AdaptNSW

# Soil Properties: NSW Climate Change Impact Snapshot

2nd edition

# Overview of Impacts on Soil Properties in **NSW**

Soils support the agricultural potential and natural ecosystems of New South Wales, but many soil properties are sensitive to climate variables such as temperature and rainfall.

New South Wales is projected to undergo a change in three important soil properties to approximately 2070, based on projections derived from an ensemble of 12 climate models:

- The amount of organic carbon stored in soils is projected to decline over the State, typically varying between a loss of 0 to 10 tonnes per hectare (t/ha) but reaching a maximum decline of over 20 t/ha in the southern alpine region.
- Soil pH is projected to increase (becoming more alkaline) across the State, generally increasing from east to west. Projections for the southern alpine region display the greatest increases: up to 0.5 pH units or more.
- A subset of macro-nutrients in soils is projected to increase over the State, with relative increases typically varying between 5 and 20%. As with pH, there is a general increase from east to west and in areas of higher elevation. Projections for the far southern alpine regions display the greatest increases: up to 30% or more.

These projected changes are an important consideration for the management of soils and associated agricultural and native ecosystem landscapes across New South Wales in future decades. Changes in these soil properties may also signify changes to other important trace elements, which may have other significant potential impacts.

These results only reflect the influence of the altered climate, they do not consider the impacts from ongoing land management over agricultural lands.

# Climate Change Impact Snapshot

## Climate Change Impact Research Program (CCIRP)

This impact report is part of the NSW Climate Change Impact Research Program (CCIRP). CCIRP aims to understand the biophysical impacts of climate change in New South Wales using the climate change projections from the NSW and ACT Regional Climate Modelling (NARCliM) project. CCIRP is designed to ensure the research delivered meets the information needs of the NSW community. The CCIRP program is ongoing and will continue to provide updated information on the likely impacts of climate change in New South Wales.

## NSW and ACT Regional Climate Modelling Project (NARCliM)

The climate change projections in this impact snapshot are from the NARCliM project. NARCliM is a multi-agency research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW. NSW Government funding comes from the Office of Environment and Heritage (OEH), Sydney Catchment Authority, Sydney Water, Hunter Water, NSW Office of Water, Transport for NSW and Department of Primary Industries.

The NARCliM project has produced a suite of 12 regional climate projections for south-east Australia spanning the range of likely future changes in climate. NARCliM is explicitly designed to sample a large range of possible future climates.

For more information on the modelling project and methods go to the AdaptNSW website: climatechange.environment.nsw.gov.au.

## Impact science technical reports

This climate change impact snapshot is based on detailed technical reports. *Climate Change Impacts on Three Key Soil Properties in New South Wales* (Gray & Bishop 2018) details the results of impact science research and can be accessed from the AdaptNSW website: climatechange.environment.nsw.gov.au.

The snapshots provide descriptions of climate change projections for two future 20-year periods: 2020–39 and 2060–79.

1. The climate projections for 2020–39 are described in the snapshots as **NEAR FUTURE, or as 2030**, the latter representing the average for the 20-year period.

2. The climate projections for 2060–79 are described in the snapshots as **FAR FUTURE, or as 2070**, the latter representing the average of the 20-year period.

Climate change projections for the near future and far future are compared to the baseline modelled climate (1990–2009). Interpreting climate projections can be challenging due to the complexities of our climate systems. 'Model agreement', that is, the number of models that agree on the direction of change (for example increasing or decreasing rainfall) is used to determine the confidence in the projected changes. The more models that agree, the greater the confidence in the direction of change.

Help on how to interpret the maps and graphs in this report is provided in the Appendix.

# Introduction

Climate change may impact our soils. Soils support the growth of most plant life and are a crucial element of all terrestrial ecosystems. The physical and chemical character of soils has a great influence on the type of vegetation and ecosystem that can be supported and the agricultural potential of land.

Many soil properties are sensitive to climate variables such as rainfall and temperature (Jenny 1980). It is important to understand the potential change in soil properties that may occur due to projected changes in rainfall and temperature in New South Wales over the coming decades.

This snapshot examines how soil properties are projected to change over time in New South Wales, due to climate change. It focuses on three important soil properties: soil organic carbon (SOC), pH and the level of a set of macro-nutrients (sum-of-bases) in soils. These are important chemical attributes that influence agricultural productivity and native ecosystem functions.

This report examines the potential climate change impacts on these three key soil properties using the NARCliM project projections (Evans et al. 2014).

# Soil organic carbon

Soil organic carbon (SOC) is one of the most widely used indicators of soil health. It is associated with many chemically and physically desirable attributes including high biological activity, nutrient availability, soil physical structure, water-holding capacity and aeration. SOC is also important for its potential role in contributing to climate change mitigation programs. Changes in the quantity of carbon stored in the soil can impact the global carbon cycle and can alter carbon levels present in the atmosphere as carbon dioxide (Lal 2004; Wilson et al. 2011; Baldock et al. 2012). Thus, increases in soil carbon may correspond with lowering greenhouse gas levels in the atmosphere. Alternatively, decreases in soil carbon may exacerbate climate change. SOC change is considered a priority for national soil monitoring programs (McKenzie & Dixon 2006).

## Current distribution patterns

The present-day distribution of SOC stocks (in tonnes per hectare, t/ha) over the upper depth interval of 0–30 centimetres (cm) across New South Wales is shown in Figure 1. Under current conditions, SOC stocks vary from less than 20 t/ha in the far west of the State to greater than 100 t/ha in the eastern highlands. Stocks generally increase in wetter, cooler conditions in soils derived from lower quartz parent materials and in areas containing native vegetation. Similar patterns are evident for the lower depth interval (30–100 cm).

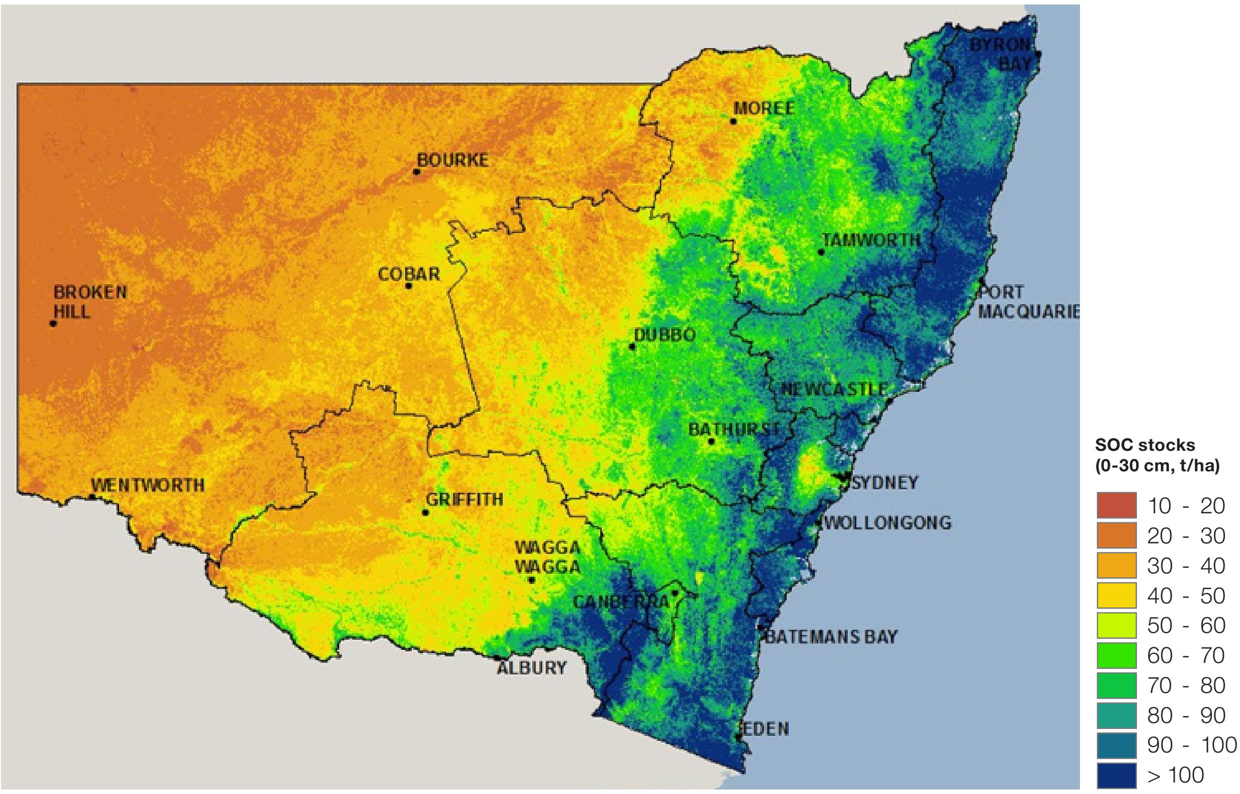



Figure 1: Organic carbon stocks over New South Wales (0–30 cm)
Source: Soil and Landscape Grid of Australia, TERN 2014

# Future changes

New South Wales is projected to experience an overall decline in SOC stocks in both the near and far future.

Almost all models project a mean state-wide decline in SOC, which becomes more pronounced in the far future (Figure 2). Over the upper depth interval (0–30 cm), there is an average 2.5 t/ha and 5.1 t/ha decline in the near and far futures respectively. Smaller declines are projected for the lower depth interval (30–100 cm).

From the average of all models for the far change period, most of the State is projected to undergo a modest decrease in SOC stocks (0 to 7.5 t/ha in the upper depth, 3 to 5 t/ha in the lower depth) (Figures 3 and 4). Projected losses are greater in the highland areas, exceeding 20 t/ha (in the upper depth) in the far southern alpine regions. Minor areas along the far north coast, however, have a projected slight increase in stocks (generally less than 2 t/ha).

The SOC change demonstrated over any region primarily depends on the balance between the changing temperatures and rainfall over that region. SOC generally decreases with rising temperatures and increases with increasing rainfall (Jenny 1980; Badgery et al. 2013; Gray et al. 2015a). For example, the notable decreases in the southern highlands reflect the projected lower average rainfall and hotter temperatures. However, the extent of the SOC change also varies depending on the precise environmental regime, such as the combination of current climate, parent material/soil type and land use, which adds complexity to the above trends.

## Implications

The projected changes in SOC have implications for the health of NSW soils. Lower SOC contents are associated with a decline in soil health, due to the multiple benefits associated with organic material (including improved nutrient supply, soil structure, aeration and water-holding capacity) (McKenzie & Dixon 2006). For those regions identified as undergoing a moderate or greater decline in SOC, a decline in agricultural productivity may occur unless remediating measures are undertaken. These projections also have implications for atmospheric carbon levels and global carbon cycles.

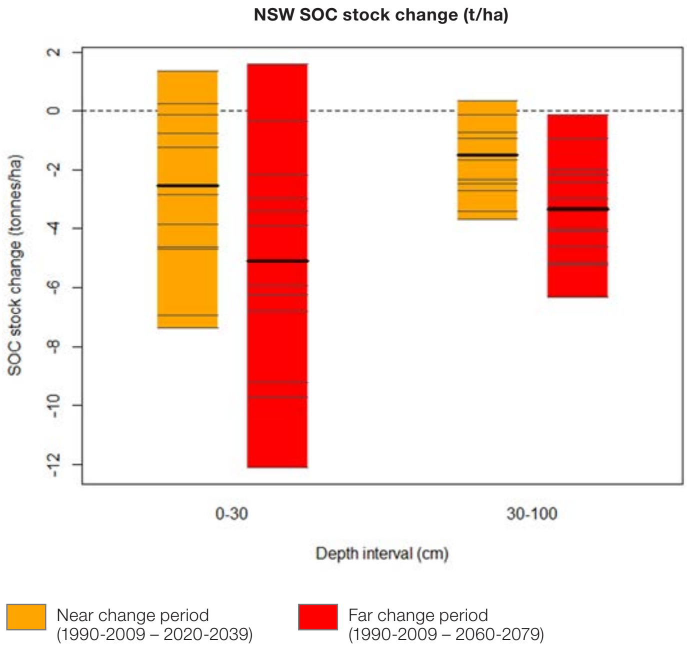



Figure 2: Absolute change in SOC stocks from the 12 climate models for both change periods

# Future changes

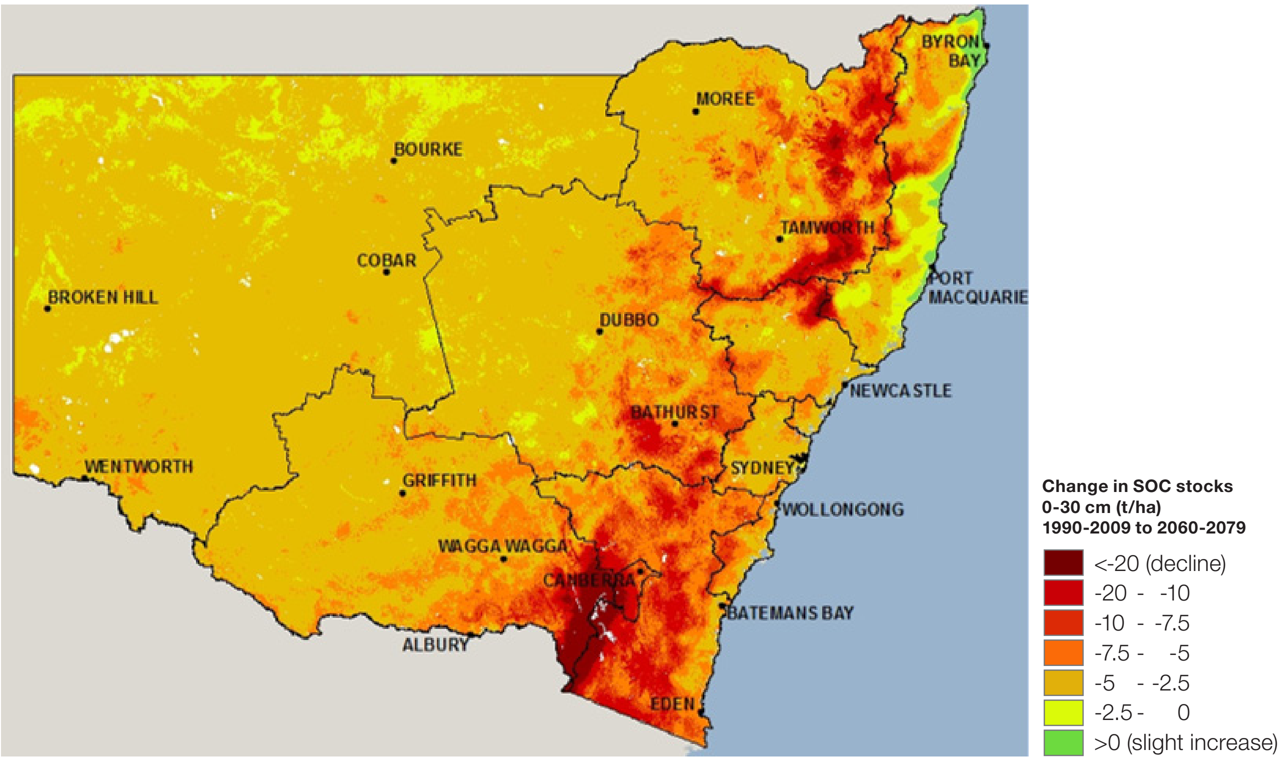



Figure 3: Absolute change in SOC stock (t/ha) across New South Wales for the far-future change period (0–30 cm)

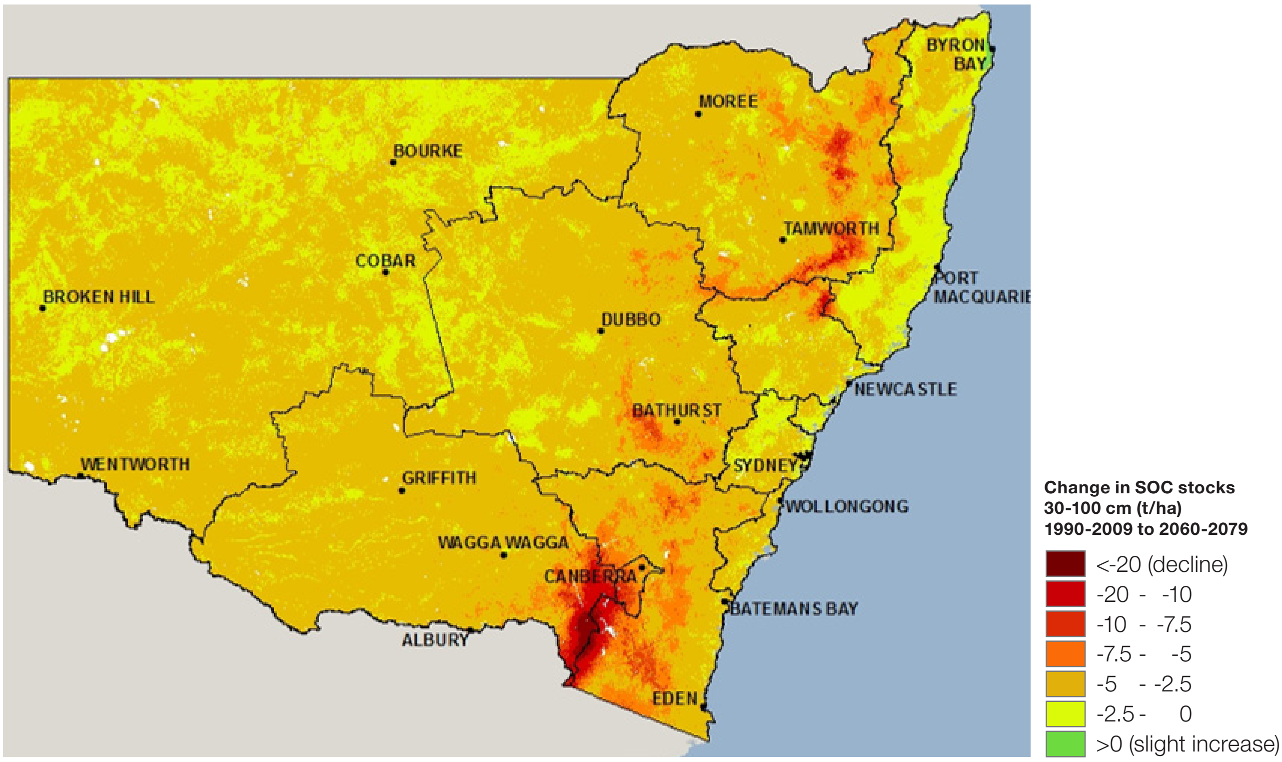



Figure 4: Absolute change in SOC stock (t/ha) across New South Wales for the far-future change period (30–100 cm)

# pH

The pH of a soil represents the degree of acidity or alkalinity. Most agricultural plants are suited to ranges between pH 4.5 and 8.0 (measured in calcium chloride) (NSW Agriculture 2000; Hazelton & Murphy 2007). All plants however, including both agricultural and native vegetation species, have particular pH suitability ranges, beyond which they will suffer. Some plants have a broad range while others may have a relatively narrow range. pH levels also influence the availability of nutrients and toxic elements which also impact plant growth. Change in soil pH is also considered a priority for national soil monitoring programs (McKenzie & Dixon 2006).

## Current distribution patterns

The present-day distribution of pH over the upper depth interval (0–30 cm) across New South Wales is shown in Figure 5. Under current conditions, pH varies across the State from less than 4.5 to greater than 8.0 pH units, with values increasing, i.e. becoming more alkaline, in drier conditions (lower rainfall, higher temperatures) in soils derived from lower quartz parent materials. Similar patterns are evident for the lower depth interval (30–100 cm).

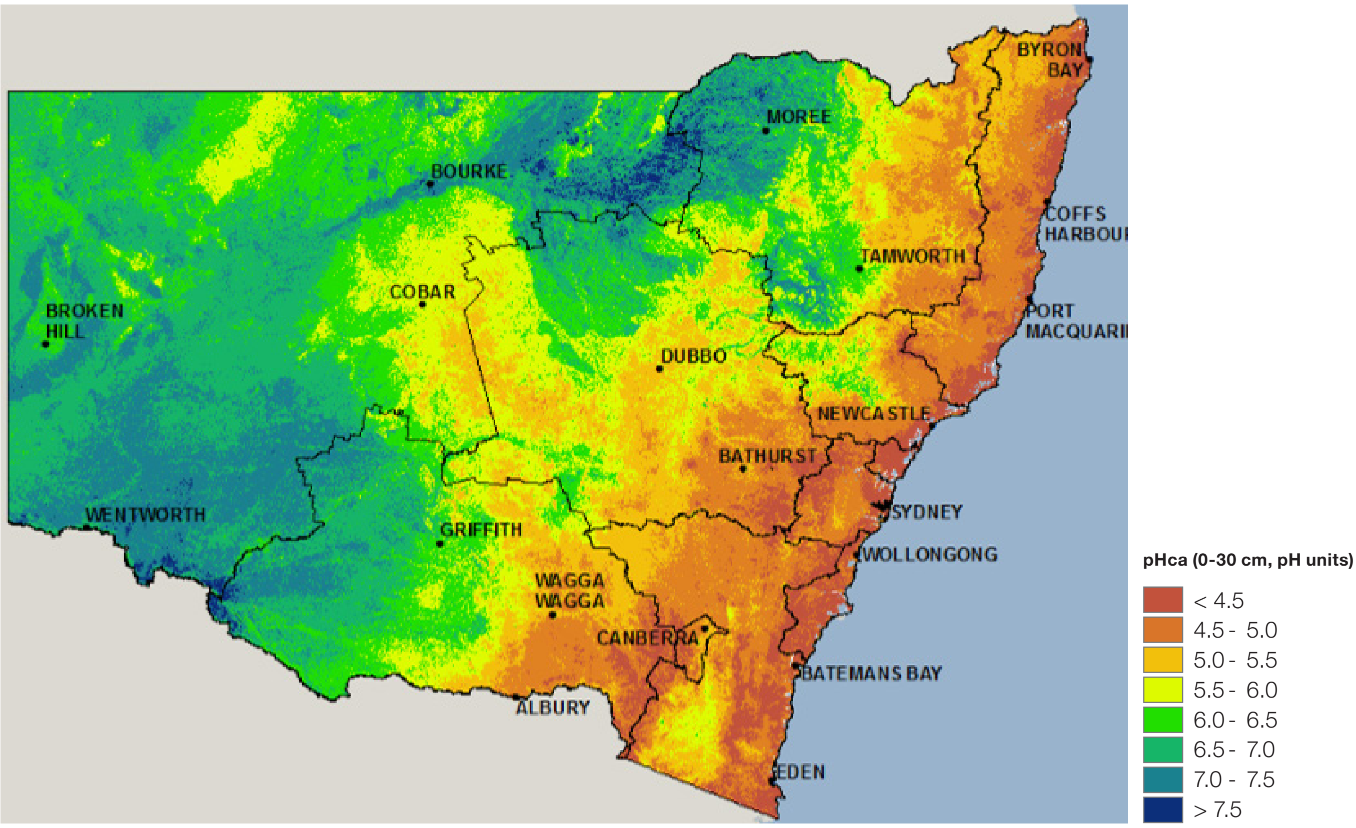



Figure 5: pH over New South Wales (0–30 cm)
Source: Soil and Landscape Grid of Australia, TERN 2014

# Future changes

New South Wales is projected to experience a slight alkalisation of soils in the near- and far-future periods.

For the upper depth interval (0–30 cm) all 12 models project mean state-wide increases in pH over both change periods, albeit at different levels, with average increases of 0.09 and 0.21 for the near- and far-future periods respectively (Figure 6). For the lower depth interval (30–100 cm) up to four models project a very slight decrease (i.e. becoming more acidic) with average increases of 0.09 and 0.19 for the near- and far-future periods respectively.

From the average of all models for the far change period, the entire State is projected to undergo varying degrees of pH increase, typically ranging up to 0.3 pH units, and generally increasing from east to west (Figures 7 and 8). The far southern alpine region displays the greatest increases up to 0.5 pH units or more.

The pH change demonstrated over any region by the maps is primarily controlled by the balance between the changing temperatures and rainfall. pH normally increases with rising temperatures and declining rainfall (Gray et al. 2015b; Rubinic et al. 2015). Thus, the decreases in pH observed in the far west of New South Wales are primarily a response to projected increased rainfall. In contrast the notable increases in pH demonstrated for many central parts of the New England region reflect relatively drier conditions (driven mainly by warmer temperatures). However, the extent of the pH change also varies depending on the environmental regime, such as the combination of current climate, parent material/ soil type and land use, which adds complexity to the above trends.

## Implications

Changes in soil pH have a major influence on soil condition and agricultural productivity. Over most of the State the changes are quite small and not likely to significantly impact agricultural practices, but may still need to be considered by farm managers, especially where their crop or pasture species requires a narrow pH range, for example some varieties of wheat (Hazelton & Murphy 2007; Stokes & Howden 2010). These projected changes do not consider the influence of ongoing intensive land management over agricultural lands, which often contribute to an acidification trend (Fenton and Helyar 2007).

Changes in soil pH may impact natural ecosystems, which have normally established under particular pH ranges. Where significant increases or decreases (for example, 0.25 pH units or more) are demonstrated, native ecosystems are likely to be impacted – an issue that may need to be considered and addressed by managers of these ecosystems (Steffen et al. 2009; Prober & Wiehl 2012).

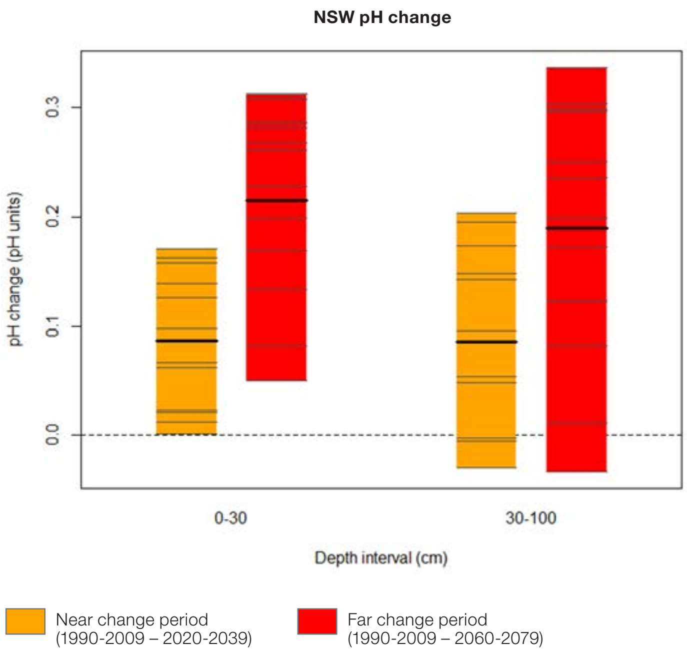



Figure 6: Absolute change in pH from the 12 climate models for both change periods

# Future changes

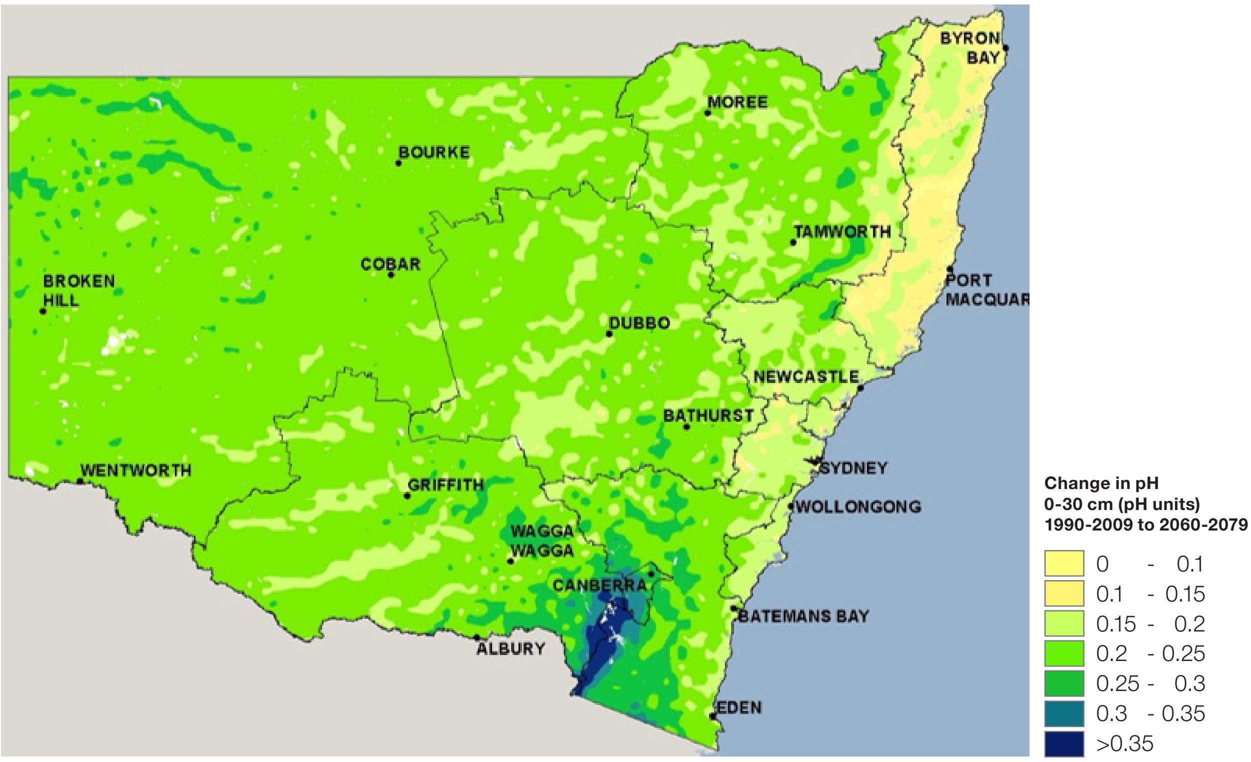



Figure 7: Absolute change in pH across New South Wales for the far-future change period (0–30 cm)

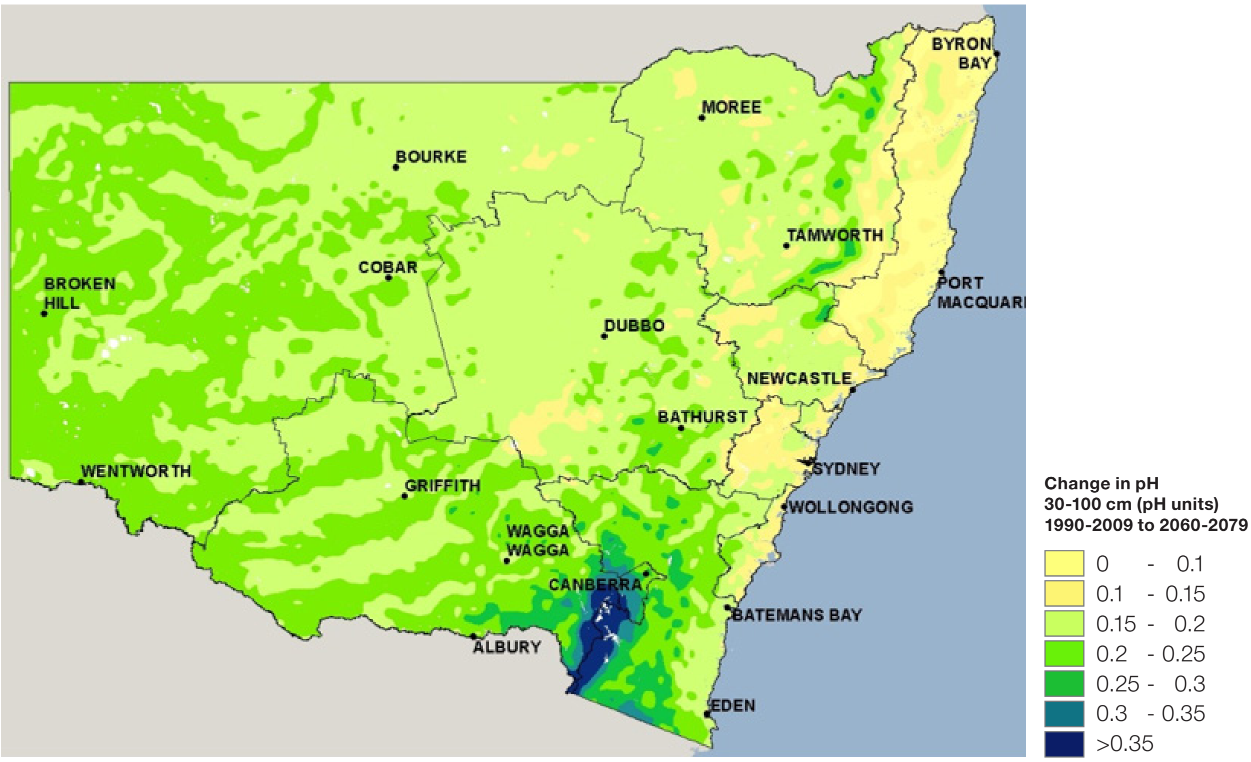



Figure 8: Absolute change in pH across New South Wales for the far-future change period (30–100 cm)

# Sum of bases

This soil property represents the level of macro-nutrients, and is defined as the sum of the calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) in the fine material fraction (<2 millimetres [mm]) of the soil. Higher levels of macro-nutrients indicate higher fertility soils and associated agricultural productivity (McKenzie et al. 2004). Different plants, both agricultural and native vegetation species, have differing requirements and tolerances of macro-nutrients. Significant changes in macro-nutrients can indicate important changes in other minor and trace elements, which equally can have a major impact on plant growth (Russell & Russell 1988; Mulvey & Elliot 2007).

## Current distribution patterns

The present-day distribution across New South Wales of sum of bases (macro-nutrients) over surface layers (0–30 cm) is shown in Figure 9. This property ranges from almost zero in eastern parts of the State up to greater than 50 centimoles of charge per kilogram (cmolc/kg) in central and western regions. It follows a similar distribution pattern to pH, increasing with drier and warmer conditions, and more clay-rich soils.

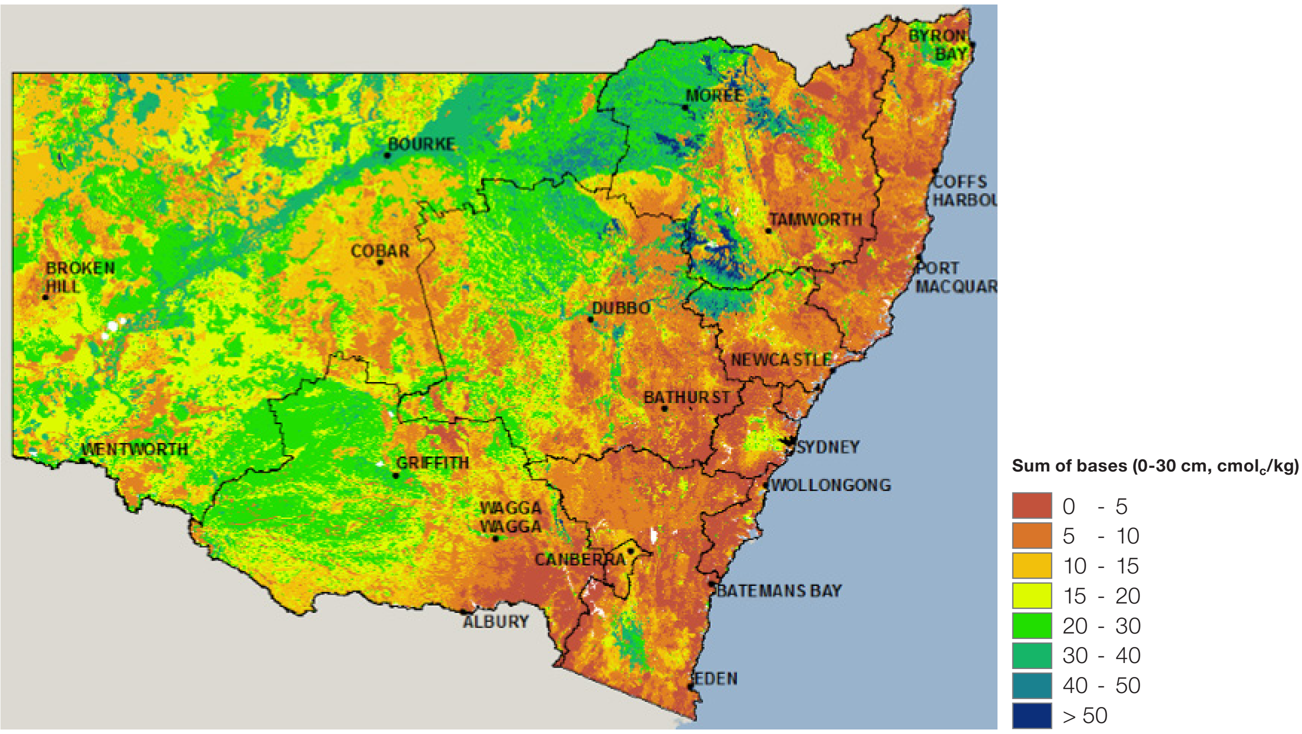



Figure 9: Sum of bases over New South Wales (0–30 cm)

# Future changes

New South Wales is projected to experience an overall increase in the sum of bases (macro-nutrients).

Almost all of the 12 models project mean state-wide increases, the only exception being one model in the upper depth interval near-change period, but the extent of increase varies between the models. Greatest increases are projected for the far-future change period where there are overall relative mean increases of 14.6% and 17.4% in the upper and lower depth intervals respectively (Figure 10).

From the average of all models for the far-future change period, the entire State is projected to undergo varying degrees of increase in sum of bases, typically ranging between 5% and 20%, and being somewhat greater in the lower depth interval (Figures 11 and 12). As for pH, there is a general increase from east to west and in higher altitude areas. The far southern alpine regions display the greatest increases of up to 30% or more.

The change in sum of bases demonstrated over any region is primarily controlled by the balance between the changing temperatures and rainfall over that region. It normally increases with rising temperatures and declining rainfall (Gray et al. 2015b; Rubinic et al. 2015). Thus, the increase over almost the entire State is a consequence of warmer conditions outweighing widely projected increases in rainfall. However, the extent of the change in sum of bases also varies depending on the environmental regime, such as the combination of current climate, parent material/soil type and land use, which complicates the above trends.

## Implications

Changes in the level of macro-nutrients have an influence on soil fertility and agricultural productivity. Such changes may also indicate similar changes in many important minor and trace nutrients which may be a cause for concern if crop or pasture species have narrow tolerance ranges. The projected modest rise in macro-nutrients over most of the State should generally benefit agricultural productivity, except if the rise came from sodium, which can have adverse effects on soil. These projected changes do not consider the influence of ongoing intensive land management over agricultural lands, which may contribute to nutrient decline (Charman 2007).

Any changes in the level of major nutrients, and the potentially associated minor and trace nutrients, have the potential to also impact natural ecosystems, which often have narrow and typically low nutrient level regimes, for example low phosphorous levels. Where significant increases or decreases (for example 10% or more) are demonstrated, it is likely that native ecosystems may be impacted through an introduction of environmental weeds and alterations in floral and faunal compositions. These are issues that may need to be considered and addressed by managers of these ecosystems (Steffen et al. 2009; Prober & Wiehl 2012).

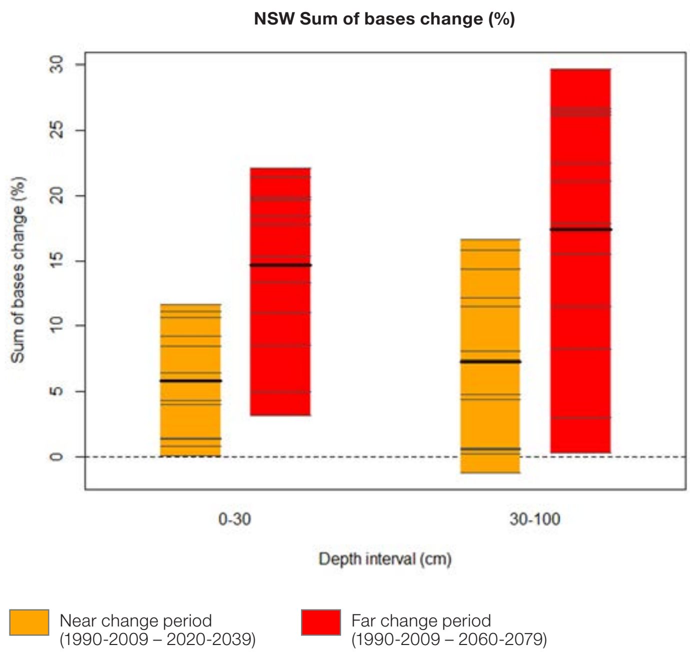



Figure 10: Relative change in sum of bases from the 12 climate models for both change periods

# Future changes

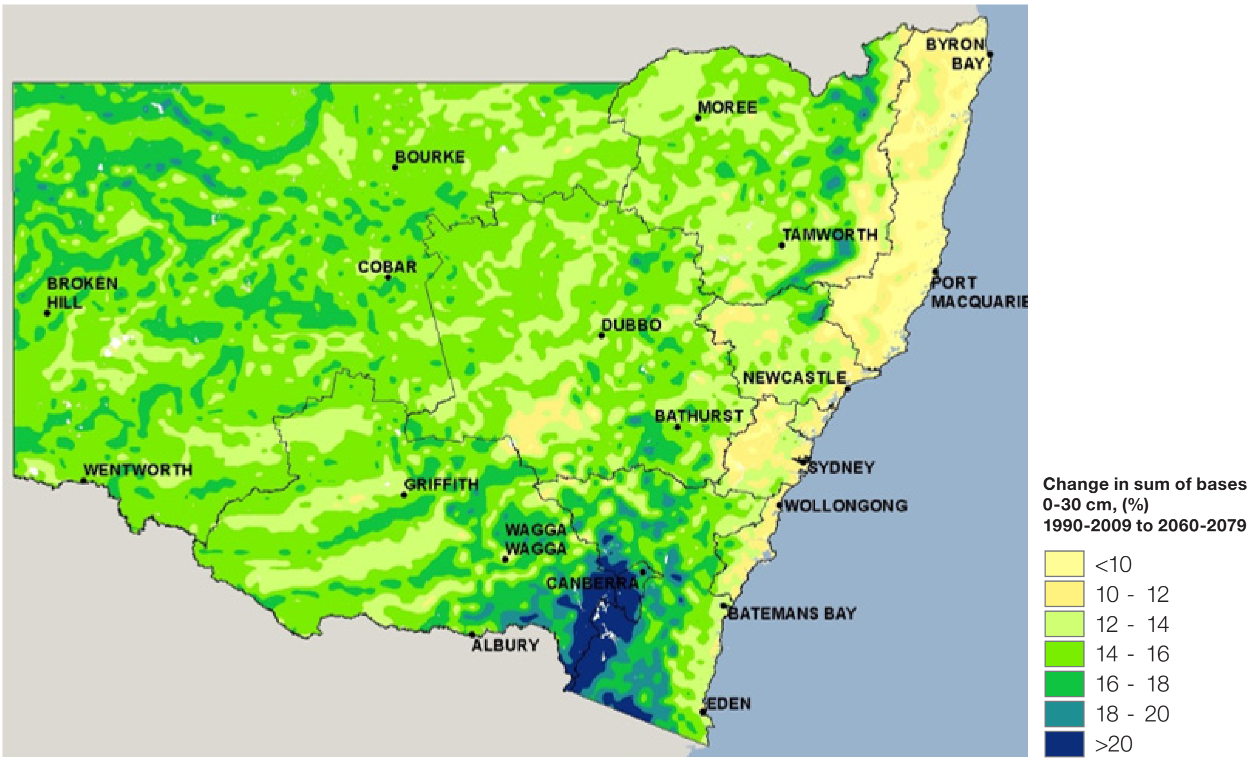



Figure 11: Relative change in sum of bases mass across New South Wales for the far-future change period (0–30 cm)

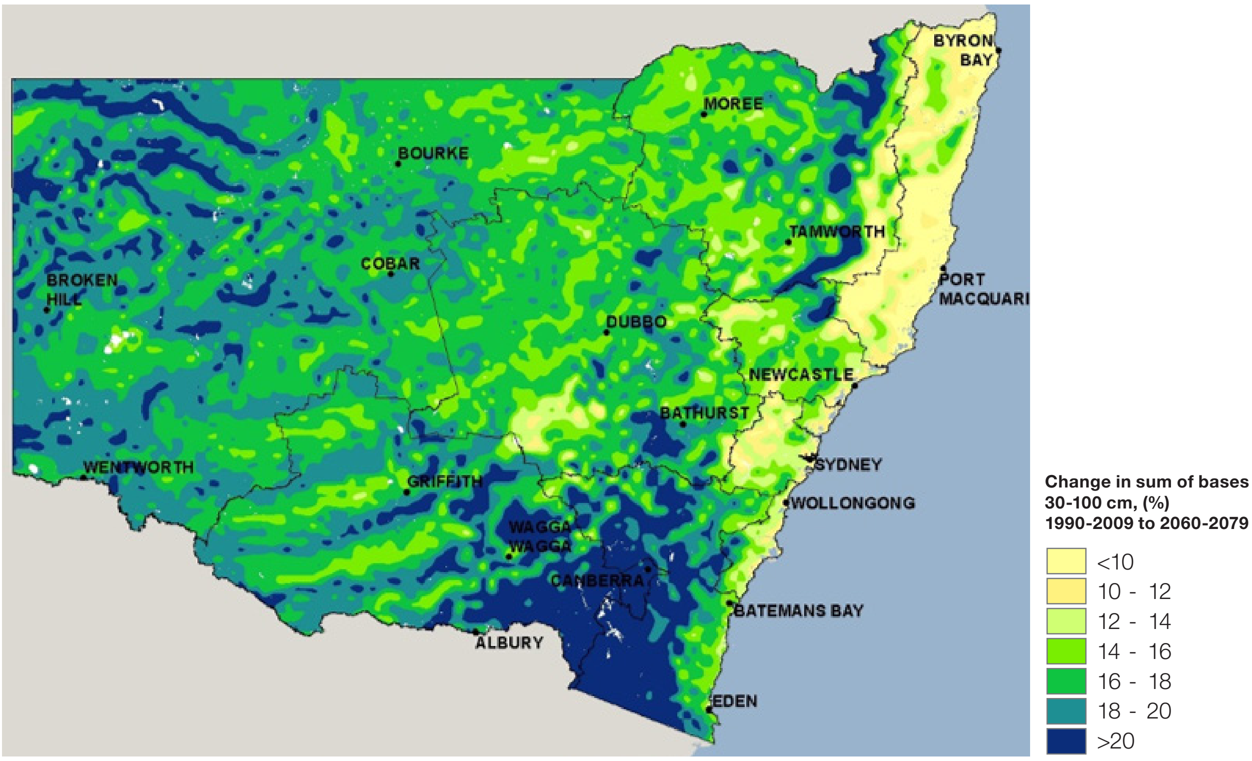



Figure 12: Relative change in sum of bases mass across New South Wales for the far-future change period (30–100 cm)

# Appendix: Guide to reading the maps and graphs

This document contains maps and bar graphs of the climate change projections, which are used to present the 12 model outputs as a central estimate calculated by averaging the results from the 12 models. The bar graphs show future projections averaged across the entire region and are not representative of any particular location within the region. For more detailed spatial information, maps are presented showing the central estimates of future projections. Below is information on what is displayed in the bar graphs and maps.

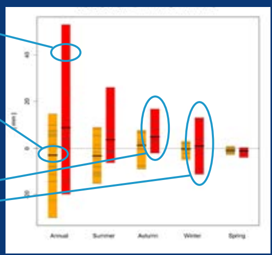
## How to read the bar graphs

The thin grey lines are the **individual models**. There are 12 thin bars for each bar.

The thick line is the **average of all 12 models** for the region.

The length of the bar shows the **spread of the 12 model** values for the region.

Each bar is the **average for 1 model** for the region. They do not represent a single location in the region.



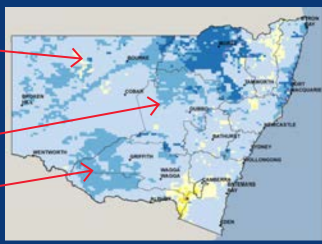
Note: The yellow bars represent near-future scenarios (2020–39), while the red bars represent far-future scenarios (2060–79).

## How to read the maps

The map display a **10km** grid.

NSW has been divided into State Planning Regions and each region has a Local Snapshot report.

The colour of each grid is the **average of all 12 models** outputs for that grid.



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ISBN 978-1-925753-69-1
OEH2018/0264

December 2018

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