

Assessing the Impact of Climate Change on Water Resources: Waimea Plains, New Zealand Case Example

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Abstract

Climate change is impacting and will increasingly impact both the quantity and quality of the world's water resources in a variety of ways. In some areas warming climate results in increased rainfall, surface runoff, and groundwater recharge while in others there may be declines in all of these. Water quality is described by a number of variables. Some are directly impacted by climate change. Temperature is an obvious example. Notably, increased atmospheric concentrations of CO₂ triggering climate change increase the CO₂ dissolving into water. This has manifold consequences including decreased pH and increased alkalinity, with resultant increases in dissolved concentrations of the minerals in geologic materials contacted by such water. Climate change is also expected to increase the number and intensity of extreme climate events, with related hydrologic changes.

A simple framework has been developed in New Zealand for assessing and predicting climate change impacts on water resources. Assessment is largely based on trend analysis of historic data using the non-parametric Mann-Kendall method. Trend analysis requires long-term, regular monitoring data for both climate and hydrologic variables. Data quality is of primary importance and data gaps must be avoided. Quantitative prediction of climate change impacts on the quantity of water resources can be accomplished by computer modelling. This requires the serial coupling of various models. For example, regional downscaling of results from a world-wide general circulation model (GCM) can be used to forecast temperatures and precipitation for various emissions scenarios in specific catchments. Mechanistic or artificial intelligence modelling can then be used with these inputs to simulate climate change impacts over time, such as changes in streamflow, groundwater-surface water interactions, and changes in groundwater levels.

The Waimea Plains catchment in New Zealand was selected for a test application of these assessment and prediction methods. This catchment is predicted to undergo relatively minor impacts due to climate change. All available climate and hydrologic databases were obtained and analyzed. These included climate (temperature, precipitation, solar radiation and sunshine hours, evapotranspiration, humidity, and cloud cover) and hydrologic (streamflow and quality and groundwater levels and quality) records. Results varied but there were indications of atmospheric temperature increasing, rainfall decreasing, streamflow decreasing, and groundwater level decreasing trends.

Artificial intelligence modelling was applied to predict water usage, rainfall recharge of groundwater, and upstream flow for two regionally downscaled climate change scenarios (A1B and A2). The AI methods used were multi-layer perceptron (MLP) with extended Kalman filtering (EKF), genetic programming (GP), and a dynamic neuro-fuzzy local modelling system (DNFLMS), respectively. These were then used as inputs to a mechanistic groundwater flow-surface water interaction model (MODFLOW). A DNFLMS was also used to simulate downstream flow and groundwater levels for comparison with MODFLOW outputs.

MODFLOW and DNFLMS outputs were consistent. They indicated declines in streamflow on the order of 21 to 23% for MODFLOW and DNFLMS (A1B scenario), respectively, and 27% in both cases for the A2 scenario under severe drought conditions by 2058-2059, with little if any change in groundwater levels.

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