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

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Introduction and purpose of the study

- To understand the governing processes and variables that affect the temporal and spatial variability of recharge from a number of sites.
  - The factors discussed here are not an exhaustive list

- Attempt to improve the conceptual model of recharge in the Limpopo basin, thus addressing some of the barriers to groundwater sustainability.
The Limpopo Basin

- Area: 420000 Km² (SA 45%)
- Semi-arid climate
- Rainy season (Oct-Apr)
- Average rainfall 590mm/a
- Population: 15m (SA)

*(Statistics: LIMCOM, 2013)*

Image: Traumbauer et al. 2015
Map of the sites

Image: Cai et al. 2017
Advantages of long-term groundwater level observations

- Observations show presence and recurrence of episodic recharge events, these are defined by substantial groundwater level rises in the record.
Recharge estimation methods

• Conjunctive use of two methods in both diffuse and focused recharge contexts

1) Water Table Fluctuation method: Recharge estimates are dependant on event based rises in the saturated zone (includes both potential diffuse and focused recharge components).

2) Soil-moisture balance model: Hydrus-1D, calculates fluxes at the base of the root zone, thus estimates diffuse recharge component.
Result one: Effects of changing Land use / cover

• In a diffuse setting, far away from the ephemeral river, both seasonal and episodic responses in groundwater levels were observed. The responses are then calibrated for using Hydrus-1D.

Annual dynamic groundwater level responses
Calibrated using root system at 100cm_max_15cm_min, changeable with the growing season

Episodic groundwater level responses
Calibrated using perennial root system at 2m depth, typical of natural savannah vegetation
Result one: Effects of changing Land Use

- In a diffuse setting, far away from the ephemeral river, both seasonal and episodic responses in groundwater levels were observed. The responses are then calibrated for using Hydrus-1D.

Annual dynamic groundwater level responses

Calibrated using root system at 100cm_max_15cm_min, changeable with the growing season.
Result two: Evidence of focused recharge

- The WTFM and Hydrus 1D recharge estimations are then carried out at sites next to the river.
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WTFM estimations (Diffuse and focused sources)

Diverging recharge estimates, indicator for focused recharge

Hydrus 1D (Diffuse)
Result two: Evidence of focused recharge

- Two wells from upper section of the Mogalakwena river.
- Coinciding daily flow and groundwater level rises.
Result three: Climatic factors affecting recharge

- Why do years of similar rainfall sums have different groundwater level responses?
- Two years of relatively extreme rainfall: Unimodal vs. Bimodal distribution
- Large single event (>150mm) in 09-10 produced no response
Result three: Effects of ENSO on recharge

- The prevalence of large episodic recharge events coincides with negative indices, particularly in 1995-96 and 1999-00 seasons, observed consistently throughout the region during these years.

- The occurrence of negative ENSO coefficients, La Niña conditions, acts as a precursor but not an accurate predictor of episodic recharge.

![Graphs showing the relationship between ENSO coefficients and recharge](image-url)
Conclusions and groundwater management implications

1. Episodic events observed in the record are critical for aquifer replenishment and groundwater sustainability within the region.

2. Greater cultivated land use, typified by seasonal root depths, leads to enhanced diffuse recharge fluxes.

3. Focused recharge is the dominant recharge mechanism in proximity to ephemeral rivers, this may result in larger potential resources in these areas.

4. High inter-annual climate variability is responsible for recurring episodic recharge events that punctuate the long-term records, partially driven by ENSO regimes.
References


• Cai et al 2017, Mapping Irrigated Areas in the Limpopo Province, South Africa, IWMI

• LIMCOM (2013) Consultancy services for the project on the Limpopo River basin Monographs, AGES (Pty) Ltd, S Meyer, M Hill, Reviewed by Dr M Levin, LIMCOM with support of GIZ