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Inferring groundwater recharge associations to ephemeral rivers, land use and climate using multi-decadal groundwater level observations from the semi-arid Limpopo basin of South Africa

Master Thesis

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Submitted: 3rd September 2019

Abstract

Determining the long-term sustainability of groundwater use in semi-arid regions with high climate variability requires an understanding of the recharge processes that replenish the aquifers as well as their major drivers that significantly affecting their temporal and spatial variability. Ten hydrographs that range from 13 to 45 years in duration, across multiple aquifer settings, were chosen on the basis of their proximity to rain gauges, interpretability throughout, and visible evidence of recharge events in the records. Recharge is quantified using: (1) the Water Table Fluctuation method, applying an inverse approach to estimate recharge from the event-based rises in groundwater level at yearly intervals; and (2) the HYDRUS 1D model: computing recharge using a dynamic soil-moisture balance model incorporating rainfall, evapotranspiration, soil properties and vegetation characteristics. Two opposing responses observed in diffuse settings display seasonal and episodic groundwater responses respectively; these are calibrated using contrasting root depths representative of their respective land use/cover environments. The seasonal groundwater response is simulated with respect to root depths that vary between 100cm_max and 15cm_min associated to cultivated land that estimates a diffuse flux of 152.1 ± 80.5 mm. In contrast, the episodic response is simulated using a perennial root system of 2m depth, typical of natural vegetation, estimating fluxes at 56.7 ± 45.6 mm. The use of this calibration and the WTFM at sites in proximity to the ephemeral rivers are used to infer the presence of focused recharge in conjunction with river flow data from a number of gauges. The hydrographs show that groundwater levels after each rainy season, Oct-Apr, are highly variable in terms of recovery from the previous dry season levels though large episodic recharge events that disproportionately contribute to groundwater replenishment. Hence, characterising these recharge events with regards to their recharge sources, reveals complex relationships between rainfall and episodic rises in diffuse contexts that is not just related to rainfall volumes but also its distribution within seasons. In terms of focused recharge responses, flow gauge data reveals synchronicity between increased volumes of river discharge and rises in groundwater levels. Correlations from the records show a tendency for episodic recharge to occur during La Niña years, but no direct relationship to increasingly negative ENSO indices. Finally, the inference of focused recharge with respect to hydrograph observations shows that wells located upstream and closer to these ephemeral rivers, at three different sights, are indicative of higher focused recharge volumes.