	• Regional soil health program annually developed in collaboration with government agencies, industry and community groups to increase the capacity of land managers to sustainably manage their land for production and natural resource benefits	CMA	DEPI, Industry Groups, Community Groups
3.3	Increase knowledge of land use and land condition trends across the catchment integrating on-ground monitoring and other data sources to inform regional planning processes and government investment decisions	• 1 project established to undertake monitoring of land use in the catchment through bi-annual drive-by transect with observations linked with Victorian Land Use Information System and other data sources to identify trends in land use and land use change over time • Development of updated regional land use map by 2015	CMA	DEPI
3.4	Ensure work on soil health is integrated with other catchment management planning and activities*	• Development of guidelines for Regional Catchment Action Plans by end 2015, which includes consideration of soil health	CMA	DEPI, Industry Groups
4	**Goal - Build government, industry and community partnerships to manage soil health**			
4.1	Collaborate with Indigenous communities, community organisations, local government, agencies, tertiary institutions and industry groups to develop partnership projects and joint initiatives[+]	• 20 landscape scale sustainable agriculture partnership projects implemented regionally	CMA	DEPI, Parks Victoria, LGAs, Industry Groups, Community Groups
		• 4 Indigenous Partnership Projects developed with Traditional Owner groups by 2019	CMA	Traditional Owners
		• 1 indigenous ecological knowledge education program developed for schools and implemented in partnership with Traditional Owners (1 Junior Ranger Program)	CMA	Traditional Owners
4.2	Develop and implement programs to build community capacity in Natural Resource Management[+]	• 20 regional communities or groups, including 2 indigenous groups, increase capacity and involvement in natural resource management activities	CMA	DEPI
4.3	Undertake community awareness and extension activities to promote Natural Resource Management and best practices in agriculture[+]	• 10 awareness raising and extension activities undertaken annually to promote natural resource management and best practices in agriculture	CMA	DEPI, Industry Groups, Community Groups

[§]Measures are for implementation during the life of the Strategy, unless otherwise indicated.
[+]Management Measures as identified in the Soil and Land, and Community Participation chapters in the Regional Catchment Strategy 2013 - 2019.
*Actions as identified in the DSE Soil Health Strategy July 2012. [#]Actions that form the basis of Regional Salinity Action Plan.

Acronyms:
CMA - Glenelg Hopkins Catchment Management Authority. **CMAs** - Victorian Catchment Management Authorities. **DEPI** - Department of Primary Industries and Environment. **IG** - Industry Groups (group is broadly recognised as representative of the industry e.g. WestVic Dairy, Southern Farming Systems, Victorian No-Till Farmers Association. **CG** - Community Groups (e.g. Landcare and production groups).

CASE STUDY

DEPI LAND HEALTH PROGRAM 2013-2017

Overview

The Department of Environment and Primary Industries (DEPI) Land Health Program will continue to work with the regional community to manage the resource base to support increased productivity. The Implementation Plan (Table 8) details the actions and associated measures on which DEPI will deliver to ensure the four goals of the Strategy are achieved. DEPI has a lead or coordinating responsibility on 6 of the 25 Actions (mostly under Goal 2 - Promote the value and importance of soil health and services) and is a partner on the remainder.

As part of that Statewide program, DEPI's Glenelg Hopkins Land Health extension program 2013-2017 aims to deliver products and services tailored to the specific needs of regional farmers. These products and services will focus on building the interest, knowledge and skills of farmers to adopt better soil management practices and reduce the impact of soil degradation issues.

Activities of the Land Health program include those designed to:

- ***create awareness** (e.g. field days on building soil function and monitoring soil health); and*
- ***achieve practice change** (e.g. whole farm planning and grazing management training courses to improve soil management, maintain ground cover and reduce risks associated with climate variability).*

The extension program will help farmers to identify and address soil constraints in their production systems and manage land capability to improve both soil condition and productivity. This is done through workshops (such as Productive and Sustainable Soils Workshops), the design of which is informed by ongoing interaction with farmers.

*Industry and community networks are key to the delivery of soil health messages and provide an ongoing context for interactive learning. These include BestWool/BestLamb, BetterBeef, Grains Network groups and Landcare. DEPI Land Health officers will work with groups to provide evidence-based, scientific information to support the **development of innovative land management practices** that can improve soil condition and production.*

*This may include opportunities for **Land Holder Demonstration Sites** at which improved soil management practices and innovations can be evaluated. The pasture cropping demonstration currently underway with Glenelg BestWool/BestLamb group is such an opportunity.*

Output targets

The three Statewide targets for this four year period:

- *improve the productive potential of **600,000ha** of agricultural land;*
- *improve management decisions on **15,000ha** of agricultural land where significant land use change is occurring;*
- *remediate **450ha** of degraded[¥] agricultural land to protect priority assets.*

Four-year targets for the Glenelg Hopkins region:

- *improve the productive potential of **40,000ha** of agricultural land;*
- *improve management decisions on **2,300ha** of agricultural land where significant land use change is occurring;*
- *remediate **5ha** of degraded[¥] agricultural land to protect priority assets.*

Visual Soil Assessment soil structure investigation. Photo: DEPI.

[¥] Land severely impacted by soil degradation e.g. erosion and soil loss.

MONITORING, EVALUATION, REPORTING AND IMPROVEMENT

The Soil Health Strategy Monitoring, Evaluation, Reporting and Improvement (MERI) framework will be guided by the MERI framework that was established for the Glenelg Hopkins RCS. This framework will provide the overarching direction for the application of MERI principles and processes to the implementation of the Strategy.

A MERI framework is vital for understanding success (and failures) and how best to learn from them. MERI provides the information that is required to adaptively respond and manage programs in an often uncertain field of management.

The MERI framework is based on the following principles:

- During the life of the Strategy, new information and knowledge will most likely become available. This information and knowledge will need to be incorporated into the Strategy by taking an adaptive management approach.
- Management interventions for natural resource management often have impacts at different temporal scales. Not all impacts of management interventions will be expected to be apparent within the lifetime of this Strategy. Ongoing monitoring may be required to recognise these longer term achievements.
- The success of MERI for the Strategy will require strong partnerships to ensure data and its interpretation is up to date and available. Data collection and sharing procedures may need to be established.
- Various standards (for example vegetation works standards and standard output protocols) are or will be available to support MERI and should be considered.

OUTCOMES HIERARCHY

The Glenelg Hopkins RCS is informed by a hierarchy of outcomes or in other words, things that can be achieved both in the short and long-term. A series of 20-year objectives, have been developed that will be required to achieve the region's 50-year vision. The goals of this strategy are linked to RCS Soil and Land, and Community Participation objectives, and the actions designed to support the achievement of these objectives over time.

CRITICAL ASSUMPTIONS FOR THE OUTCOMES HIERARCHY

Assumptions are the expectations, based on current knowledge and experience, about what is important for a strategy's success.

The following broad assumptions can be applied:

- Data is available and can be meaningfully applied when evaluating and reporting on implementation.
- Resources are available for monitoring activities, data collection and management.
- Resources and funding are available to deliver the necessary action.
- New land management practices will be adopted.
- Predicted conditions (e.g. climate, land use) for the life of the RCS are correct.
- Land managers engage and are encouraged and empowered to act.
- Land managers are interested in attending training and workshop events and actively seek technical advice.

ARE THE RIGHT RESULTS BEING ACHIEVED?

Key evaluation questions, that set the direction for monitoring and reporting, form the basis for assessing whether the management measures have occurred as required and whether they have been effective in bringing about the desired change (whether objectives are being met). Key evaluation questions against the categories of impact, appropriateness, effectiveness, efficiency and legacy are detailed in *Table 9* opposite.

Table 9: Key evaluation questions

Impact
In what ways and to what extent has the Soil Health Strategy contributed to changing management practices? What increase has there been in the number of land managers applying best management practices?
What is the status and trend in asset condition in the region?
What progress has been made towards achieving the 20-year RCS objectives?
Appropriateness
Do the management measures and actions remain the best management practices available or are there more appropriate methods that should be implemented?
Effectiveness
How effective were the implemented measures at meeting the objectives?
Are the current management measures and actions still the most effective for meeting the 20-year objectives or are there other, more effective ways?
Efficiency
To what extent were the Strategy implementation actions completed?
To what extent have the program of measures been implemented?
Legacy
How are the effects of Soil Health Strategy implementation expected to continue over time, particularly after the strategy has reached the end of its cycle?

*Below: In 2011-12 wheat produced in the Glenelg Hopkins region had a gross commodity value of $68,700,000.** Photo: James Pevitt.*

**Australian Bureau of Statistics, Value of Agricultural Commodities, 2011-12.

APPENDIX 1 - ECOSYSTEM DISSERVICES

DRYLAND SALINITY

Dryland salinity is generally categorised as primary or secondary. Primary salinity is considered to be a natural feature of the landscape, and may have existed for thousands of years prior to European settlement in many parts of Victoria. Some of the best examples of primary salinity occur in the Glenelg Hopkins, Corangamite and Mallee Catchment Management Authority regions.[78]

Secondary salinity refers to salinity that has occurred as a "direct consequence of post-European settlement activity" (e.g. land use change, land clearing), which has 'unbalanced' the natural water table levels, causing a rise in saline water tables.

Dryland salinity has been estimated to affect more than 27,000ha of the catchment and based on current estimates; the region has the second largest area of land affected by dryland salinity in Victoria.[80]

A 2010 literature review of salinity research undertaken within the Glenelg Hopkins area identified 60 studies that have investigated salinity across the region from 1958 to 2009. The study concluded "that different landscapes have unique explanations for dryland salinity" and the main findings are summarised below:

- **Eastern Dundas Tablelands** - Predominantly primary salinity. The stable discharge environment has been disturbed by land clearing and agricultural activities leading to secondary salinity and land degradation without shift in the regional groundwater system.
- **Willaura** - Dominated by primary saline wetlands and shallow water tables. Areas of secondary salinity caused by the concentration of salts from surface water flow and evaporation along drainage lines not rising water tables.
- **Woorndoo** - Primary saline and fresh water lakes, with the distribution of secondary salinity controlled by regional groundwater flow discharging at the edges of basalt flows. Areas of shallow water tables can lead to increased salt concentration in topsoil. The degree of salinisation appears to be controlled by permeability of topsoil.[81]

The 2013 *Victorian Dryland Salinity Update* outlines the management approaches and understanding of dryland salinity in Victoria. It highlights advancements in the understanding of dryland salinity at a Statewide level, including: 1) the identification of salinity provinces across Victoria; 2) that the "potential risk caused by salinity appears to be cyclic, following variations in climate"; and 3) that dryland salinity can be the result of anthropogenic sources, a natural feature of the landscape, or the result of a combination of both.[82]

Figure 9 shows 'mapped' salinity discharge areas at a catchment level. Based on the data available, some areas of the catchment are more affected than others, particularly in the north and east.

Data from a 2012 technical report[83] on salinity status within Victoria's catchment management regions indicates that little change in groundwater levels have occurred within the Glenelg Hopkins region as a result of the 1998-2009 period where rainfall was below the long-term average. Based on available data, high water tables were still identified in discharge areas in monitored provinces, and little change was found in water levels following recent wet years. Consequently, salinity status was considered largely unchanged from the 1990s based on the data available. It was noted however, that changes in salinity status could not be assessed in all salinity provinces, due to a lack of active monitoring.

Although the spread of dryland salinity is considered to have slowed or receded in many areas of Victoria due to the recent dry period, the threat is likely to increase if there is a return to wetter conditions,[84] as more water is available to "drive salinity processes".[85]

Salinity provinces have been mapped at a Statewide level using available data.[86] These areas have a "higher than average density of saline discharge, coupled with locally based conceptualisations of the drivers of salinity occurrences" (e.g. geologic features, discontinuities at the interface between geologies and groundwater flow systems).[87] High priority salinity provinces that have been identified within the Glenelg Hopkins region are shown in Figure 10. When overlaid with high value assets, salinity provinces assist NRM practitioners with "prioritising investment and management for the protection of assets against dryland salinity threats".[88]

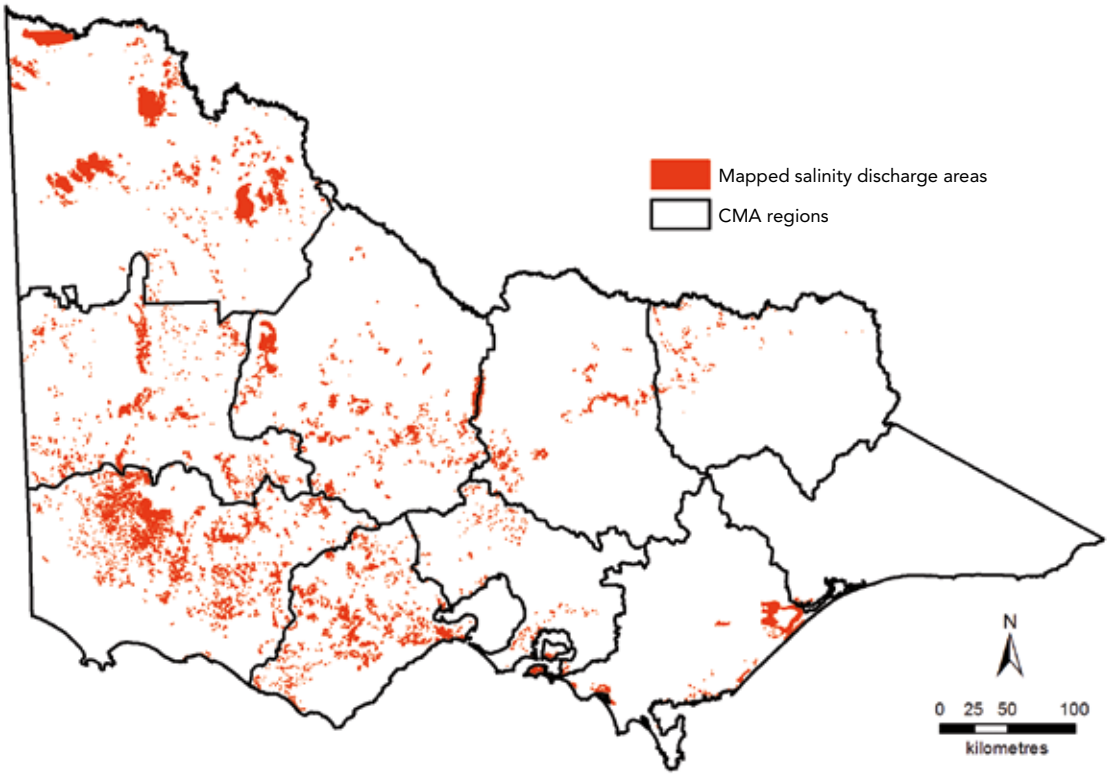


Figure 9: Mapped saline discharge areas in Victoria. Source: DEPI 2014.

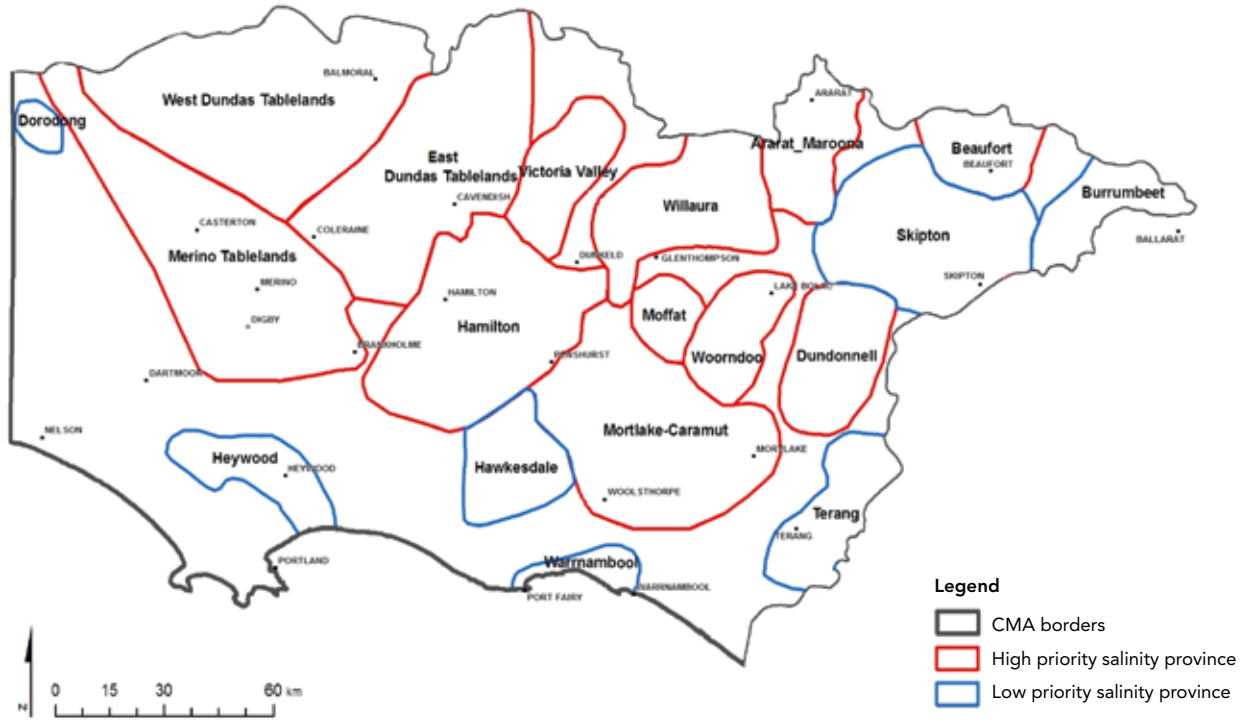


Figure 10: Glenelg Hopkins catchment salinity provinces with observation bore monitoring status indicated. Source: DEPI 2013.

SOIL ACIDIFICATION

Soil acidification is a "naturally occurring soil chemical process" that occurs very gradually in undisturbed ecosystems. It can be accelerated by vegetation clearing and agriculture.[89] The main impacts of soil acidification include: a reduction in productivity and plant growth, reduced soil biological activity and availability of nutrients, loss of vegetation, and increase risks of erosion and soil structure decline; which can have a significant economic impact on the landholder.[90]

Naturally acidic and acidifying soils typically occur in areas where rainfall is in excess of 500 mm/year; with the most strongly acidic soils occurring in permanent pasture areas.[91]

Some agricultural practices can accelerate the rate of acidification. Examples of production systems and significant factors that can impact soil acidification rates include: cropping (product removal and nitrate leaching); grazing (nitrate leaching / build-up of organic matter); and horticulture (fertigation).[92]

A key production system challenge is to manage the cause of the acidity, to either neutralise the additional acid or slow the acidification rate.

Most of the Glenelg Hopkins region has a high, inherent susceptibility to soil acidification. Strongly acidic soils can be defined as soils with a pH less than 4.5.[93] Estimated surface soil pH ranges across Victoria are shown in Figure 11. The geographic extent of acid soils on agricultural land was last mapped at a Statewide level in 1996, and data on the spread of soil acidification at a catchment level is limited.[94]

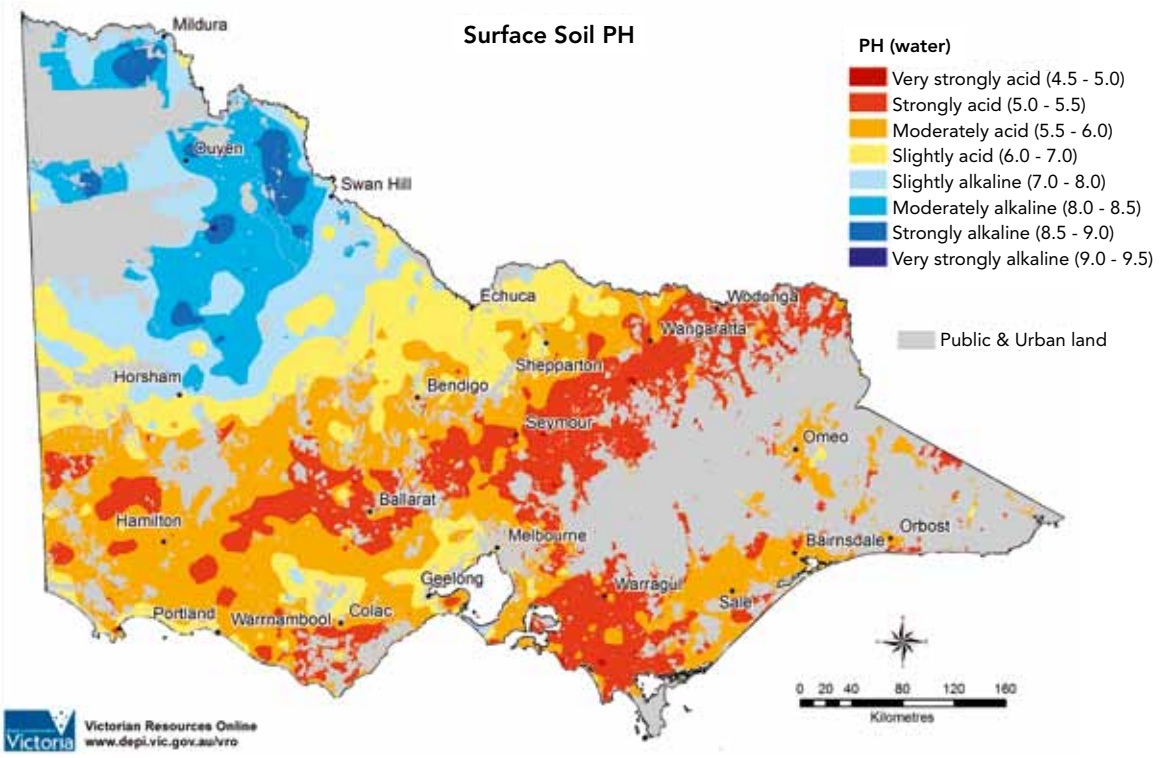


Figure 11: Estimated surface soil pH ranges on private land across Victoria. Source: DPI 2007.

WIND EROSION

Erosion and soil structure decline are closely linked as soil structure degradation increases the potential for removal of topsoil from wind and water erosion. This in turn impacts soil health, as organic matter and nutrients are lost, and habitat is reduced for species such as fungi and earthworms, which help stabilise soil structure.[95]

Soil erosion is a naturally occurring process that is influenced by a range of factors including soil type and slope. The rate of erosion can be accelerated by factors such as production system type (e.g. cropping - burning of crop residues) and ground cover.

Soil landscapes most susceptible to wind and water erosion have been modelled at a Statewide level in 2011.[96] Figure 12 shows soil susceptibility to wind erosion based on dominant soil type. Rankings for each figure relate to the soils inherent capacity to resist erosion, one of the services provided by soils. Soil landscapes in the west of the catchment in the Glenelg Plain and Dundas Tablelands areas have very high inherent susceptibility to wind erosion. Discovery Bay and the Nelson Plain (near Portland) are particularly prone to wind erosion.[97]

Approximately 16% of the catchment has been estimated as having a high to very high inherent susceptibility to wind erosion using GMU250 mapping data.[98]

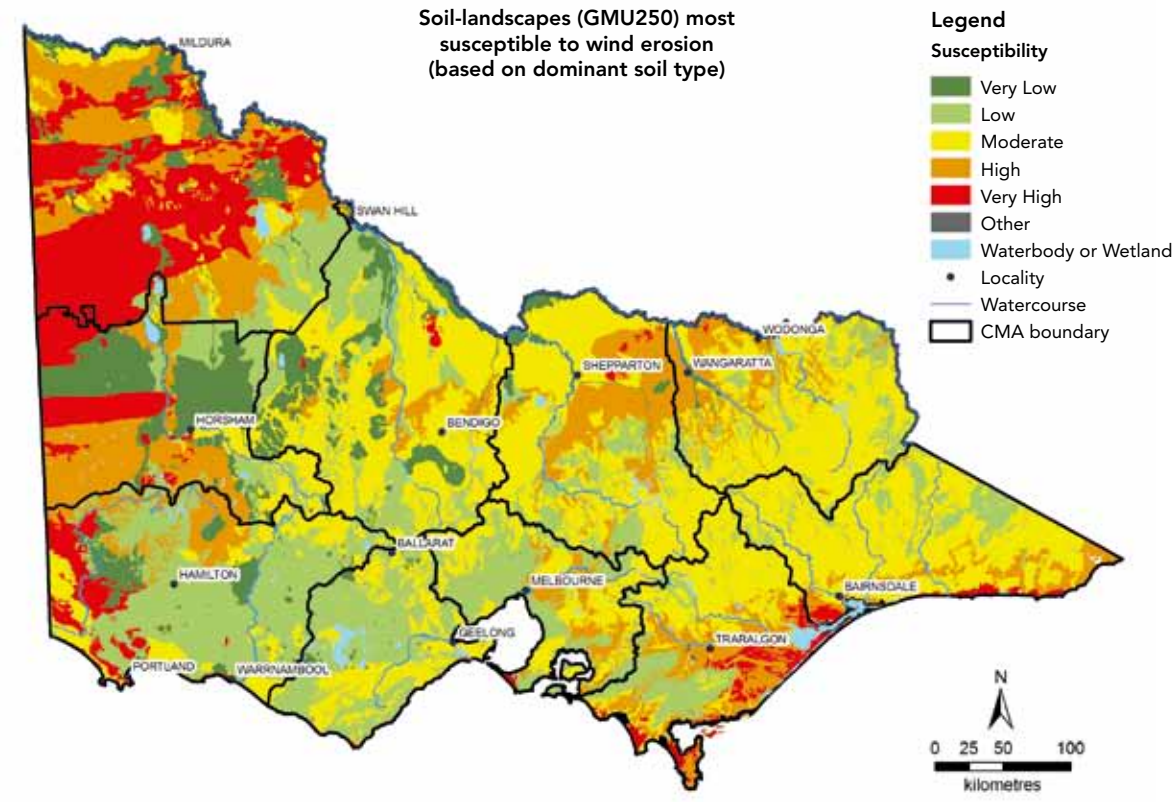


Figure 12: Soil landscapes most susceptible to wind erosion.[99]

Satellite imagery has been used to model areas under threat of wind erosion in Victoria between 2001-2009, considering inherent susceptibility and land use (Figure 13). Although the results of this modelling show much of the catchment under low to very low threat during this period, some areas were under high threat, such as the Dundas Tablelands; and smaller areas in the vicinity of the Grampians and to the north of Portland. Around 9% of the catchment was considered to have a moderate to very high threat of wind erosion between 2001 and 2009.[100]

Wind erosion is strongly influenced by soil moisture, and areas that receive less than 400mm annual rainfall are at higher risk of dust storms due to increased likelihood of soils being moved by wind due to soils being more likely to be dry.[101]

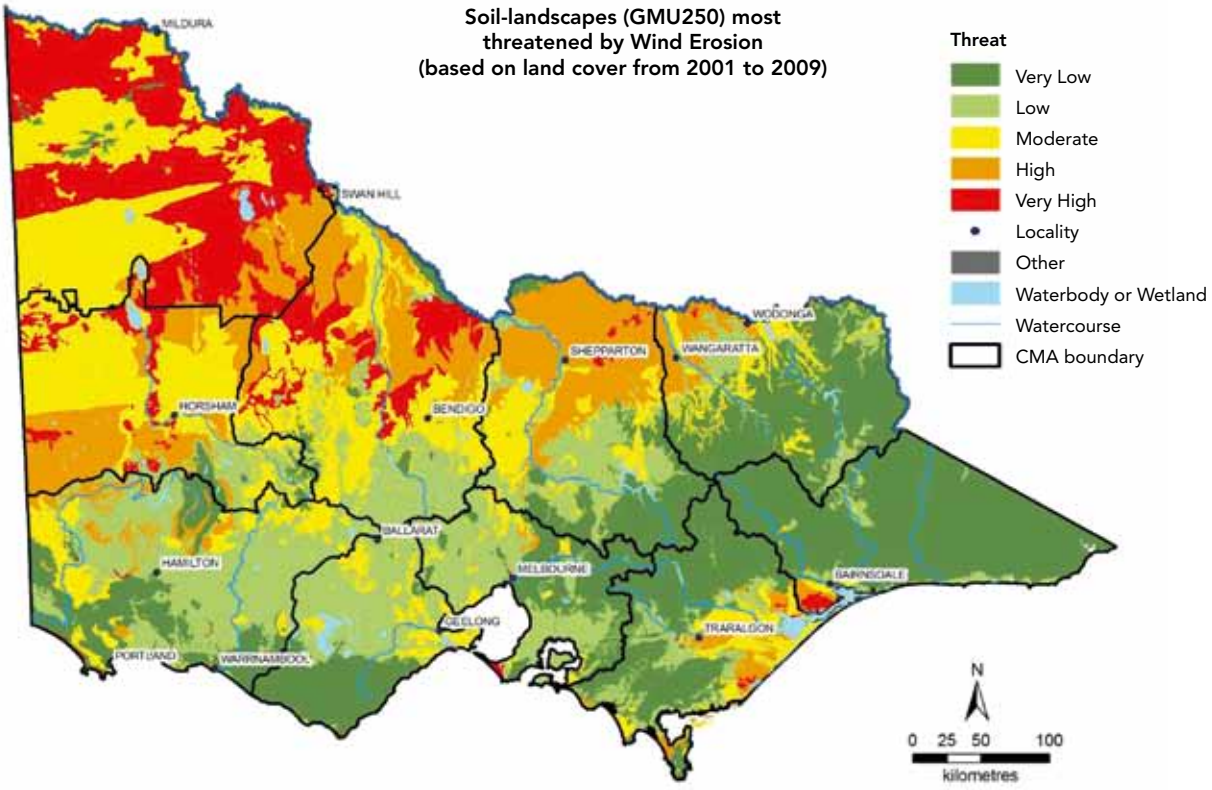


Figure 13: Cumulative threat of wind erosion in Victoria based on land cover history (2001-2009) and soil susceptibility.[102]

WATER EROSION

At a national scale, the Glenelg region of Victoria was identified in the 2001 Australian Agricultural Assessment as among the areas where deposition of sand and suspended sediments in rivers and streams was greatest due to a combination of high intensity rainfall events and significant vegetation clearance. Extensive sheet, tunnel, gully and stream bank erosion has led to large volumes of sand being trapped in the Glenelg River and its tributaries.[103] Sand and gravel deposits in streams arising from gully and stream bank erosion can occur to the extent that instream river health is significantly impacted.[104]

Large quantities of sand moved into the Glenelg River from tributaries in the 1930s and 40s following widespread vegetation clearance for agriculture. The majority of waterholes did not fill with sand until the extensive program of large wood removal occurred in the 1960s and 70s. Substantial remediation works have been undertaken over the past decade to address this threat, including the reinstatement of logs to 'plug' sand movement through a combination of immobilisation using logs and fencing to promote in-stream vegetation.

The percentage area of the catchment threatened by sheet and rill erosion, and gully and tunnel erosion has been estimated using land cover data for the 2001-2009 period (Figure 14 and 15). Around 27% of the catchment was considered to have a moderate to very high threat of sheet and rill erosion during this period, and around 16% for gully and tunnel erosion. Approximately 18% of the catchment has been estimated as having a high to very high inherent susceptibility to sheet and rill erosion using GMU250 mapping data, and around 12% for gully and tunnel erosion.[105]

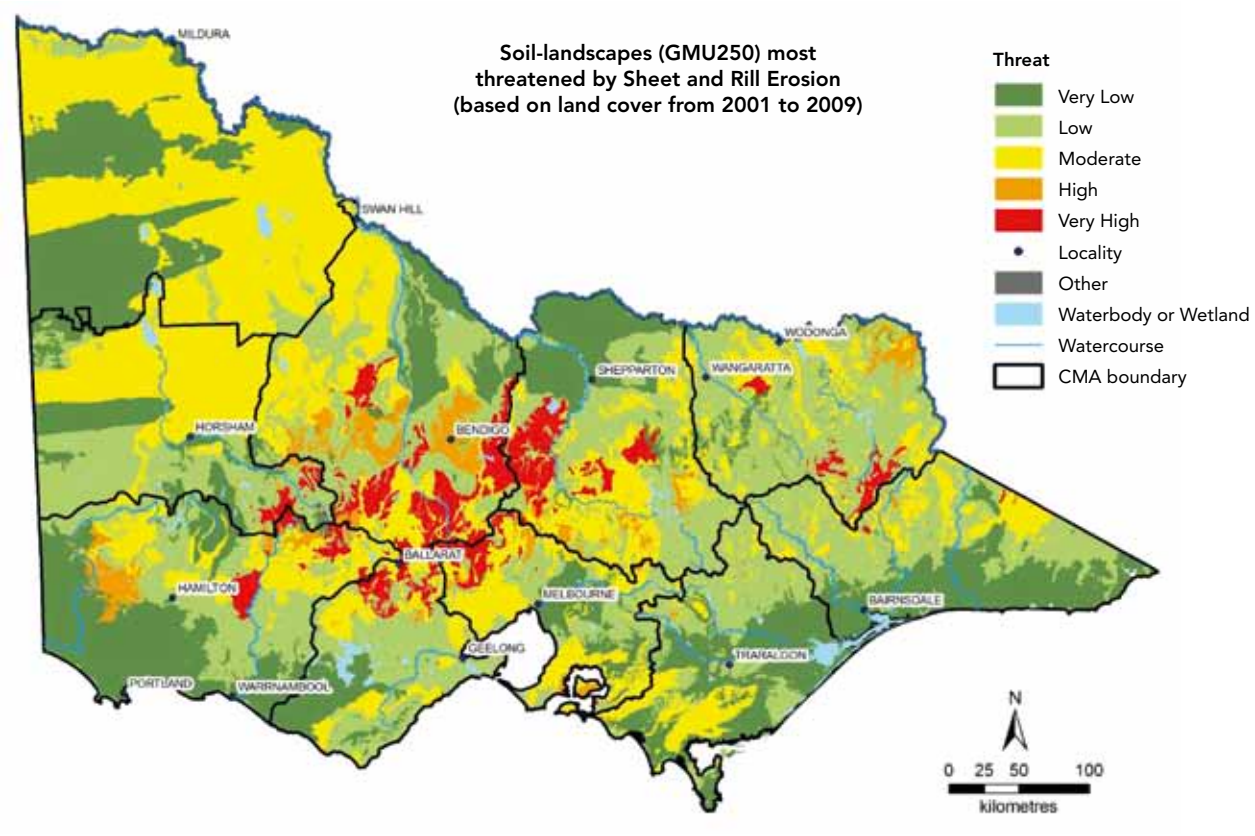


Figure 14: Cumulative threat of sheet and rill erosion in Victoria based on land cover history (2001-2009) and soil susceptibility.[106]

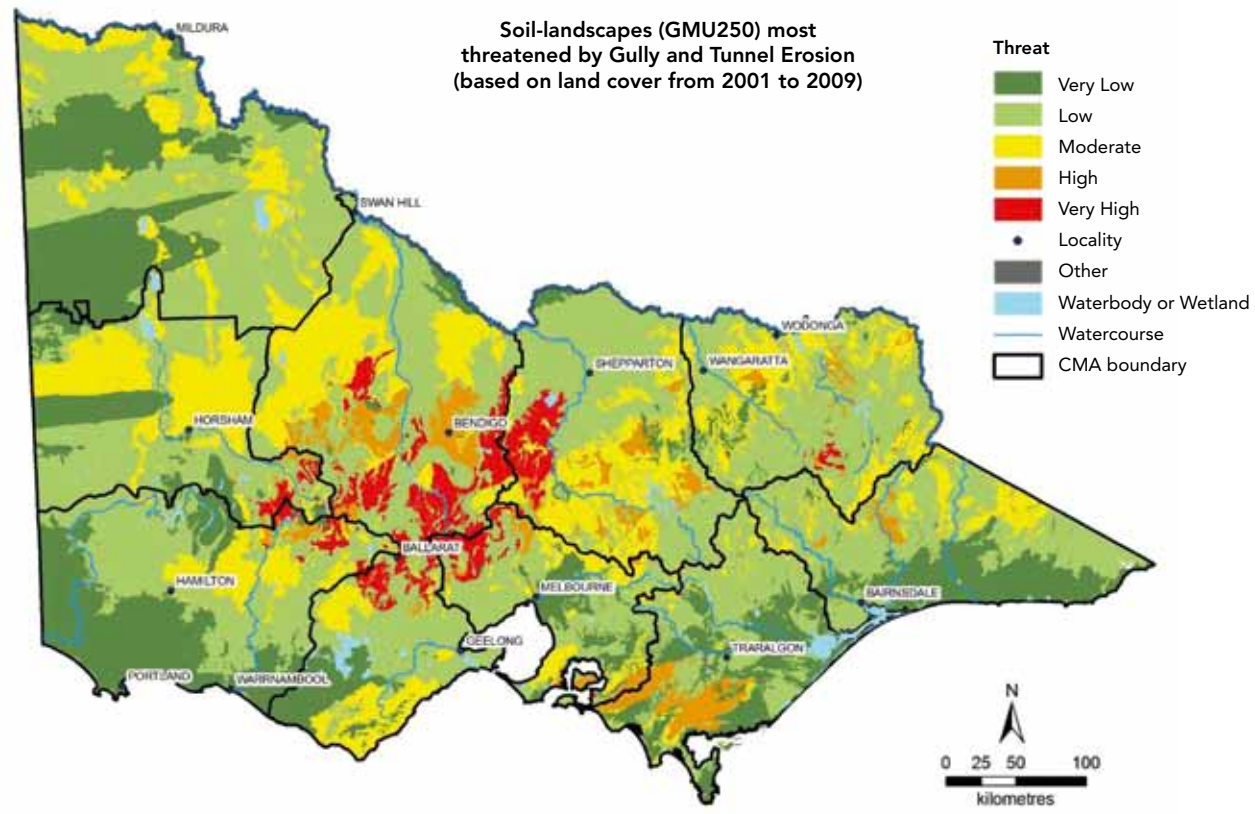


Figure 15: Cumulative threat of gully and tunnel erosion in Victoria based on land cover history (2001-2009) and soil susceptibility.[107]

Water erosion from storm surges also remains a key threat to regional coastal assets, such as sensitive dune environments and public/private infrastructure. For example, storm surges can alter the conditions on which vegetation types depend on and remove stretches of beach.[108] The recently released Victorian Coastal Strategy highlighted Dutton Way in Portland as an example of a coastal area that has been subject to long-term erosion. A 4.5km informal sea wall has been built to protect road and residential properties.[109] Other coastal assets in areas such as Port Fairy are also under threat from storm surges and water erosion.

The 2010 Index of Stream Condition found that the physical condition of Glenelg Hopkins region river reaches ranged from poor to excellent, with most variance in physical condition being identified in the Hopkins Basin. Reach 28 on Fiery Creek was the poorest reach recorded across the Glenelg Hopkins catchment, scoring poorly for bank stability and fish passage in particular. Reach 11 in the Hopkins Basin was also noted as having poor bank stability. Reach locations are shown in Figure 17. Bank condition assessments included an assessment "of the level of erosion/instability on the bank face and whether it is above what is expected for the type of stream".[110]

Above: Soil erosion results in loss of agricultural land, increased sediment and reduced water quality of waterways. Photo: Glenelg Hopkins CMA.

WATER QUALITY

Degradation of soil and subsequent movement of soil through erosive processes (wind and water) can cause soil to become a threat to riparian health and degrade water quality. Along with threats of turbidity and sedimentation, movement of soil can carry urban and agricultural chemicals (applied nutrients, animal wastes, pesticides and herbicides), salt (salinity) and other pollutants.[111]

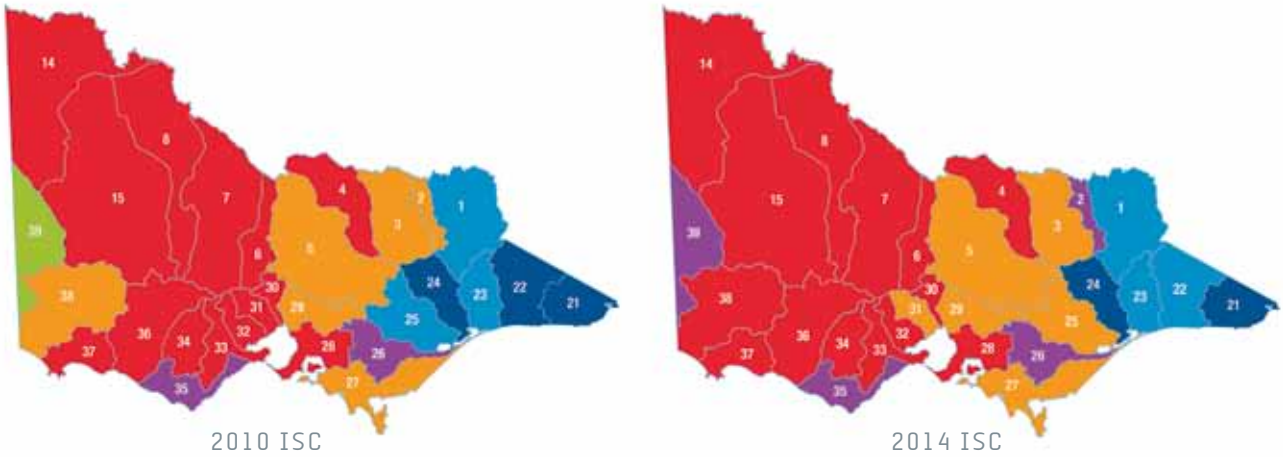
Soil erosion can result in a number of downstream impacts on river and streams, estuaries and marine environments. For example, water erosion can result in an increase in sediment to rivers, which can result in increased flooding, inhibit respiration and feeding for instream species and impact plant photosynthesis through reduced light. Higher risk areas of the catchment include parts of the Glenelg basin. Sand slugs in particular can impact aquatic habitats, through filling pools (and refuge areas) and blocking fish passages.

The results of the 2010 Index of Stream Condition (ISC) assessment are shown in Figure 16. The ISC aims to "assess the environmental condition of Victoria's major rivers and streams and to provide Statewide data for CMA regional waterway action planning and priority setting".[112] Five metrics (sub-indices) were used for the ISC3 assessment: hydrology, physical form, streamside zone, water quality and aquatic life. Figure 17 shows the results of all five sub-indices combined. At a basin level, the percentage of river length in good or excellent condition had improved for the Glenelg basin, between the 2004 and 2010 assessments.

The Water Quality component of the 2010 ISC3 assessment considered total phosphorus, turbidity, salinity and pH. 21 of the regions 122 reaches were assessed for water quality, with results ranging from poor to excellent.[113] Water quality was assessed in 14 reaches of the Glenelg Basin, with results ranging from poor to good. Reaches 2 and 28 were found to be in the best condition. Both were located in forested parts of the basin on the lower Glenelg River and the Upper Wannon River respectively. Reach 27 of the Glenelg Basin had the poorest result, and was found to have highly elevated phosphorus, salinity and turbidity levels. These results were attributed to impacts associated with the 2006 Grampians Bushfire. Poor results were also identified in reaches 33, 49 and 51.

Two reaches were tested for water quality in the Portland Basin. Reach 16 was found to have extremely high levels of phosphorus and salinity, while reach 3 had an excellent rating for all parameters. The difference in results was attributed to the majority of the Surrey River course occurring through forested land, compared to the Moyne River, which occurs predominantly through land cleared for agriculture.

Highly elevated results for phosphorus and salinity were identified in all five reaches within the Hopkins basin that were tested. The five reaches were found to be in poor condition and occurred in the lower area of the basin where land has been largely cleared.



Environmental Condition

- >70%
- 51-70%
- 31-50%
- 11-30%
- <10%
- Insufficient Data

Basin Names

1	Upper Murray	14	Mallee	27	South Gippsland	35	Otway
2	Kiewa	15	Wimmera	28	Bunyip	36	Hopkins
3	Ovens	21	East Gippsland	29	Yarra	37	Portland
4	Broken	22	Snowy	30	Maribyrnong	37	Glenelg
5	Goulburn	23	Tambo	31	Werribee	39	Millicent Coast
6	Campaspe	24	Mitchell	32	Moorabool		
7	Loddon	25	Thomson	33	Barwon		
8	Avoca	26	LaTrobe	34	Corangamite		

Figure 16: Percentage river length in good or excellent condition: 2010 ISC (left), 2004 ISC (right).

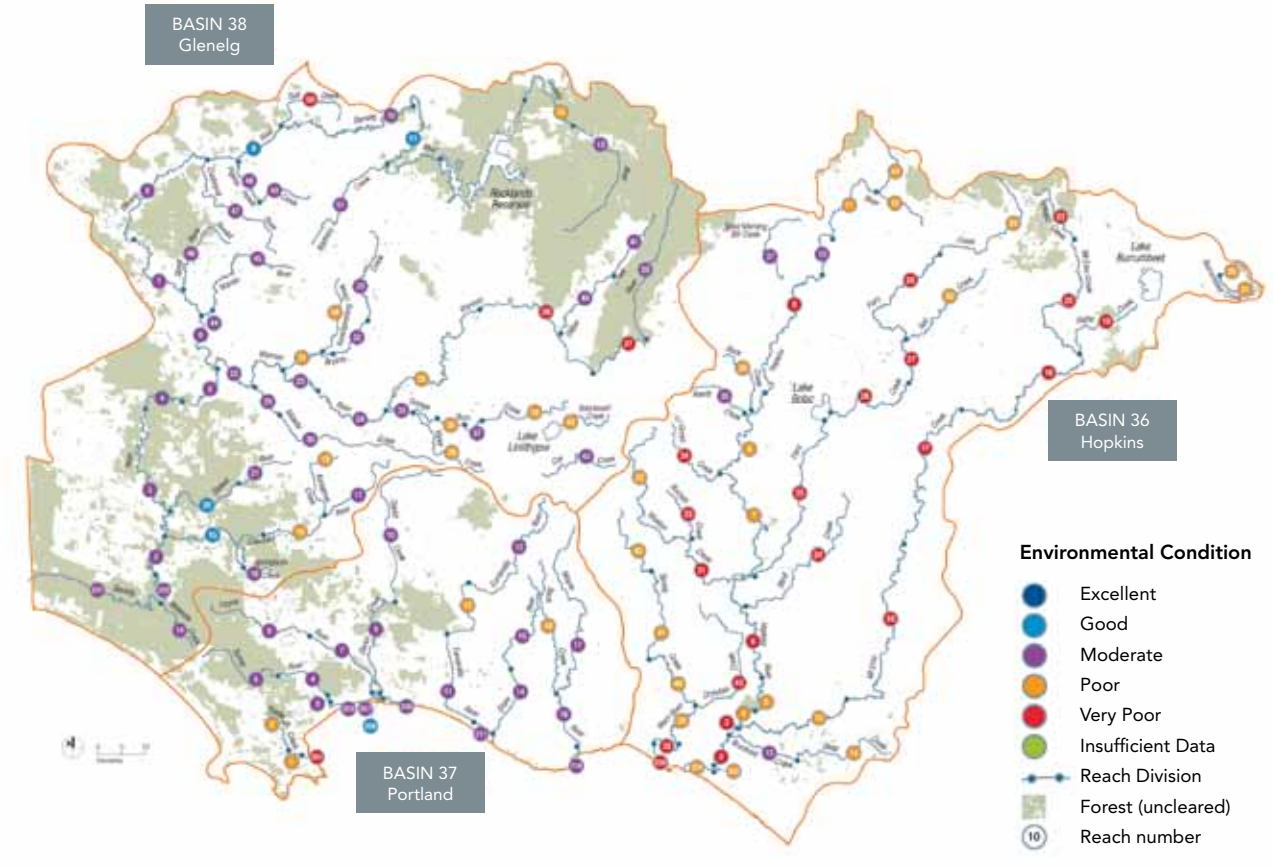
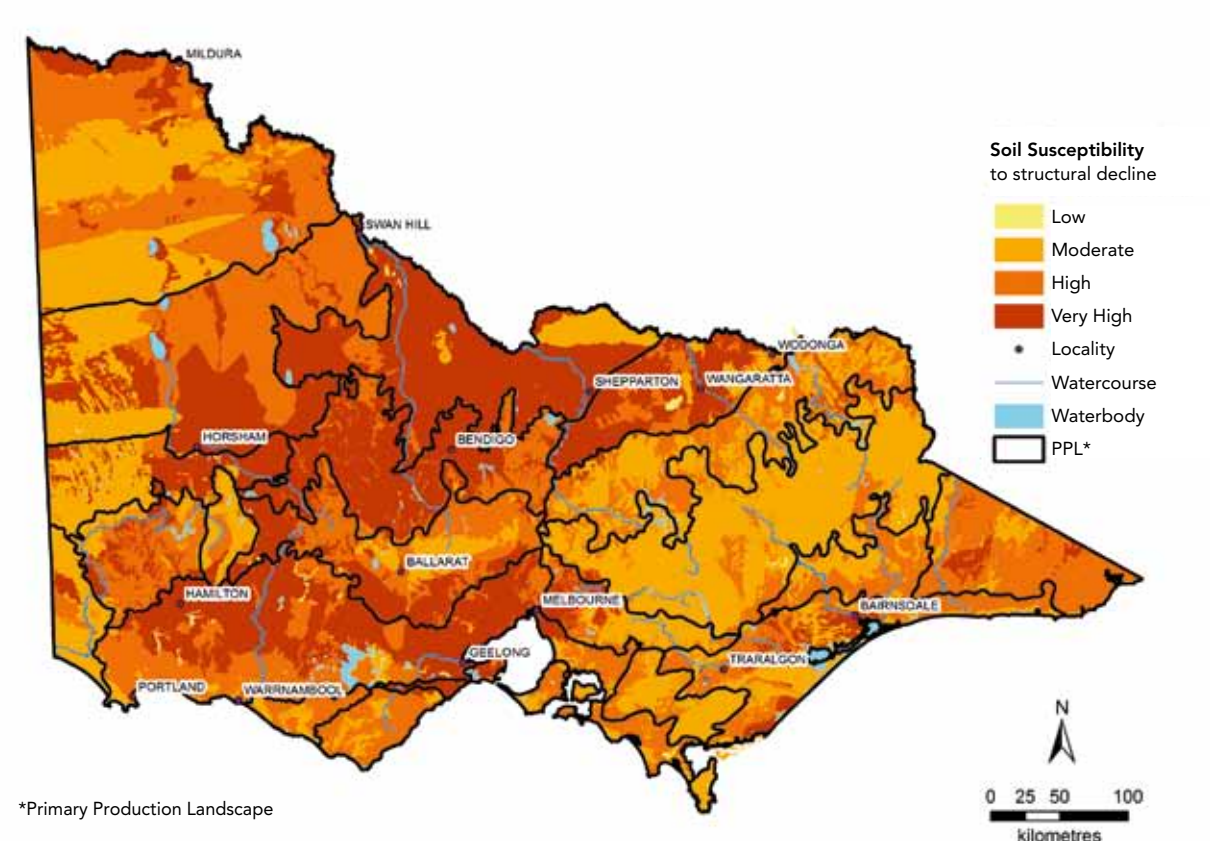


Figure 17: Environmental condition of rivers and streams, Glenelg Hopkins region, based on 2010 ISC3 Data.

DECLINE OF SOIL STRUCTURE

Soil structure controls the movement of water and air through the soil and therefore affects the supply of oxygen and the removal of carbon dioxide resulting from the respiration of roots and soil organisms. Soil structure decline is influenced by soil type and slope.[114] It can be accelerated by human activities such as trafficking by animals or vehicles and agricultural practices that reduce soil biological activity. This can damage soil structure and lead to compaction, decreased infiltration rates, increased runoff with attendant increased erosion as well as surface ponding and increased waterlogging. Surface crusts and compaction are the direct result of soil structure decline.[115] Much of the catchment has been modelled as having either high or very high susceptibility to soil structure decline (Figure 18).[116]



*Primary Production Landscape

Figure 18: Soil susceptibility to soil structure decline, independent of land management.
Source: State of Environment Report, Victoria 2008

LOSS OF SOIL ORGANIC CARBON

Soil organic carbon "is a measure of the organic content (e.g. plant roots, vegetation debris, soil organisms) held in the soil".[117] Soil organic carbon is a key indicator of soil health.[118] Higher amounts of soil organic matter (mostly organic carbon) generally indicate more healthy soils. Soil organic matter is a vital component of healthy soils and has many benefits including improved soil structure, water holding ability and drainage, maintaining soil organism diversity, enhanced soil nutrition, and prevention of erosion.[119]

Soil cultivation can result in loss of organic matter and carbon, although minimum tillage practices can help reduce this, through less soil disturbance.[120] Farming practices that encourage oxidation of carbon may reduce soil organic matter, such as burning.[121]

The 2013 Victorian State of the Environment report noted that "data on soil carbon levels is poor in Victoria, particularly for private land …".[122] In general, soil organic carbon levels will typically be higher in high rainfall areas that are under pasture, compared to cropping, but will vary with climate and agricultural system. Bushfires can impact on carbon stocks through reduction in soil organic matter, and soil organic carbon is "likely to be impacted by climate change with increased periods of drought and fire risk".[123]

MASS MOVEMENT

Around 4% (97,400ha) of the catchment was estimated in the 2001 Land Resource Assessment of the Glenelg Hopkins Region to have high susceptibility to mass movement (Figure 19). The Merino Tablelands and Eastern Dundas Tablelands are shown to be particularly prone to mass movement, as are the older terraces of the Wannon River.[124]

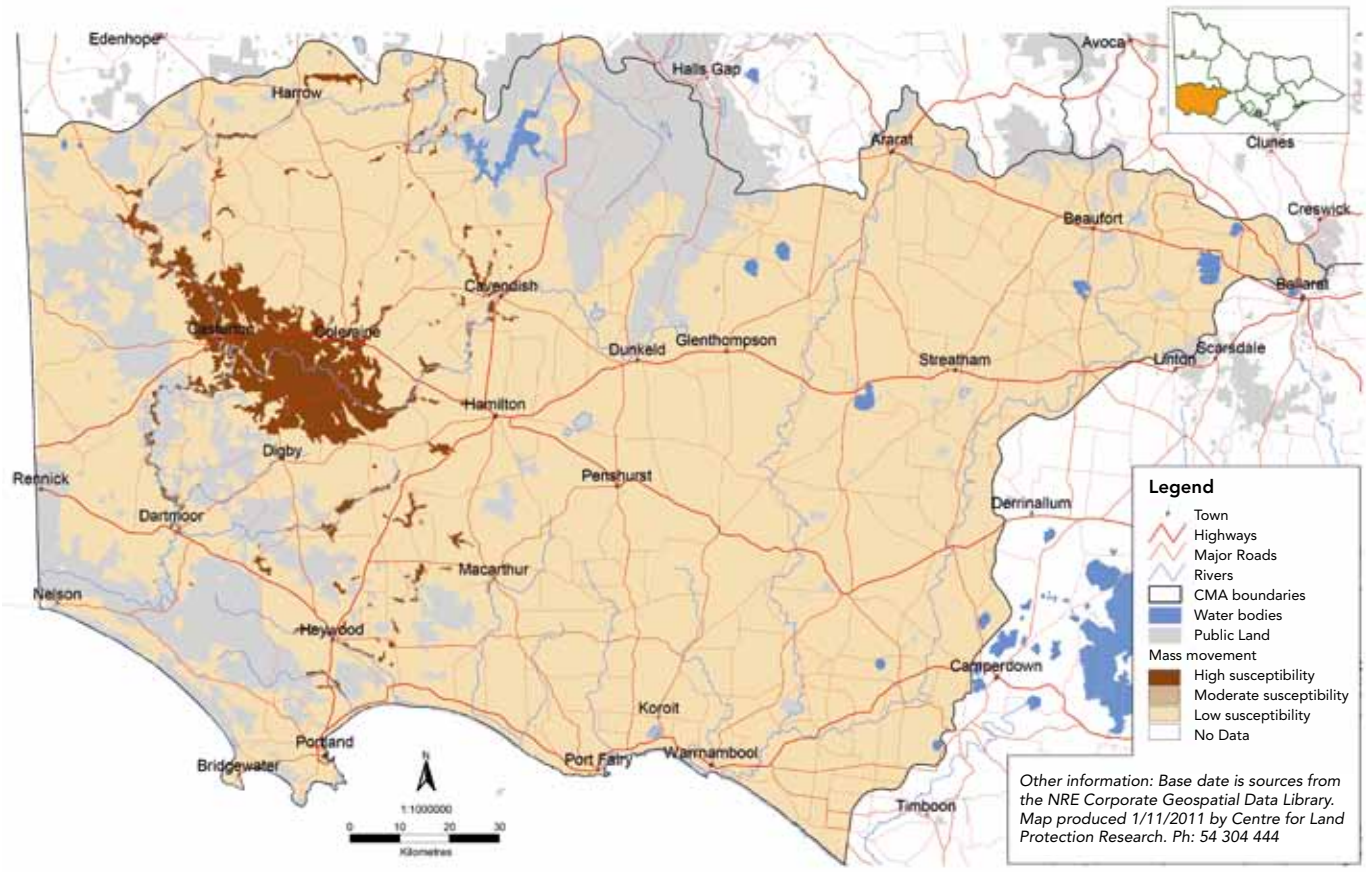


Figure 19: Inherent susceptibility to mass movement - Glenelg Hopkins region.

WATERLOGGING

The clay soils of the Victorian Volcanic Plains become impermeable when saturated from prolonged periods of rainfall. In areas where water cannot drain away, soils become waterlogged; and in areas that are naturally ephemeral wetlands, water will pool on the surface until a drainage point is reached.

When waterlogged, pores within the soil structure become filled with water preventing gas exchange between the atmosphere within soil pores and plant roots. Anaerobic conditions limits or prevents respiration by plants ultimately killing most pasture species. Nitrogen is also lost through denitrification and mobile minerals are leached through the soil profile.

Traffic by animals on saturated soils can cause pugging, which can result in an uneven soil surface and damage to pastures. Pugging also increases soil compaction and reduces soil structure and permeability, which can make an area more susceptible to waterlogging events.

Traditionally, waterlogging has been a high priority threat to soil health in the Glenelg Hopkins region. In recent decades, lower annual rainfall and longer periods between rainfall events has reduced the incidence of waterlogging at a catchment level.

LOSS OF SOIL BIODIVERSITY

Soil is important habitat in its own right, and underpins terrestrial ecosystems. It supports a diverse mixture of microbial, fungal, invertebrate and vertebrate life. A single gram of soil can support up to 10,000 different species of fungi, bacteria and soil animals.[125]

Soil organisms provide the following key functions:

- decomposition of organic matter and recycling and storage of the nutrients released during decomposition;
- stabilisation of soil-fungal filaments and exudates from microorganisms and earthworms bind soil particles into stable aggregates;
- reducing erosion and improving infiltration of water and air into soil;
- improving root growth and function by providing air and water-filled pores in soil;
- improving water quality by detoxifying and decomposing potential pollutants; and
- improving plant health by controlling pathogenic organisms and mineralising nutrients to make them more available for plants.[126]

There is currently no standard method for assessing soil biology quality, or programs in place for monitoring soil biological data within Victoria.[127] It is therefore not currently possible to assess the biological condition of regional soils.[128]

COASTAL ACID SULFATE SOILS

Acid sulfate soils are soils or sediments that contain (or once contained) high levels of reduced inorganic sulfur. When exposed to oxygen, the soils or sediments undergo a chemical reaction (called oxidation) that produces acid.

Disturbance of acid sulfate soils can result in fish deaths or other negative effects on waterways. The processes through which acid sulfate soils affect waterways are not all well understood and their location and level of risk is often uncertain. Acid sulfate soils occur predominantly in the coastal area but are also found inland for example, on the Dundas Tablelands (associated with permanently flowing springs) and in waterways affected by dryland salinity.

Management of coastal acid sulfate soils is guided by the Victorian Coastal Acid Sulfate Soil Strategy and the Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils. The Strategy maps potential acid sulphate soils and identifies locations where immediate action, protection or installation of detailed monitoring networks might be warranted.

APPENDIX 2 - CLIMATE CHANGE REGIONAL IMPACTS

CLIMATE CHANGE AND SOILS

Climate has a direct impact on soil health and has its most severe impacts in extremes of dryness leading to wind erosion and, in extremes of wetness leading to sheet, rill and gully erosion. Soil health is also linked to climate benefits on a global scale because soils can store carbon, leading to improved soil quality and reduced greenhouse impacts.[129] Carbon within the terrestrial biosphere can behave either as a source or sink for atmospheric CO_2 depending on land management, thus potentially mitigating or accelerating the greenhouse effect.[130]

In addition to an increase in hot days, climate models indicate a related increase in extreme events such as heat waves, droughts and wildfires.[131] The impact of heat-related extremes and wildfire can seriously impact on soils as well as water quality as dry, burnt soils are more prone to erosion. Severe wildfire removes organic matter resulting in soil structure deterioration and considerable nutrient loss. Associated with this loss is a significant reduction in the quantity and composition of microbes and invertebrates. These impacts may be ameliorated through the early restoration of vegetative cover.[132]

Soil carbon is expected to decrease under climate change due to decreased net primary production.[133] Any gains due to elevated CO_2 are likely to be outweighed by reduced annual and growing season rainfall. A shift in land suitability for farming may lead to increased and significant land use change.

Soil biology and microbial populations are expected to change under conditions of elevated CO_2 and changed moisture and temperature regimes. As soil biology regulates nutrient dynamics and many disease risks, nutrient availability to crops and pastures could change as could the exposure to soil-borne diseases.[134]

Soil erosion is likely to be exacerbated by increases in intense rainfall events where those rains fall on dry, denuded soils. In combination, drier soils, reduced vegetation cover and more intense rainfall will present significant challenges to soil conservation even with moderate climate change.[135]

Other climate change impacts such as heavy rains and winds from storm events will also contribute to crop damage and soil erosion. Indirect impacts due to changes in weeds, pests and international markets may also place farms under stress. Victorian farmers have developed many useful adaptation skills from managing current climate variability, but they will need to plan for new challenges and opportunities associated with climate change.

Changes in average temperatures and in precipitation patterns will influence soil organic matter. This in turn will affect important soil properties such as aggregate formation and stability, water holding capacity, cation exchange capacity, and soil nutrient content.[136]

The complexity of climate systems makes it difficult to determine exactly how soil organic matter will be influenced by predicted change.[137] However, it is possible that increasing temperatures could result in the enhanced decomposition of carbon turning soils from carbon sinks to carbon sources and releasing carbon dioxide into the atmosphere and accelerating climate change.[138,139]

The impact of climate change on the capacity of soils to sequester carbon in soil is not sufficiently understood. There is for potential climate change to increase the capacity of soils to sequester carbon from the atmosphere and hence mitigate climate change. The loss or gain of carbon in soil is strongly regulated by plant–microbial–soil interactions.[140] There remains a great deal of uncertainty about how soil organisms directly respond to warming. It is not clear whether increases in microbial activity and carbon cycling in response to warming will be sustained due to short-term depletion of fast-cycling soil carbon pools, or whether soil communities will adapt to a warmer world.[141]

Increasing the amount of carbon sequestered in soil has the potential to contribute greatly to the mitigation of, and adaptation to, climate change. This is possible through the management of arable and degraded soils to increase carbon sequestration and by increasing plant diversity. Increased diversity enhances community-level carbon dioxide uptake and below-ground allocation to roots and mycorrhizal fungi, which is a key mechanism governing carbon sequestration in soil.[142] Increasing the cover and diversity of species has multiple benefits and would contribute to the increased resilience of both the agricultural and ecological systems, allowing for adaptation.

IMPACT ON AGRICULTURE

Despite anticipated climatic changes, the impact of climate change on agriculture is expected to be less damaging to south west Victoria than other parts of the State.[143] Temperatures are expected to remain moderate while rainfall is anticipated to remain adequate in the medium term, particularly in the region's south.[144] It is likely that the area most suitable for grains production (mainly wheat and barley) will move southward. As such, the Glenelg Hopkins region may become more attractive to agricultural producers in northern Victoria, who may experience more negative production impacts due to climate change and wish to relocate.

Increasing atmospheric carbon dioxide (CO_2) concentrations are expected to have a slight positive effect on vegetation growth. This stimulates photosynthesis, improving the nutrient and water use efficiency of crops and other plants. However, the benefits of increased CO_2 atmospheric concentrations cannot be expected to match those achieved in experiments, as other climate change factors, such as higher temperatures and reduced water availability are likely to limit growth.

Above: Soil without ground cover is highly susceptible to erosion by both wind and water.
Photo: DEPI.

One of the most significant factors expected to influence production in south west Victoria is the increased frequency of hot days. An increased frequency of hot (>35°C) days can result in poor fertilisation if occurring around flowering time. Further, if prolonged periods of high temperature occur, crops will develop and mature more quickly. This reduces the time available for the plant to utilise scarce water resources, resulting in lower growth and yield.[145]

Changing seasonal patterns are also expected to impact agricultural production. Warmer temperatures predicted earlier in the season may improve crop growth rates in winter and early spring, but would probably be followed by a progressive shortening of favourable conditions later in spring due to hotter temperatures and reduced rainfall.[146] Warmer temperatures during the season would accelerate plant growth stages, restricting the time available for the plant to accumulate radiation and nutrients. This would negatively affect yield and quality and cause earlier maturity and harvesting of fruits, silage and other crops.[147]

To maximise the length of the growing season south west Victoria farmers are likely to sow crops earlier and apply more nitrogen at sowing. Whilst this is an effective productivity response, it could act against greenhouse gas mitigation.

Nitrogen fertiliser production is energy intensive and if nitrogen is applied on wet winter soils, significantly higher emissions of nitrous oxide (NO_2) would be produced.[148] Increases in the volume of nitrogen applied may also result in increases in the volume of nitrogen discharged into water sources.[149] Another factor for agriculture is increasingly variable weather. This could cause farmers to be more responsive to short-term weather forecasts and may lead to production becoming more opportunistic.

Farm level adaptations to gradual climate change could occur incrementally and on an as-needs basis. Initial on-farm adaptations could involve refinement of current farm system management and best management practices to match the changing climate. In the medium term, as the climate becomes drier and warmer, additional tactical farm system changes may be required such as conversion from annual to deep rooted perennial species. In the longer term, there may be a requirement for more radical, strategic decisions such as a change in enterprise.

APPENDIX 3 - LAND MANAGEMENT PRACTICE TRENDS

Regional land management practice trends in Victoria have been described in a series of 2013 Australian Government reports for different agricultural industries, using data from the 2007-08 and 2009-10 ARMS.[150,151,152] Key results from these reports are summarised below for cropping, grazing and dairying, including comparisons with Victorian NRM regions where applicable.

CROPPING

There are a range of strategies available to farmers to help better manage ground cover including: increasing crop residue retention and reducing tillage, testing and liming soils, and building soil carbon. Retaining crop residue can assist in improving soil organic matter and help protecting against soil loss through wind and water erosion.[153]

The percentage of businesses leaving crop residues intact, rather than modifying through ploughing or mulching or removing (e.g. burning) in Victoria increased marginally from 23% to 24 % between 2007-08 and 2009-10, and 16% to 19% in the Glenelg Hopkins region (Figure 20).

One-pass sowing systems can help reduce the risk of soil loss from wind and water erosion.[154] The proportion of broadacre cropping businesses using no cultivation apart from sowing during the preparation of cropping land increased from 39% to 54% in Victoria between 2007-08 and 2009-10, with the greatest increase occurring in the Glenelg Hopkins region (35% to 57%) (Figure 21).

It has been estimated that approximately 85% of cropping land within the Glenelg Hopkins region is at moderate to high risk of soil acidification. Highly acidic soils are "unlikely to support good ground cover, increasing the risk of soil loss through wind and/or water erosion and reducing input to soil carbon."[155] Areas at high risk are where agricultural practices are highly acidifying (past or present), soil pH is low and the inherent capacity of the soil to buffer against pH decreases is low. Methods for managing surface soil pH include application of lime and/ or dolomite to land holdings, and testing of soil pH. Matching of fertiliser applications to crop requirements through soil nutrient testing can also assist in slowing soil acidification.

The percentage of broadacre cropping businesses in the Glenelg Hopkins region undertaking pH and nutrient testing was consistent between 2007-08 and 2009-10; with 35% of business undertaking pH testing during the two sample periods, and a small increase from 35% to 36% for nutrient testing. The percentage of businesses using lime and/or dolomite to manage soil acidity on their holdings was also consistent.

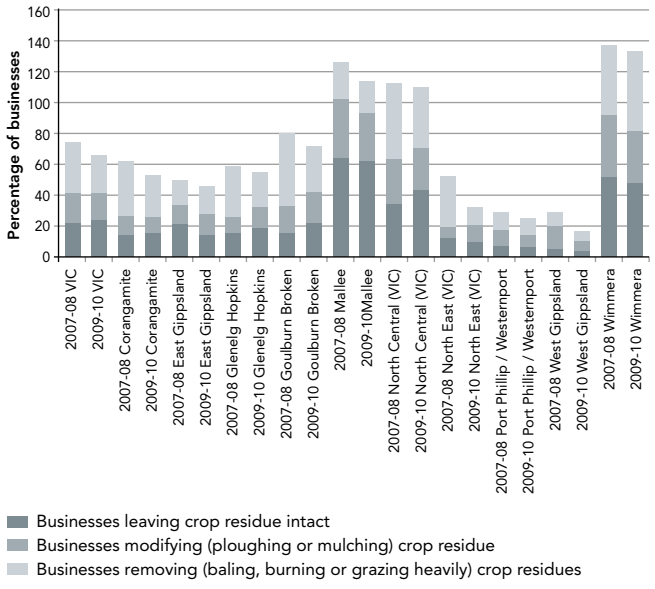


Figure 20: Percent of broadacre cropping businesses in Victorian NRM regions using different crop residue management practices, 2007-08 to 2009-10.††

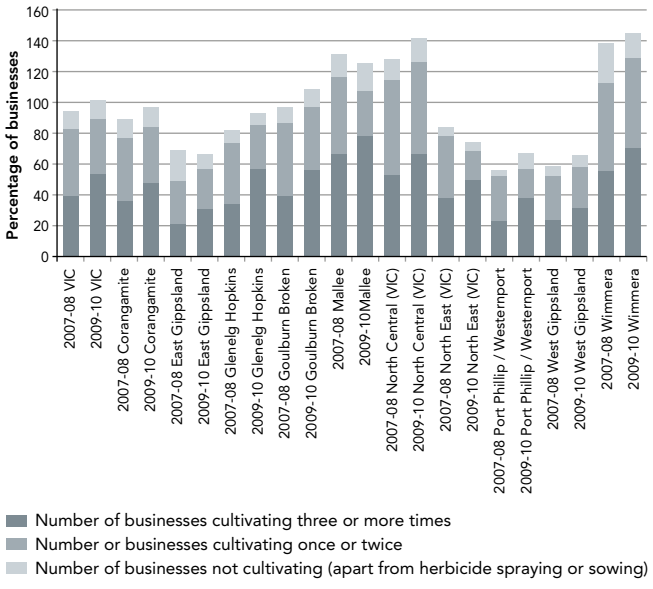


Figure 21: Percent of businesses in Victorian NRM regions using different cultivation intensities to prepare land for broadacre crops, 2007-08 to 2009-10.Δ

††The percentage of farmers reporting using particular practices can exceed 100 where more than one method (such as crop residue retained in some areas, burnt in others) is used on a holding.

ΔThe 2007-08 numbers include businesses preparing land for pasture.

DAIRY

The proportion of dairy businesses undertaking soil pH testing and soil nutrient testing in the Glenelg Hopkins region increased slightly from 57% to 62% and 56% to 59%, respectively, from 2007-08 to 2009-10, but was relatively high, when compared at a Statewide level (Figure 22). The percentage of dairy business applying lime or dolomite to manage soil acidity in the Glenelg Hopkins region in 2007-08 and 2009-10 was also steady, decreasing slightly from 38% to 36%.

Ground cover level monitoring in paddocks and the establishment of ground cover targets to manage grazing levels can help reduce the risk of soil loss through erosion (wind and water). Good ground cover levels can also help ensure pastures respond quickly to rain. The estimated percentage of dairy farmers monitoring ground cover was very high in the Glenelg Hopkins region, increasing from 69% to 96% during the two reporting periods (Figure 23). However, the proportion of dairy businesses in the Glenelg Hopkins region setting ground cover targets dropped from around 41% to 17%.[§§]

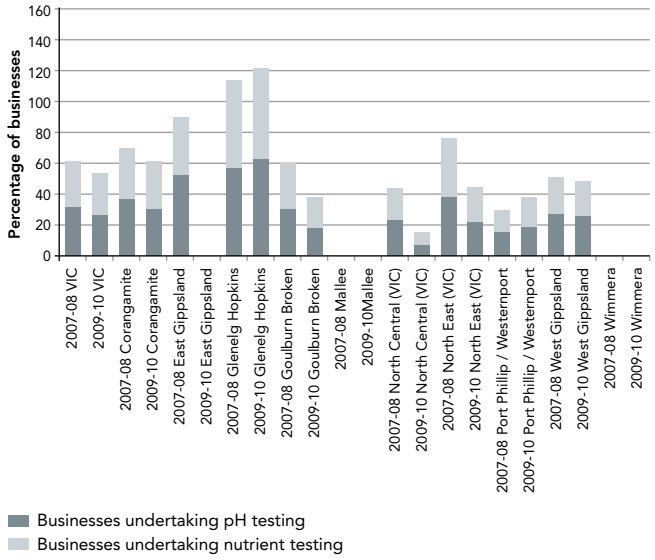


*Figure 22: Percent of dairy businesses in Victoria undertaking pH and soil nutrient testing, 2007-08 and 2009-10.****

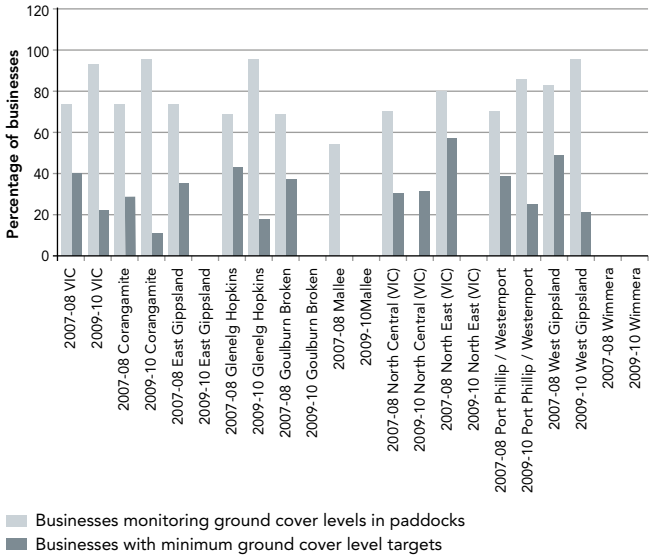


Figure 23: Percent dairy businesses in Victoria monitoring ground cover in paddocks and with targets for minimum ground cover levels, 2007-08 and 2009-10.†††

[§§]The reduced percentage of businesses reporting setting ground cover targets may have been due to changes in the 2009-10 survey question; respondents may have had difficulty providing the additional information sought.

***Note: Results for pH and soil nutrient testing were not publishable for the Mallee, the Wimmera or East Gippsland regions in 2009-10.

†††Note: Results for dairy businesses monitoring ground cover in paddocks were not publishable for the East Gippsland (2009-10), Goulburn-Broken (2009-10), Mallee (2009-10), North Central (2009-10), North East (2009-10) and Wimmera (2007-08 and 2009-10) regions. Results for dairy businesses with targets for minimum ground cover level were not publishable for the East Gippsland (2009-10), Goulburn-Broken (2009-10) and North East (2009-10) regions.

GRAZING

Approximately 49% of grazing land within the Glenelg Hopkins region has been estimated to be at high risk of soil acidification and 25% a moderate risk. The proportion of beef cattle/sheep businesses testing soil pH and soil nutrient levels was 25% and 51% respectively, during both survey periods (Figure 24); while the percentage of grazing businesses applying lime and/or dolomite to manage soil acidity on their holdings increased marginally from 26% to 29%.

The percentage of beef cattle and sheep businesses in the Glenelg Hopkins region monitoring ground cover levels increased significantly between 2007-08 and 2009-10, from 61% to 87% – consistent with the statewide trend (65% to 84%. However, the proportion of regional grazing businesses setting ground cover targets (the desired percentage of soil covered by living or dead vegetation) decreased during this period, from 34% to 21% (Figure 25).

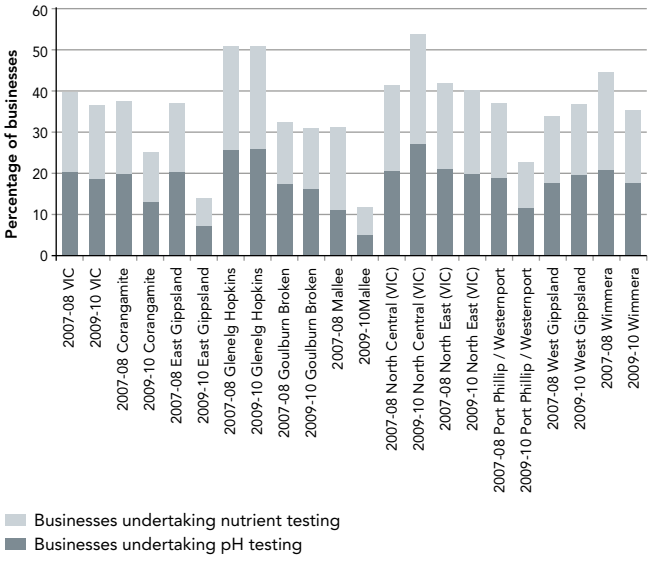


Figure 24: Percent of beef cattle/sheep businesses in Victoria undertaking pH and soil nutrient testing, 2007-08 and 2009-10.

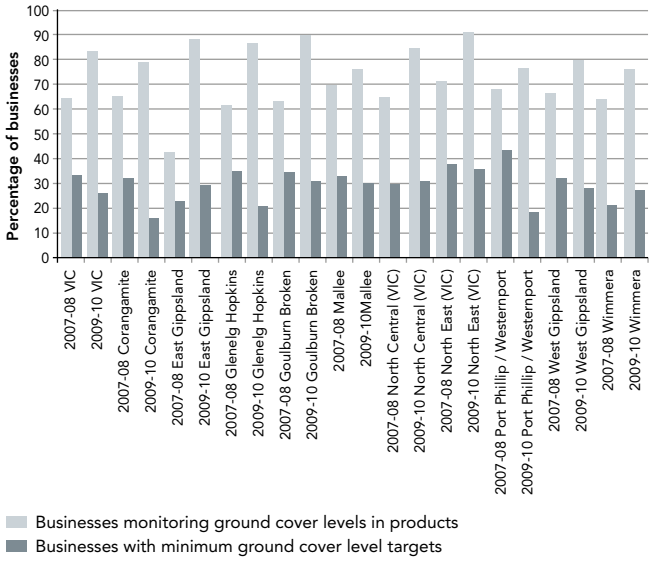


Figure 25: Percent of beef cattle/sheep businesses in Victoria monitoring ground cover and with targets for minimum ground cover levels, 2007-08 and 2009-10.

Below: A balance of nature and productive farming in a red gum landscape. Photo: Southern Grampians Shire.

APPENDIX 4

IDENTIFICATION OF AREAS WHERE IMPROVING MANAGEMENT PRACTICES WILL MOST BENEFIT SOIL CONDITION, NATIONAL SCALE

Maps have been prepared at a national scale by researchers and stage agency experts to show indicative areas where improved land management practices are likely to have the biggest impact in reducing wind and water erosion and soil acidification risk, and increasing soil organic matter (and in turn, soil carbon) (Figures 26-29). This work was undertaken as part of Caring for Our Country Phase 1. Further background information on this process is available on the Australian Government Department of Agriculture website (including high resolution maps).[156]

The national maps indicate that the potential benefits of increased adoption of improved management practices that reduce the risk of soil acidification and soil organic matter in the Glenelg Hopkins region are high when considered within a national NRM region context; particularly for soil acidification, where the Glenelg Hopkins region is one of the NRM regions that is likely to benefit most. It is important to note that there will be some high priority areas within NRM regions for intervention, particularly when considered at a finer spatial scale (e.g. erosion).

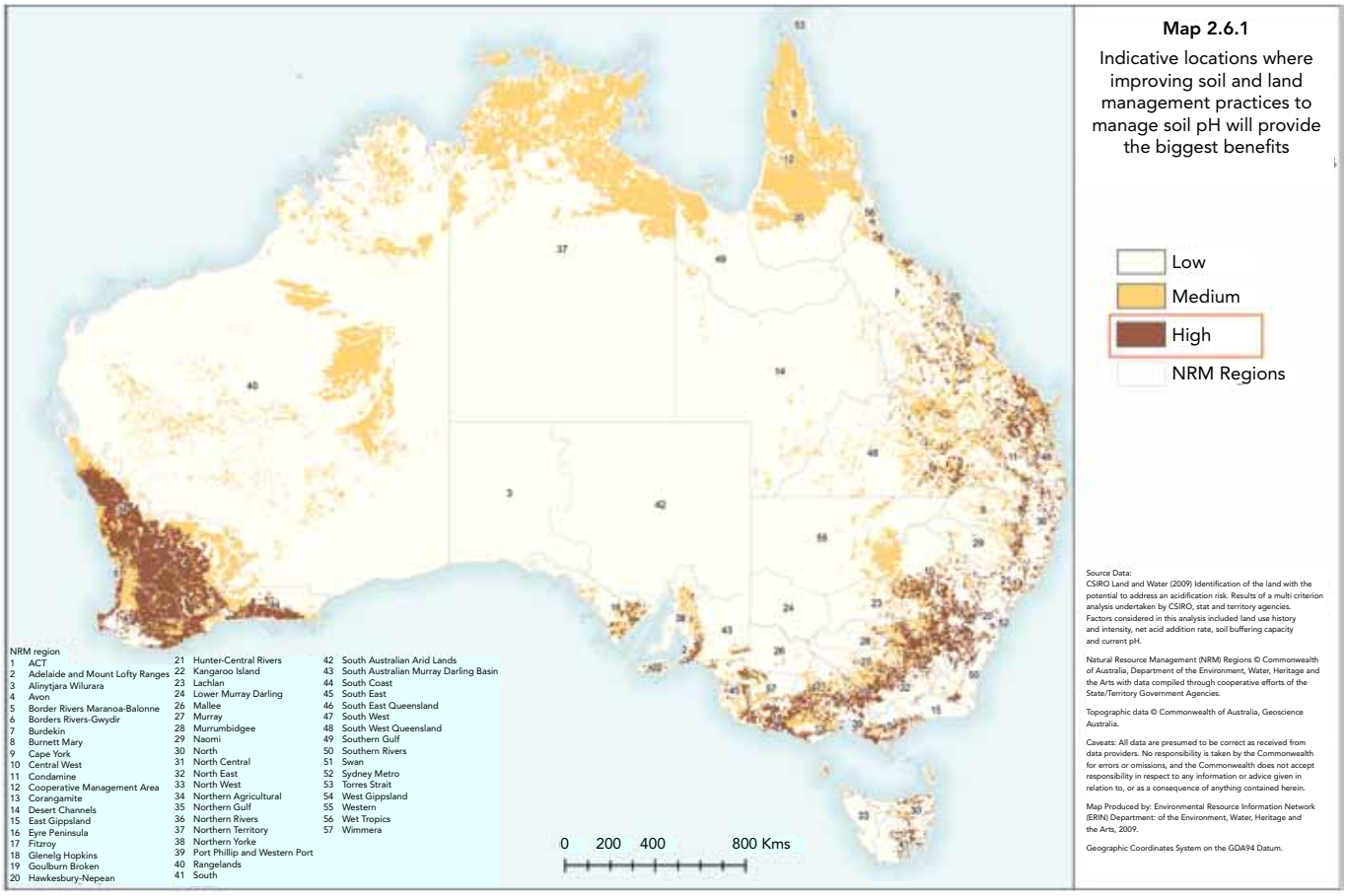


Figure 26: Indicative locations where improving soil and land management practices to manage soil pH will provide the biggest benefits.

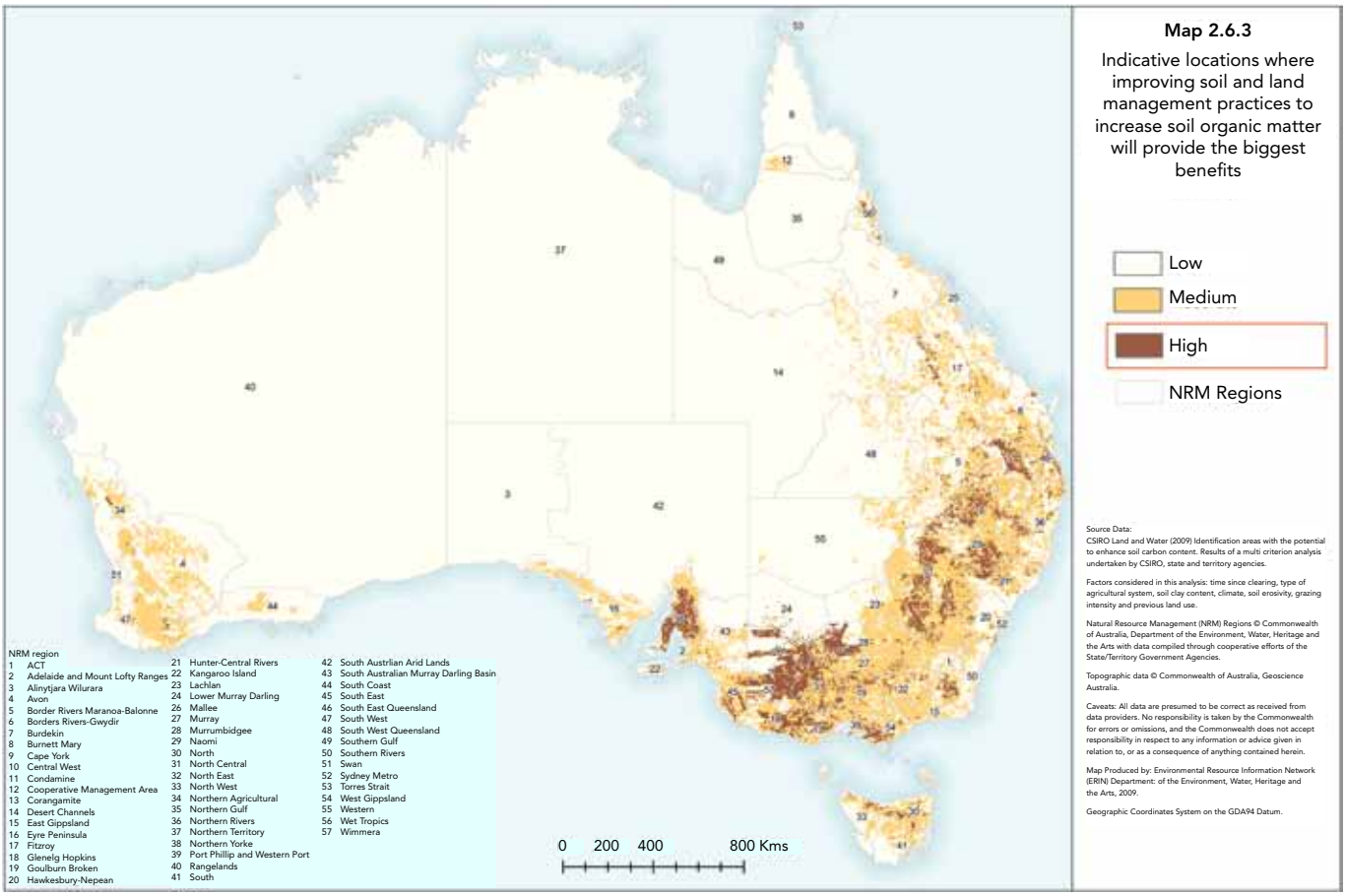


Figure 27: Indicative locations where improving soil and land management practices to increase soil organic matter will provide the biggest benefits.

Below: Whole farm planning enables progressive change towards a landscape that is productive, biodiverse and a scenic place to work.

Photo: Glenelg Hopkins CMA.

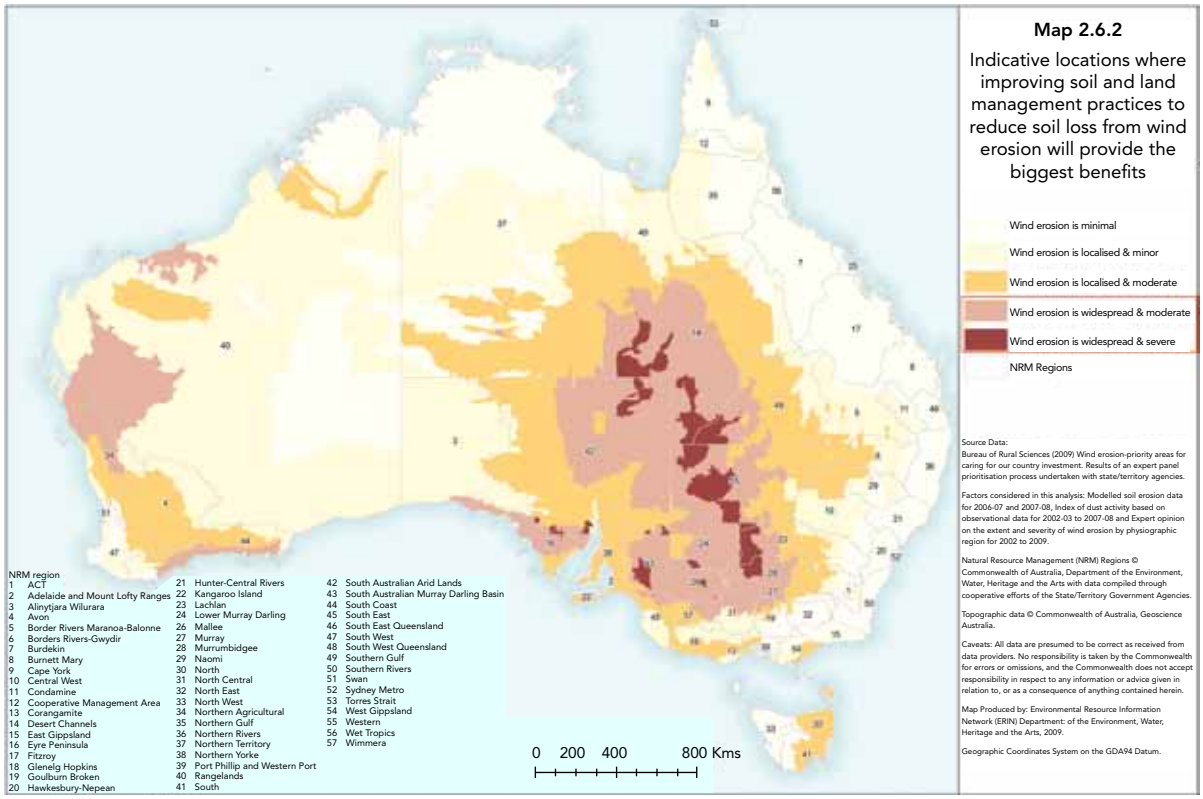


Figure 28: Indicative locations where improving soil and land management practices to reduce soil loss from wind erosion will provide the biggest benefits.

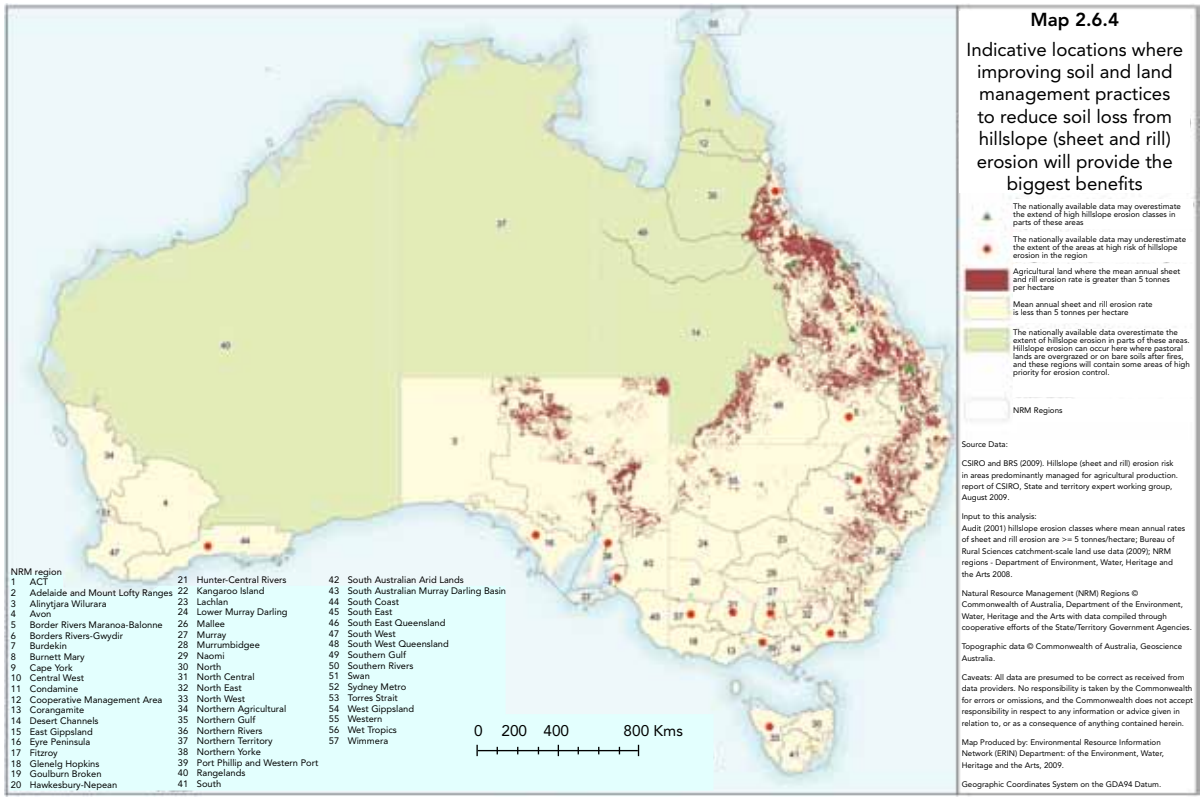


Figure 29: Indicative locations where improving soil and land management practices to reduce soil loss from hillslope (sheet and rill) erosion will provide the biggest benefits.

REFERENCES

1 Victorian Government, Statement of Obligations, *Catchment and Land Protection Act 1994*, Victorian Government, Melbourne, 1994.

2 Department of Sustainability and Environment, Soil Health Strategy - Protecting soil health for environmental values on public and private land, Victorian Government, Melbourne, 2012.

3 RJ MacEwan, Soil Health for Victoria's Agriculture - Context, Terminology and Concepts, Department of Primary Industries, Bendigo, 2007.

4 Department of Sustainability and Environment, Soil Health Strategy - Protecting soil health for environmental values on public and private land, Victorian Government, Melbourne, 2012.

5 Department of Sustainability and Environment, Soil Health Strategy - Protecting soil health for environmental values on public and private land, Victorian Government, Melbourne, 2012.

6 M Crawford and J Fisher, Policy and science of soil change – A Victorian perspective. Paper. In: Soil Change Matters International Workshop 24-27 March 2014, Bendigo, Australia.

7 M Crawford and J Fisher, Policy and science of soil change – A Victorian perspective. Paper. In: Soil Change Matters International Workshop 24-27 March 2014, Bendigo, Australia.

8 Department of Sustainability and Environment, Soil Health Strategy - Protecting soil health for environmental values on public and private land, Victorian Government, Melbourne, 2012.

9 M Crawford and J Fisher, Policy and science of soil change – A Victorian perspective. Paper. In: Soil Change Matters International Workshop 24-27 March 2014, Bendigo, Australia.

10 Department of Sustainability and Environment, Victorian Dryland Salinity Update January 2013, Victorian Government, Melbourne, 2013.

11 Department of Agriculture, Ecosystem Services, viewed 18 June 2014, http://www.daff.gov.au/natural-resources/ecosystem-services.

12 UK Department for Environment, Food and Rural Affairs. Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services, viewed 18 June 2014, https://www.gov.uk/ecosystems-services.

13 Department of Agriculture, Ecosystem Services, viewed 18 June 2014, http://www.daff.gov.au/natural-resources/ecosystem-services.

14 UK Department for Environment, Food and Rural Affairs. Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services, viewed 18 June 2014, https://www.gov.uk/ecosystems-services.

15 UK Department for Environment, Food and Rural Affairs. Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services, viewed 18 June 2014, https://www.gov.uk/ecosystems-services.

16 Department of Agriculture, Land management affects soil condition, viewed 3 April 2014, www.daff.gov.au/natural-resources/soils/improving-land-management-practices.

17 UK Department for Environment, Food and Rural Affairs. Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services, viewed 18 June 2014, https://www.gov.uk/ecosystems-services.

18 S Cork, L Eadie, P Mele, R Price and D Yule. The relationship between land management practices and soil condition and the quality of ecosystem services delivered from agriculture land in Australia, Kiri-ganai research, Canberra, 2012.

19 Department of Sustainability and Environment, Soil Health Strategy - Protecting soil health for environmental values on public and private land, Victorian Government, Melbourne, 2012.

20 Department of Sustainability and Environment, Soil Health Strategy - Protecting soil health for environmental values on public and private land, Victorian Government, Melbourne, 2012.

21 Glenelg Regional Catchment and Land Protection Board, Glenelg Regional Catchment Strategy, Glenelg Regional Catchment and Land Protection Board, Hamilton, 1997.

22 Department of Environment and Primary Industries, Victorian Resources Online, viewed 3 April 2014; <http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/landform_geomorphology>.

23 Commissioner for Environmental Sustainability Victoria, State of Environment Victoria 2008 – Part 4; Commissioner for Environmental Sustainability Victoria, Melbourne, 2008.

24 Water and Land use Change Study Steering Committee and Sinclair Knight Merz, Water and land use change study, Water and Land use Change Study Steering Committee and Sinclair Knight Merz, Hamilton, 2005.

25 Commissioner for Environmental Sustainability Victoria, State of Environment Victoria 2008 – Part 4; Commissioner for Environmental Sustainability Victoria, Melbourne, 2008.

26 New Forests, Rationalizing Timberland Managed Investment Schemes - The Changing Landscape of Australia's Forestry Investment Sector, New Forests Asset Management Pty Ltd, Sydney, 2013.

27 NM Baxter and NJ Robinson, Land Resource Assessment in the Glenelg Hopkins Region, Department of Natural Resources, Bendigo, 2001.

28 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

29 Australian Bureau of Statistics, 75030DO003_201112 Value of Agricultural Commodities Produced, Australia, 2011-12

30 Australian Bureau of Statistics, 75030DO003_201112 Value of Agricultural Commodities Produced, Australia, 2011-12

31 Australian Bureau of Statistics, 75030DO003_201112 Value of Agricultural Commodities Produced, Australia, 2011-12

32 Cattle numbers – as at June 2011 Natural Resource Management Region, Meat & Livestock Australia, 2012.

33 Sheep numbers – as at June 2011 Natural Resource Management Region, Meat & Livestock Australia, 2012.

34 Intergovernmental Panel on Climate Change, Climate Change 2013: The Physical Science Basis – Summary for policy makers, Intergovernmental Panel on Climate Change, Switzerland, 2013.

35 Intergovernmental Panel on Climate Change, Climate Change 2013: The Physical Science Basis – Summary for policy makers, Intergovernmental Panel on Climate Change, Switzerland, 2013.

36 Intergovernmental Panel on Climate Change, Climate Change 2013: The Physical Science Basis – Summary for policy makers, Intergovernmental Panel on Climate Change, Switzerland, 2013.

37 Department of Sustainability and Environment, Climate Change in the Glenelg Hopkins Region, Victorian Government, Melbourne, 2008.

38 CSIRO, Interim Climate Projection Statement – Southern Slopes cluster, CSIRO, 2013.

39 Department of Sustainability and Environment, Climate Change in the Glenelg Hopkins Region, Victorian Government, Melbourne, 2008.

40 Department of Sustainability and Environment, Climate change impacts on land use: Victorian Climate Change Adaptation Program Technical Report, Department of Sustainability and Environment, 2010.

41 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

42 J Nuttall, R Armstrong, M Crawford, Climate Change – identifying the impacts on soil health in Victoria, Department of Primary Industries, 2007.

43 French National Institute for Demographic studies, Population & Societies: The population of the World 2013, Monthly bulletin of the French National Institute for Demographic Studies No. 503, September 2013.

44 Department of Agriculture, Fisheries and Forestry, National Food Plan – Our food future, Australian Government, Canberra, 2013.

45 Department of Agriculture, Forestry and Fisheries, National Food Plan Green Paper 2012, Australian Government, Canberra, 2012.

46 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

47 NJ McKenzie and J Dixon, Monitoring soil condition across Australia - Recommendations from the Expert Panels, National Committee on Soil and Terrain for the National Land and Water Resources Audit, Canberra, 2006

48 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

49 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

50 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

51 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

52 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

53 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

54 NM Baxter and NJ Robinson, Land Resource Assessment in the Glenelg Hopkins Region, Department of Natural Resources, Bendigo, Victoria, 2001.

55 Water and land use change study. Land use and hydrologic change in south-west Victoria. Final Technical Report. Sinclair Knight Merz, 2005

56 Commissioner for Environmental Sustainability Victoria, State of Environment Victoria 2008 – Part 4; Commissioner for Environmental Sustainability Victoria, Melbourne, 2008.

57 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

58 TQA Research, Communication Research, Wave 2, TQA Research, Sandringham 2001.

59 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

60 Commissioner for Environmental Sustainability Victoria, Foundation Paper Two - Land and Biodiversity Victoria: the science, our private landholders, incentive and connectivity, Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

61 Commissioner for Environmental Sustainability Victoria, Foundation Paper Two - Land and Biodiversity Victoria: the science, our private landholders, incentive and connectivity, Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

62 NM Baxter and NJ Robinson, Land Resource Assessment in the Glenelg Hopkins Region, Department of Natural Resources, Bendigo, 2001.

63 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

64 Glenelg Hopkins CMA, Glenelg Hopkins Native Vegetation Plan, Glenelg Hopkins CMA, Hamilton, 2007.

65 van de Graaff & Associates Pty Ltd, Glenelg Hopkins Catchment Regional Soil Health Action Plan, 2006, Glenelg Hopkins CMA, Hamilton, 2006.

66 van de Graaff & Associates Pty Ltd, Glenelg Hopkins Catchment Regional Soil Health Action Plan, 2006, Glenelg Hopkins CMA, Hamilton, 2006.

67 van de Graaff & Associates Pty Ltd, Glenelg Hopkins Catchment Regional Soil Health Action Plan, 2006, Glenelg Hopkins CMA, Hamilton, 2006.

68 van de Graaff & Associates Pty Ltd, Glenelg Hopkins Catchment Regional Soil Health Action Plan, 2006, Glenelg Hopkins CMA, Hamilton, 2006.

69 Department of Environment and Primary Industries, Index of Stream Condition: The Third Benchmark of Victorian River Condition, Victorian Government, Melbourne, 2013.

70 Corinne Celestina, Southern Farming Systems, personal communication

71 Department of Agriculture, Land management affects soil condition, viewed 3 April 2014, www.daff.gov.au/natural-resources/soils/improving-land-management-practices.

72 Department of Agriculture, Land management affects soil condition, viewed 3 April 2014, www.daff.gov.au/natural-resources/soils/improving-land-management-practices.

73 S Cork, L Eadie, P Mele, R Price and D Yule. The relationship between land management practices and soil condition and the quality of ecosystem services delivered from agriculture land in Australia, Kiri-ganai research, Canberra, 2012.

74 S Cork, L Eadie, P Mele, R Price and D Yule. The relationship between land management practices and soil condition and the quality of ecosystem services delivered from agriculture land in Australia, Kiri-ganai research, Canberra, 2012.

75 S Cork, L Eadie, P Mele, R Price and D Yule. The relationship between land management practices and soil condition and the quality of ecosystem services delivered from agriculture land in Australia, Kiri-ganai research, Canberra, 2012.

76 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

77 S Cork, L Eadie, P Mele, R Price and D Yule. The relationship between land management practices and soil condition and the quality of ecosystem services delivered from agriculture land in Australia, Kiri-ganai research, Canberra, 2012.

78 Department of Sustainability and Environment, Victorian Dryland Salinity Update January 2013, Victorian Government, Melbourne, 2013.

79 Department of Sustainability and Environment, Victorian Dryland Salinity Update January 2013, Victorian Government, Melbourne, 2013.

80 Commissioner for Environmental Sustainability Victoria, State of Environment Victoria 2008 – Part 4; Commissioner for Environmental Sustainability Victoria, Melbourne, 2008.

81 Sinclair Knight Merz, Dryland Salinity Processes Literature Review, Glenelg Hopkins CMA, Hamilton, 2010.

82 Department of Sustainability and Environment, Victorian Dryland Salinity Update January 2013, Victorian Government, Melbourne, 2013.

83 B Gill, H, Zydor and P Hekmeijer, Victoria's Salinity Status 2012: Technical Report, Department of Primary Industries, Epsom, 2012.

84 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

85 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

86 Department of Sustainability and Environment, Victorian Dryland Salinity Update, Department of Sustainability and Environment, East Melbourne, 2013.

87 Department of Sustainability and Environment, Victorian Dryland Salinity Update, Department of Sustainability and Environment, East Melbourne, 2013.

88 Department of Sustainability and Environment, Victorian Dryland Salinity Update, Department of Sustainability and Environment, East Melbourne, 2013.

89 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, Victoria, 2012.

90 B Slattery, C Hollier, The Impact of Acid Soils in Victoria, Department of Natural Resources and Environment, Rutherglen, 2002.

91 B Slattery, C Hollier, The Impact of Acid Soils in Victoria, Department of Natural Resources and Environment, Rutherglen, 2002.

92 Victorian Commissioner for Environmental Sustainability, Victoria State of the Environment: Science Policy People; Commissioner Environmental Sustainability, Melbourne, 2013.

93 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, 2012.

94 Victorian Catchment Management Council, Catchment Condition and Management Report 2012, Victorian Catchment Management Council, 2012.

95 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

96 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

97 NM Baxter and NJ Robinson, Land Resource Assessment in the Glenelg Hopkins Region, Department of Natural Resources, Bendigo, 2001.

98 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

99 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

100 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

101 Commissioner for Environmental Sustainability Victoria, Foundation Paper Two - Land and Biodiversity Victoria: the science, our private landholders, incentive and connectivity, Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

102 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

103 TQA Research, Communication Research, Wave 2, TQA Research, Sandringham, 2001.

104 Department of Environment and Primary Industries, Victorian Waterway Management Strategy, Victorian Government, Melbourne, 2013.

105 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

106 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

107 R MacEwan, R Clark, J Hopley, K Reynard and E Morse-McNabb, Soil Assets and NRM Investment Final Report, Department of Primary Industries, Bendigo, 2011.

108 Commissioner for Environmental Sustainability Victoria, Foundation Paper Two - Land and Biodiversity Victoria: the science, our private landholders, incentive and connectivity, Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

109 Department of Environment and Primary Industries, Draft Victorian Coastal Strategy 2013, Victorian Government, Melbourne, 2013.

110 Department of Environment and Primary Industries, Index of Stream Condition: The Third Benchmark of Victorian River Condition, Victorian Government, Melbourne, 2013.

111 van de Graaff & Associates Pty Ltd, Glenelg Hopkins Catchment Regional Soil Health Action Plan, 2006, Glenelg Hopkins CMA, Hamilton, 2006.

112 Department of Environment and Primary Industries, Index of Stream Condition: The Third Benchmark of Victorian River Condition, Victorian Government, Melbourne, 2013.

113 Department of Environment and Primary Industries, Index of Stream Condition: The Third Benchmark of Victorian River Condition, Victorian Government, Melbourne, 2013.

114 Commissioner for Environmental Sustainability Victoria, State of Environment Victoria 2008 – Part 4; Commissioner for Environmental Sustainability Victoria, Melbourne, 2008.

115 van de Graaff & Associates Pty Ltd, Glenelg Hopkins Catchment Regional Soil Health Action Plan, 2006, Glenelg Hopkins CMA, Hamilton, 2006.

116 Commissioner for Environmental Sustainability Victoria, State of Environment Victoria 2008 – Part 4; Commissioner for Environmental Sustainability Victoria, Melbourne, 2008.

117 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

118 van de Graaff & Associates Pty Ltd, Glenelg Hopkins Catchment Regional Soil Health Action Plan, 2006, Glenelg Hopkins CMA, Hamilton, 2006.

119 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

120 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

121 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

122 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

123 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

124 NM Baxter and NJ Robinson, Land Resource Assessment in the Glenelg Hopkins Region, Department of Natural Resources, Bendigo, 2001.

125 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

126 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

127 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

128 Commissioner for Environmental Sustainability Victoria, Victoria: State of the Environment - Science Policy People; Commissioner for Environmental Sustainability Victoria, Melbourne, 2013.

129 RJ MacEwan, Soil Health for Victoria's Agricultural Context, Terminology and Concepts, Department of Primary Industries, Bendigo, 2007.

130 J Nuttall, R Armstrong and M Crawford, Climate Change – identifying the impacts on soil health in Victoria, Department of Primary Industries, 2007.

131 Intergovernmental Panel on Climate Change, Climate Change 2013: The Physical Science Basis – Summary for policy makers, Intergovernmental Panel on Climate Change, Switzerland, 2013.

132 G Certini, Effects of fire on properties of forest soils: a review, Oecologia 2005, 143: 1-10.

133 J Nuttall, R Armstrong and M Crawford, Climate Change – identifying the impacts on soil health in Victoria, Department of Primary Industries, 2007.

134 J Nuttall, R Armstrong and M Crawford, Climate Change – identifying the impacts on soil health in Victoria, Department of Primary Industries, 2007.

135 J Nuttall, R Armstrong and M Crawford, Climate Change – identifying the impacts on soil health in Victoria, Department of Primary Industries, 2007.

136 E Brevik, The Potential of Climate Change on Soil Properties and Processes and Corresponding Influence of Food Security, Agriculture 2013, 3(3), 398-417.

137 E Brevik, The Potential of Climate Change on Soil Properties and Processes and Corresponding Influence of Food Security, Agriculture 2013, 3(3), 398-417.

138 RD Bardgett, C Freeman and NJ Ostle, Microbial contributions to climate change through carbon cycle feedbacks, The ISME Journal 2008, 2, 805–814.

139 E Brevik, The Potential of Climate Change on Soil Properties and Processes and Corresponding Influence of Food Security, Agriculture 2013, 3(3), 398-417.

140 RD Bardgett, C Freeman and NJ Ostle, Microbial contributions to climate change through carbon cycle feedbacks, The ISME Journal 2008, 2, 805–814.

141 RD Bardgett, C Freeman and NJ Ostle, Microbial contributions to climate change through carbon cycle feedbacks, The ISME Journal 2008, 2, 805–814.

142 RD Bardgett, C Freeman and NJ Ostle, Microbial contributions to climate change through carbon cycle feedbacks, The ISME Journal 2008, 2, 805–814.

143 Department of Primary Industries, Climate change impacts and adaptation responses for South-West Victoria's primary industries: A DPI VCCAP Discussion Paper, Department of Primary Industries, Melbourne, 2010.

144 B Cullen, I Johnson, R Eckard, G Lodge, R Walker, R Rawnsley and M McCaskill, Climate change effects on pasture systems in south-eastern Australia, Crop and Pasture Science 2009, 60(10) 933–942.

145 GJ O'Leary, B Christy, A Weeks, J Nuttall, P Riffkin, C Beverly and G Fitzgerald, Biophysical Modelling: Likely response of wheat crop yield to climate change across Victoria, VCCAP Project Biophysical Modelling Theme Final Report, Department of Primary Industries, Horsham, 2010.

146 B Cullen, I Johnson, R Eckard, G Lodge, R Walker, R Rawnsley and M McCaskill, Climate change effects on pasture systems in south-eastern Australia, Crop and Pasture Science 2009, 60(10) 933–942.

147 C Stokes, and M Howden, Adapting Agriculture to Climate Change: Preparing Australian Agriculture, Forestry and Fisheries for the Future, CSIRO Publishing, 2010.

148 Cullen, B., Johnson, I., Eckard, R., Lodge, G., Walker, R., Rawnsley, R. and McCaskill, M., Climate change effects on pasture systems in south-eastern Australia, Crop and Pasture Science 2009, 60(10) 933–942.

149 C Stokes, and M Howden, Adapting Agriculture to Climate Change: Preparing Australian Agriculture, Forestry and Fisheries for the Future, CSIRO Publishing, 2010.

150 M Barson, Land management practice trends in Victoria's broadacre cropping industries, Caring for our Country Sustainable Practices fact sheet 13, Department of Agriculture, Fisheries and Forestry, Canberra, 2013.

151 M Barson, Land management practice trends in Victoria's dairy industry, Caring for our Country Sustainable Practices fact sheet 11, Department of Agriculture, Fisheries and Forestry, Canberra, 2013.

152 M Barson, Land management practice trends in Victoria's grazing (beef cattle/sheep) industries, Caring for our Country Sustainable Practices fact sheet 12, Department of Agriculture, Fisheries and Forestry, Canberra, 2013.

153 M Barson, Land management practice trends in Victoria's broadacre cropping industries, Caring for our Country Sustainable Practices fact sheet 13, Department of Agriculture, Fisheries and Forestry, Canberra, 2013.

154 S Cork, L Eadie, P Mele, R Price and D Yule, The relationship between land management practices and soil condition and the quality of ecosystem services delivered from agriculture land in Australia, Kiri-ganai research, Canberra, 2012.

155 S Cork, L Eadie, P Mele, R Price and D Yule, The relationship between land management practices and soil condition and the quality of ecosystem services delivered from agriculture land in Australia, Kiri-ganai research, Canberra, 2012.

156 Department of Agriculture, Land management affects soil condition, viewed 3 April 2014, www.daff.gov.au/natural-resources/soils/improving-land-management-practices.

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