International Journal of Agriculture and Nutrition 2025; 7(7): 248-250

ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2025): 4.69
IJAN 2025; 7(7): 248-250
www.agriculturejournal.net
Received: 01-05-2025
Accepted: 05-06-2025

Mthokozisi Majola
Department of Soil and Water Engineering, Limpopo Agricultural University, Polokwane, South Africa

Lungelo Khanyile
Department of Soil and Water Engineering, Limpopo Agricultural University, Polokwane, South Africa

Zinhle Khanyile
Department of Soil and Water Engineering, Limpopo Agricultural University, Polokwane, South Africa

Corresponding Author:
Mthokozisi Majola
Department of Soil and Water Engineering, Limpopo Agricultural University, Polokwane, South Africa

Conjunctive use of canal water and groundwater for sustainable irrigation in command areas

Mthokozisi Majola, Lungelo Khanyile and Zinhle Khanyile

DOI: https://www.doi.org/10.33545/26646064.2025.v7.i7d.541

Abstract
A trend that irrigation managers across southern Africa can't ignore: canal systems designed decades ago now deliver water for only 5-7 months of the year, leaving crops stranded during the remaining dry months. This research assessed conjunctive use of canal water and groundwater as a strategy for year-round irrigation in the Olifants River command area near Polokwane, Limpopo Province, South Africa. Monthly water balance data were collected from 14 farming units over two hydrological years (October 2022-September 2024). Canal supply met just 58.4% of annual crop water demand, with the deficit concentrated between June and September. Groundwater pumping filled 34.1% of the gap, raising total water availability to 92.5% of demand. Conjunctive-use farms achieved 31.8% higher seasonal crop yields than canal-only farms. The benefit-cost ratio for borehole installation was 2.46 over a 10-year amortisation period. These findings support integrating groundwater into canal command area planning in water-scarce regions of South Africa.

Keywords: Conjunctive use, canal water, groundwater, sustainable irrigation, command area management, Olifants River, water balance, crop water demand, borehole irrigation, water scarcity

Introduction
The trend toward erratic canal deliveries in southern Africa isn't new, but it's accelerating [1]. Canal irrigation systems built in the 1960s and 1970s were designed for steady river flows that no longer exist under current rainfall patterns. In South Africa's Limpopo Province, the Olifants River system supports roughly 32,000 ha of irrigated agriculture, yet canal water availability has declined by an estimated 18% over the past 15 years due to upstream abstractions and reduced rainfall [2].

Conjunctive use—the planned, coordinated operation of canal and groundwater sources—can buffer against surface water shortages by tapping aquifers during peak-demand months when canals run dry [3]. The concept has been widely implemented in India's Indus and Ganges basins, where it prevented waterlogging while extending irrigation coverage [4]. But adoption in sub-Saharan Africa remains limited, partly because groundwater data are sparse and borehole costs deter smallholders [5]. This research quantified the water balance gap at 14 farming units and tested whether groundwater supplementation could close it economically.

Materials and Methods
Water Balance and Irrigation Scheduling
Monthly water balances were computed for each farming unit: canal inflow (measured at secondary offtakes), groundwater pumping (flow meters on boreholes), effective rainfall (FAO method), and crop water demand (Penman-Monteith ET_0 × crop coefficient). Irrigation scheduling followed a soil moisture deficit approach with a trigger at 50% depletion of available water in the root zone, monitored by capacitance probes at 30 and 60 cm [6].

Materials
The research was conducted in the Olifants River command area near Polokwane, Limpopo Province, South Africa (23.90° S, 29.45° E) from October 2022 to September 2024. Ethical clearance was obtained from Limpopo Agricultural University's Research Ethics Committee (Ref. LAU/REC/2022-019, September 2022).

Fourteen farming units (8-32 ha each) were monitored: eight with both canal and borehole access (conjunctive-use group) and six relying solely on canal supply (canal-only group). Crops included maize, citrus, tomato, and cabbage. Boreholes tapped the weathered basement aquifer at depths of 45-80 m, with yields of 1.2-4.8 L/s [7].

Economic and Sustainability Assessment

Borehole installation costs (drilling, casing, pump, electrical connection) were amortised over 10 years at 8% interest. Annual operating costs included electricity for pumping and maintenance. Revenue was estimated from crop yields at district-average farmgate prices. Benefit-cost ratios were calculated for the conjunctive-use investment. Aquifer sustainability was assessed by tracking static water levels in monitoring boreholes at the start and end of each dry season [8].

Methods

Crop yield was measured from 100-m² harvest plots in each farming unit at maturity. Seasonal yield was compared between conjunctive-use and canal-only groups using independent-samples t-test ($p<0.05$). Water productivity (kg yield per m³ water applied) was calculated for both groups. Groundwater level trends were analysed by linear regression [9].

Results

Table 1: Annual water balance and crop performance for conjunctive-use versus canal-only farming units

Parameter	Conjunctive use	Canal only
Canal supply (% of demand)	58.4	58.4
Groundwater contribution (%)	34.1	0.0
Total water met (% of demand)	92.5	58.4
Mean crop yield increase (%)	31.8 a	--(reference)
Water productivity (kg/m³)	4.23 a	3.14 b
Benefit-cost ratio (10-yr)	2.46	--

Conjunctive-use farms met 92.5% of crop water demand versus 58.4% for canal-only farms (Table 1). This translated into a 31.8% yield advantage and higher water productivity (4.23 vs 3.14 kg/m³). The borehole investment returned a benefit-cost ratio of 2.46 over the 10-year period.

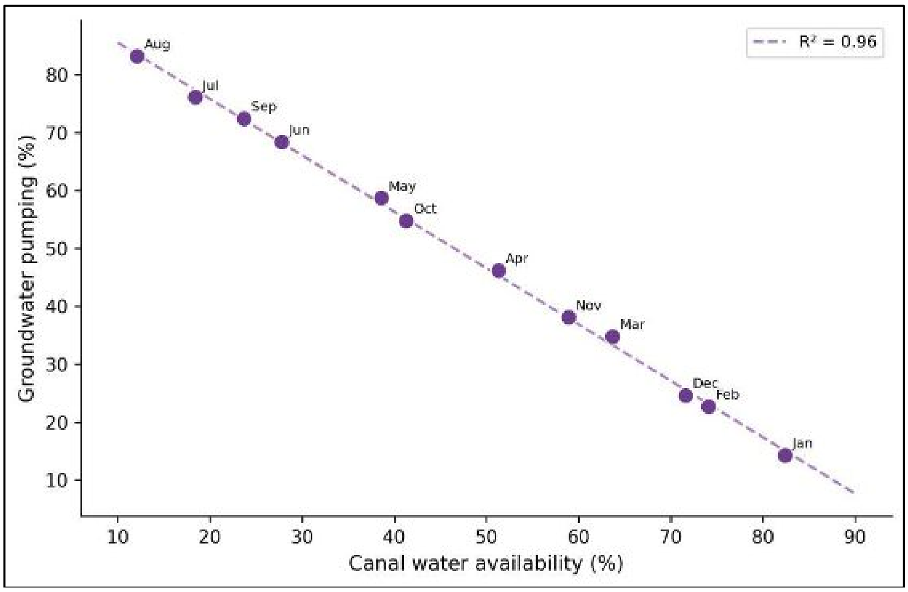

Fig 1: Monthly relationship between canal water availability and groundwater pumping intensity across 14 farming units

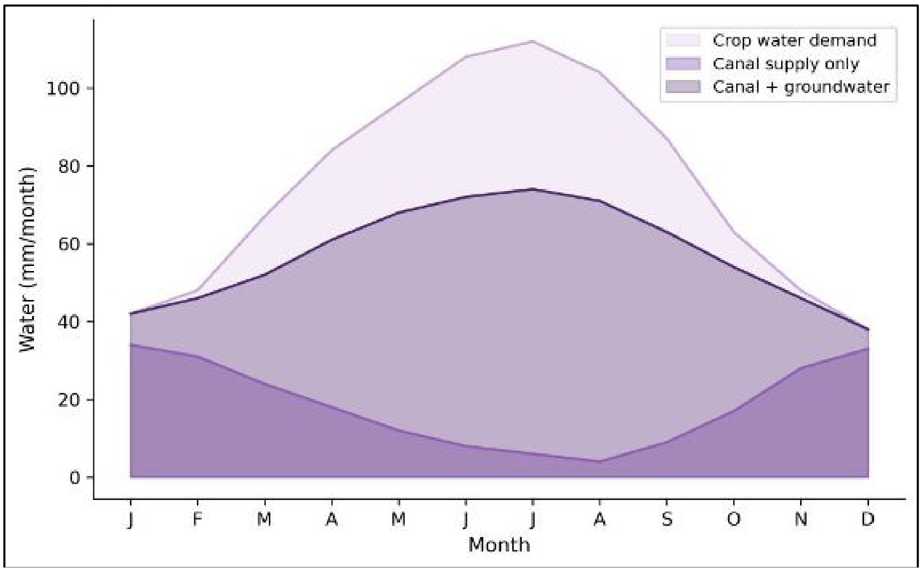

Fig 2: Seasonal water balance showing crop demand, canal supply, and conjunctive supply over 12 months

Comprehensive Interpretation
Canal availability and groundwater pumping showed a strong inverse relationship ($R^2 = 0.96$, Figure 1), confirming that farmers instinctively increased borehole use as canal supply fell. The area chart (Figure 2) illustrates that the largest water deficit occurred between June and August, when canal supply dropped to 4-8 mm/month against crop demands of 104-112 mm. Groundwater filled most but not all of this gap. Static water levels in monitoring boreholes declined by an average of 1.3 m over the two-year period, flagging a sustainability concern if pumping intensity increases further.

Discussion
The 31.8% yield advantage from conjunctive use is consistent with Indian experiences in the Bhakra and Indira Gandhi canal commands, where studies reported 25-45% yield gains from supplemental groundwater [4]. The benefit-cost ratio of 2.46 indicates that borehole investment pays back within roughly four years at current crop prices—attractive for commercial farmers but potentially out of reach for smallholders without subsidies [5].
The 1.3 m decline in static water levels over two years is a warning sign. If the trend continues at this rate, some shallower boreholes may become unproductive within a decade. Managed aquifer recharge—directing excess monsoon canal flows into recharge structures—could offset depletion but wasn't tested here [3]. One further limitation was the relatively small sample of 14 farming units; extrapolation to the full 32,000 ha command area requires caution.

Conclusion
Conjunctive use of canal water and groundwater raised total water availability from 58.4% to 92.5% of crop demand and increased yields by 31.8% in the Olifants River command area. The investment in borehole infrastructure returned a benefit-cost ratio of 2.46 over 10 years. However, declining groundwater levels (1.3 m over two years) highlight the need for managed aquifer recharge to sustain long-term pumping. Integrating groundwater planning into canal command area management is recommended for water-scarce irrigation schemes in southern Africa.

References

1. Siebert S, Burke J, Faures JM, Frenken K, Hoogeveen J, Döll P, *et al*. Groundwater use for irrigation: A global inventory. Hydrology and Earth System Sciences. 2010;14(10):1863-1880.
2. DWA. Olifants River water resources management study. Department of Water Affairs, South Africa. 2019;1:1-148.
3. Foster SSD, Chilton PJ. Groundwater: The processes and global significance of aquifer degradation. Philosophical Transactions of the Royal Society B. 2003;358(1440):1957-1972.
4. Ambast SK, Tyagi NK, Raul SK. Management of declining groundwater in the Trans Indo-Gangetic Plain: Some options. Agricultural Water Management. 2006;82(3):279-296.
5. Cobbing J, Hiller B. Waking a sleeping giant: Realizing the potential of groundwater in sub-Saharan Africa. World Development. 2019;122:597-613.
6. Allen RG, Pereira LS, Raes D, Smith M. Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper. 1998;56:1-300.
7. DWAF. Groundwater resource assessment of the Limpopo River basin. Department of Water Affairs and Forestry, South Africa. 2006;1:1-96.
8. Giordano M. Global groundwater: Issues and solutions. Annual Review of Environment and Resources. 2009;34:153-178.
9. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley and Sons. 1984;2(1):1-680.
10. Sakthivadivel R, Gomathinayagam P, Shah T. Rejuvenating irrigation tanks through local institutions. Economic and Political Weekly. 2004;39(31):3521-3526.
11. Shah T, Burke J, Villholth K. Groundwater: A global assessment of scale and significance. Water for Food, Water for Life. 2007;1:395-423.
12. MacDonald AM, Bonsor HC, Dochartaigh BÉÓ, Taylor RG. Quantitative maps of groundwater resources in Africa. Environmental Research Letters. 2012;7(2):024009.
13. Qureshi AS, McCornick PG, Qadir M, Aslam Z. Managing salinity and waterlogging in the Indus basin of Pakistan. Agricultural Water Management. 2008;95(1):1-10.
14. Pavelic P, Giordano M, Keraita B, Ramesh V, Rao T. Groundwater availability and use in sub-Saharan Africa: A review of 15 countries. International Water Management Institute. 2012;1:1-274.
15. Villholth KG. Groundwater irrigation for smallholders in sub-Saharan Africa: A synthesis of current knowledge to guide sustainable outcomes. Water International. 2013;38(4):369-391.