Groundwater recharge from intense rainfall in Indonesia: evidence from East Kalimantan

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Abstract

This study investigates how rainfall intensity controls groundwater recharge in Indonesia using stable isotopes ($\delta^{18}O$ and $\delta^{2}H$) and chloride mass balance (CMB). Across Indonesia, groundwater isotopic signatures indicate preferential recharge from heavier rainfall. In East Kalimantan, daily isotope observations reveal event-driven recharge that is less apparent in monthly averages.

Keywords: groundwater recharge; intense rainfall; amount effect; stable isotopes.

Introduction

Groundwater buffers drought and sustains water supply. Increasing demand in East Kalimantan, including the development of Nusantara, requires better knowledge of renewable recharge. Rainfall totals alone may obscure the role of individual intense events.

Study area

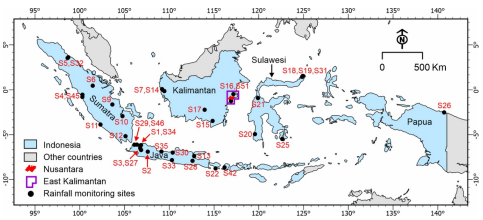

Fig. 1. Indonesia and the East Kalimantan study area.

National evidence

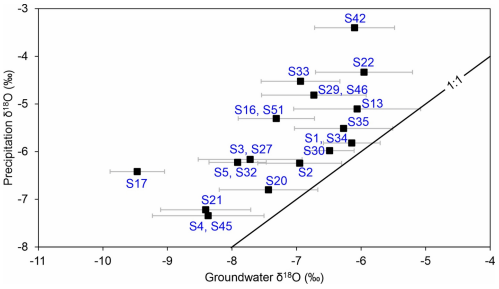

Fig. 4. Groundwater $\delta^{18}O$ is generally lower than amount-weighted monthly precipitation $\delta^{18}O$.

Across 16 locations, estimated monthly rainfall thresholds associated with recharge bias range from ~40 to ~350 mm/month (above ~50th percentile).

Research Method

Data and sampling

Monthly precipitation isotopes: 27 locations across Indonesia; groundwater isotopes: 16 locations. East Kalimantan: daily rainfall isotopes (n = 108), rainfall chloride (n = 97), and fresh groundwater (n = 38). New daily samples: April–July 2024.

Stable isotope analysis

Classify rainfall into quartiles; compute precipitation-weighted $\delta^{18}O$ and $\delta^{2}H$, compare daily and monthly local meteoric water lines (LMWLs), and assess isotope offsets.

$$\delta P\text{-}AW = \Sigma(P_j\,\delta_j) / \Sigma P_j$$

Chloride mass balance (CMB)

Estimate precipitation-derived recharge from chloride concentrations in rain and fresh groundwater.

$$GwR\ (\%) = 100 \times Cl_p\ / Clgw$$

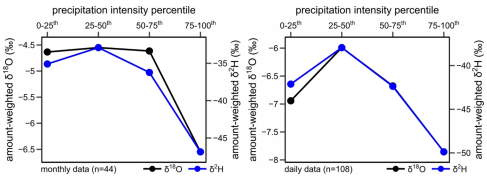

Fig. 3. Daily versus monthly precipitation isotopes by intensity percentile in East Kalimantan.

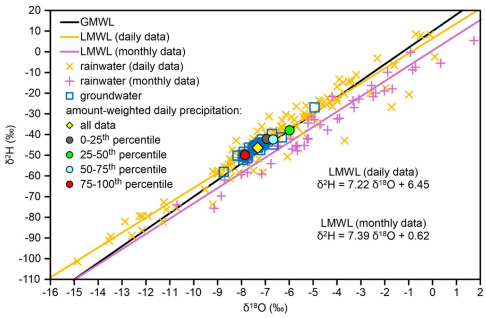

Fig. 5. Groundwater and precipitation isotopes in East Kalimantan relative to daily and monthly LMWLs.

Figures 1, 3–5 reproduced from Putri et al. (2026), Hydrological Sciences Journal, 71(7), 1466–1475.

Discussion & Result

20/27 — sites show an isotope amount effect

16/16 — groundwater sites show heavy-rainfall recharge bias

12–28% — estimated recharge fraction of precipitation (upper bound)

≈57% — estimated share of recharge from rainfall >75th percentile

Event-driven recharge

Most fresh groundwater samples cluster near daily rainfall in the 50th–100th percentile classes (Fig. 5). Monthly averaging smooths the isotope signature of intense events. Light rainfall can also contribute under favorable infiltration conditions.

Uncertainty

Short daily sampling records limit seasonal and interannual interpretation. CMB relies on conservative, meteoric chloride and may be biased by non-meteoric sources or other processes.

Conclusion

Intense rainfall disproportionately contributes to groundwater recharge in tropical Indonesia. Daily isotope observations better capture event-scale recharge than monthly aggregates. Longer monitoring and residence-time tracers are needed to constrain recharge and inform sustainable groundwater management.

Publication

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