Climate change impact on groundwater resources in Australia

Project background

Over the past few decades, much of Australia has experienced increasing pressure on groundwater resources due to a drier climate and increased scarcity of surface water. In 2004 the Council of Australian Governments agreed to form a National Water Initiative (NWI) to ensure the implementation of a transparent planning framework that would avoid over-allocation of water resources, including groundwater. Under the NWI it is necessary to incorporate risks associated with climate change and variability in water management plans. In response to these issues, the National Water Commission commissioned a project, ‘Investigating the impact of climate change on groundwater resources’, within the National Groundwater Action Plan (NGAP). The primary objective of the project was to determine how projected climate change will impact on groundwater recharge and groundwater resources across different aquifers in different climatic types across Australia. The project was undertaken by CSIRO in collaboration with SKM.

Climate change in Australia

Over the past 80 years Australian climatic trends indicated warming over most of Australia (except in the inland north-west), increasing rainfall over northern, central and north-west Australia, and decreasing rainfall in eastern, south-east and south-west Australia. This has led to a southerly expansion of the tropical climate types in the far north together with a contraction in the northern extent of the arid types. The arid types have expanded to the south and south-east, with a corresponding contraction of temperate types to the coast.

The projected future climates were inferred from 16 global climate models (GCMs) of the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4). The full range of IPCC AR4 future climate projections was accounted for by scaling these 16 GCMs results according to three global warming scenarios (low, medium and high) for both 2030 and 2050. The projected future changes in rainfall were estimated relative to 80 years baseline rainfall data of 1930-2010 (Figure 1).

Projected future changes in the spatial distribution of climate types indicate a further increase in aridity at the expense of temperate coverage. For southern Australia the projections are more consistent with observed trends in climate types over the past 80 years than are those for northern Australia. As the projected warming and southern Australian rainfall decline accelerates between 2030 and 2050, there is a possibility this will promote land cover change between now and 2050 (Figure 2).

> Figure 1. Projected changes in annual average rainfall under wet, median and dry future climate scenarios for 2050 relative to 80 years baseline (1930-2010)
Climate and renewable groundwater resources

Nationwide historical (observed) and future (projected) climate data were used to assess diffuse groundwater recharge (recharge associated with rainfall across the landscape) under the different climate types.

A common method for the estimation of renewable groundwater resources is to assume a proportion of rainfall each year generates recharge. Observations and modelling have shown that this method has a number of shortcomings. In particular, this analysis has revealed a non-linearity in the recharge to rainfall ratio ($R/P$) for any given location due to variability in rainfall intensity, or the number of consecutive rain days. Such inter-annual variability is more apparent in areas of lower recharge. Thus, compared to the long-term average, the variability of recharge in different wet and dry 15-year periods is greater in areas of low recharge and comparatively smaller in the areas of high recharge. This means that inter-annual rainfall variability is magnified 2- to 4-times in recharge variability. This so called “recharge elasticity” measure is higher in the low recharge regions, i.e. arid zones.

The median future climate at 2030 and 2050 projects a decrease in diffuse recharge across most of the west, centre and south-east of Australia while increases in recharge are projected across northern Australia and a small area of eastern Australia (Figure 3). The sensitivity of recharge to change in rainfall is relatively constant under all global warming scenarios, but changes in factors other than the total rainfall can result in a general overall increase in recharge with increased global warming. These factors include temperature, rainfall intensity and carbon dioxide ($CO_2$) concentration effects on vegetation. As a result under increased global warming, the number of GCMs, under which recharge is projected to decrease, becomes progressively low over most of the country. The south-west and some areas of the south-east of the country are an exception with all GCMs projecting lower recharge under
all future climate scenarios. Historical variability of diffuse recharge over 15-year periods (within the 80-year baseline of 1930-2010) is greater than the magnitude of modelled recharge change under the future climate scenarios over an equivalent 80-year average. This highlights the need for flexibility in water sharing plans to account for the compounding effect of current climate variability and future climate change on recharge.

Projected changes in localised recharge from disconnected losing streams were estimated to be similar to projected changes in river flow, but lower than the projected changes in river flow from connected losing streams. Sensitivity of localised recharge to changes in river flow reduces in areas with deeper groundwater (i.e. disconnected systems). An increase in groundwater depth under future climate scenarios may cause an increase in localised recharge from connected losing streams even under conditions where river flow is projected to decrease. However, when overbank floods are the sources of localised recharge, changes in localised recharge are likely to be much greater than projected changes in river flow.

Aquifer sensitivity to changing climate

The effect of climate change on groundwater resources is influenced by the hydrogeological conditions of an aquifer. The project assessed all Australian aquifers in terms of their sensitivity to climate change and their level of national importance. Fourteen priority aquifers were identified as both sensitive to climate and important groundwater resources on a national scale (Figure 4). In addition six aquifers in south-west Western Australia were also included in the high priority list. Although these aquifers were not identified as highly sensitive to climate change, this region is projected to experience the greatest reduction in recharge under a future climate.

Groundwater modelling and climate change

Groundwater models are commonly used to investigate changes in the groundwater balance due to projected climate change. Most of the models reviewed in the project (including state water authority, CSIRO sustainable yields projects and Murray-Darling Basin Authority (MDBA) programs) were suitable for the purpose of producing future climate scenarios. However, the models used for the project were not able to fully quantify the effect of climate change on recharge due to the high variability of diffuse recharge over 15-year periods. This highlights the need for flexibility in water sharing plans to account for the compounding effect of current climate variability and future climate change on recharge.

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found to be inadequate for assessing the future impacts of climate change. Modelling approaches, model designs and the criteria used for groundwater resources sensitivity assessment also vary substantially between the reviewed models. These made the comparison of the models’ results and identified groundwater resources changes under future climate scenarios a difficult task. A key recommendation of this work is that all groundwater models used in groundwater resource management in Australia should undergo a climate change audit to ensure they are fit-for-purpose when proposing climate change adaptation strategies; this study has highlighted that some models are not suitable for this purpose.

The outcomes of this project contribute to an understanding of the impact of climate change on groundwater management by considering the possible consequences of climate change on groundwater resources across the country. This study has been carried out at the regional scale and considered only gross consequences at the aquifer level and hence can only make broad recommendations. Further, and more detailed, analysis at a scale commensurate with resource utilisation on the ground should be undertaken for the identified priority aquifers.

**Further information**

**Selected publications:**


