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Modelling the distribution of tritium in groundwater across South Africa to assess the vulnerability and sustainability of groundwater resources in response to climate change

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Groundwater is critical for sustaining human populations, especially in semi-arid to arid areas, where surface water availability is low. Shallow groundwater is usually abstracted for this purpose because it is the easiest to access and assumed to be renewable and regularly recharged by precipitation. Renewable, regularly recharged groundwater is also called modern groundwater, ie groundwater that has recently been in contact with the atmosphere. Tritium can be used to determine whether or not a groundwater resource is modern because the half-life of tritium is only 12.36 years and tritium is dominantly produced in the upper atmosphere and not in the rock mass. For this reason, groundwater with detectable tritium activities likely has a residence age of less than 50 years. In this study, tritium activities in 277 boreholes distributed across South Africa were used to develop a national model for tritium activity in groundwater in order to establish the extent of modern groundwater across South Africa. The tritium model was combined with modelled depth to water using 3079 measured static water levels obtained from the National Groundwater Archive and validated against a separate set of 40 tritium activities along the west coast of South Africa. The model showed good agreement with the distribution of rainfall which has been previously documented across the globe (Gleeson et al., 2015), although the arid Karoo basin in south west South Africa shows higher than expected tritium levels given the very low regional precipitation levels. To assess the vulnerability of groundwater to degradation in quality and quantity, the tritium model was incorporated into a multi-criteria evaluation (MCE) model which incorporated other indicators of groundwater stress including mean annual precipitation, mean annual surface temperature, electrical conductivity (as a proxy for groundwater salinization), potential evaporation, population density and cultivated land usage. The MCE model was then forward projected using predicted climate change from the ECHAM5/MPI-OM model for SRES high emission scenario A2. The resultant groundwater vulnerability map for South Africa indicates that groundwater across large parts of western South Africa, particularly along the west coast and Northern Cape regions, is extremely vulnerable to deterioration in both quality and quantity and this deterioration is most strongly linked to mean annual precipitation and potential evaporation. Accordingly, the west coast region of South Africa is now, and will remain in the future, the most vulnerable region to climate change in South Africa. Further investigation of the predicted evolution of climate, biodiversity and agricultural capacity in this region will be critical for developing sustainable groundwater management protocols.

Gleeson, T., Befus, K.M., Jasechko, S., Luijendijk, E., and Bayani Cardenas, M., 2016. The global volume and distribution of modern groundwater. Nature Geosciences, 9, 161-167.