Geochemical footprints in groundwaters of Uganda: a national-scale analysis

Michael Owor[1], Richard G. Taylor[2], Andrew Muwanga[1], Callist Tindimugaya[3]

[1]Makerere University, Kampala; [2]UCL, UK; [3]Ministry of Water and Environment, Uganda

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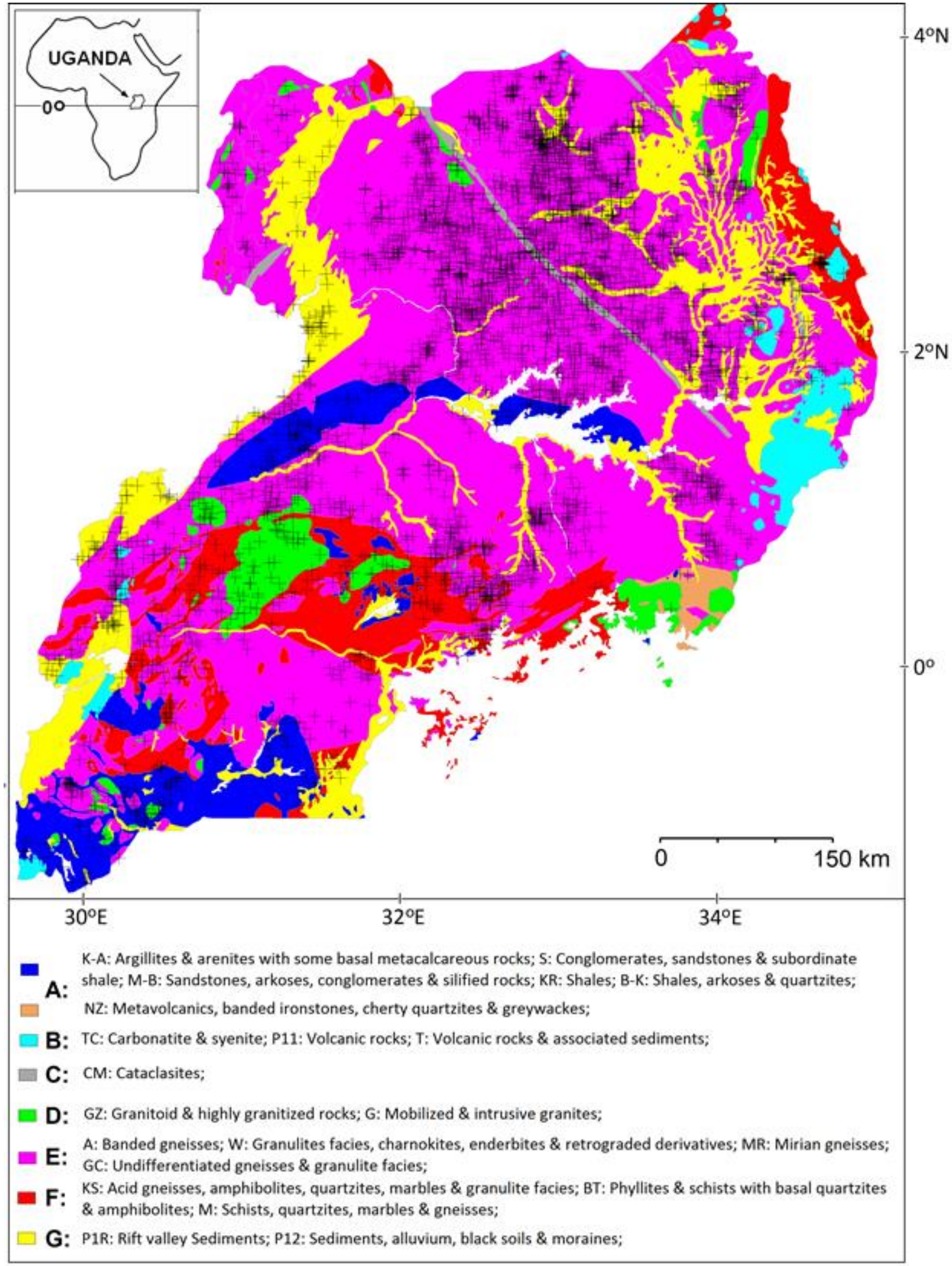
Rationale

- groundwater represents a vital source of freshwater to meet distributed, rapidly rising demands for safe drinking water, irrigation and industry in low-income countries across the tropics;
- intrinsic quality of groundwater derived from natural processes can act as a major impediment to the use and adoption of groundwater as a source of freshwater on both health and aesthetic grounds;
- here, we characterize observed relationships between shallow (**<20 mbgl**) groundwater chemistry from **3721 sites** (selected from a database of >30,000) and mapped lithologies of main aquifer environments to identify predominant water-rock interactions determining baseline groundwater quality;



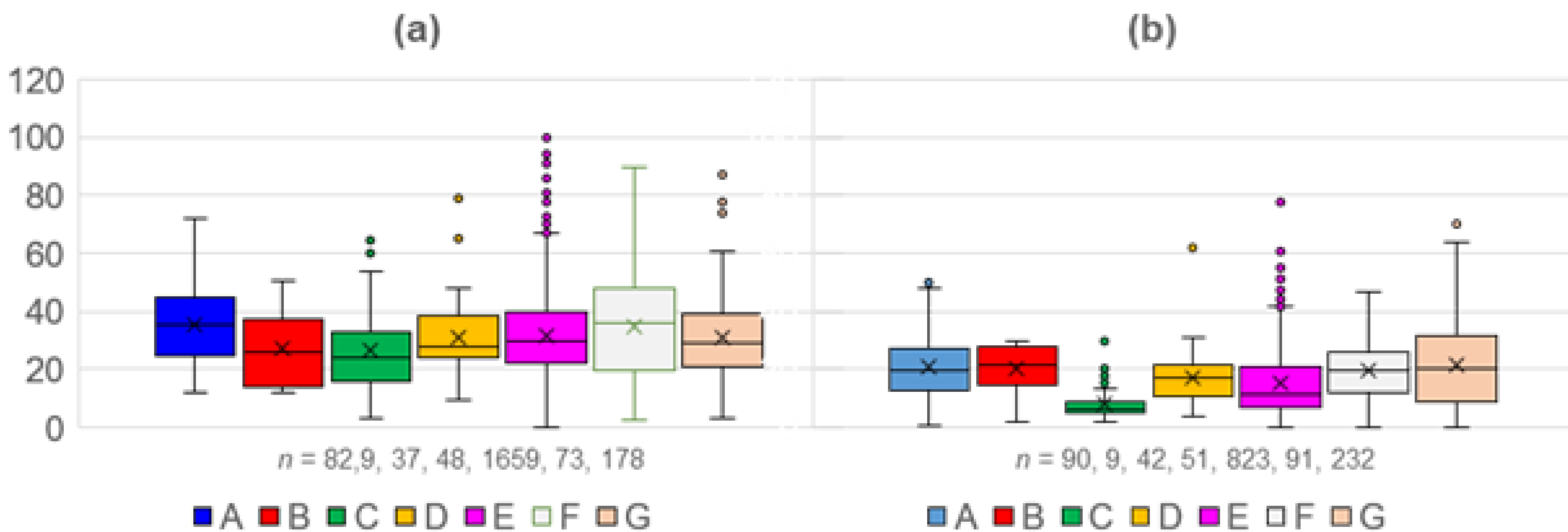
Geology of Uganda grouped into 7 broad categories:

A - Meta-sediments;
B - Volcanics;
C - Cataclasites;
D - Granites;
E - Metamorphics;
F - Meta-igneous;
G - Sediments;

+ hydrochemical sample location

- sampled groundwaters are mostly shallow (69% of samples from depths of <20 mbgl);

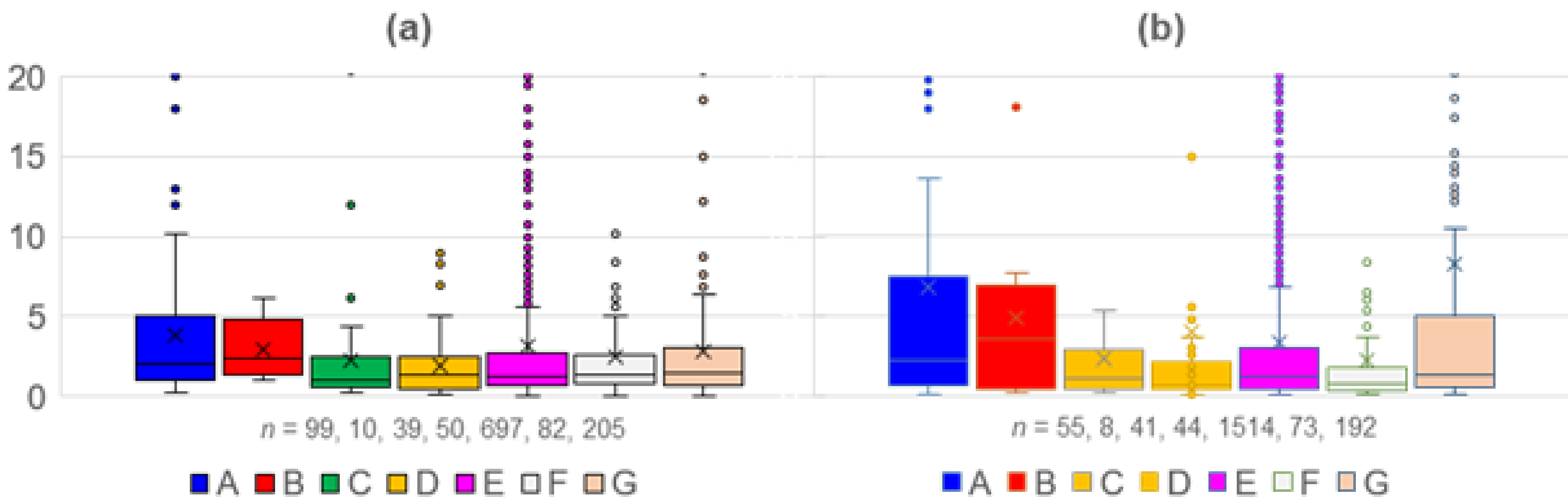
colour codes refer to mapped geological environment (majority are E: metamorphic)



(a) depth (mbgl) to bedrock

(b) static water levels (mbgl) on well completion

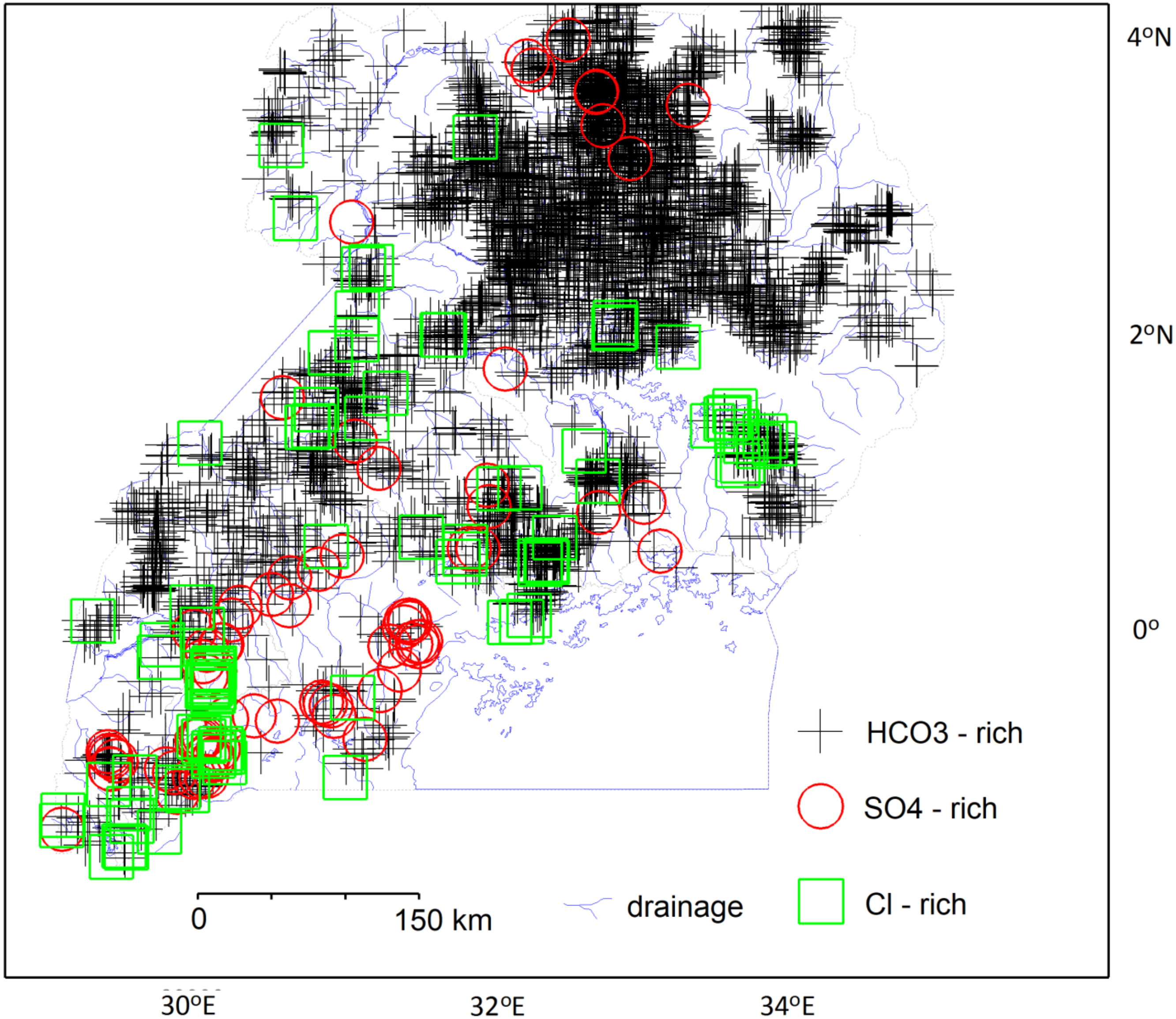
- generally low well yields (82% <3.6 $m^3 \cdot h^{-1}$), <1.8 $m^3 \cdot h^{-1}$ in crystalline basement in Africa, MacDonald *et al.* (2012);
  specific capacity (84% <5 $m^2 \cdot d^{-1}$);
- inferred low *T* and storage serve to regulate naturally groundwater withdrawals, inhibiting overdevelopment;



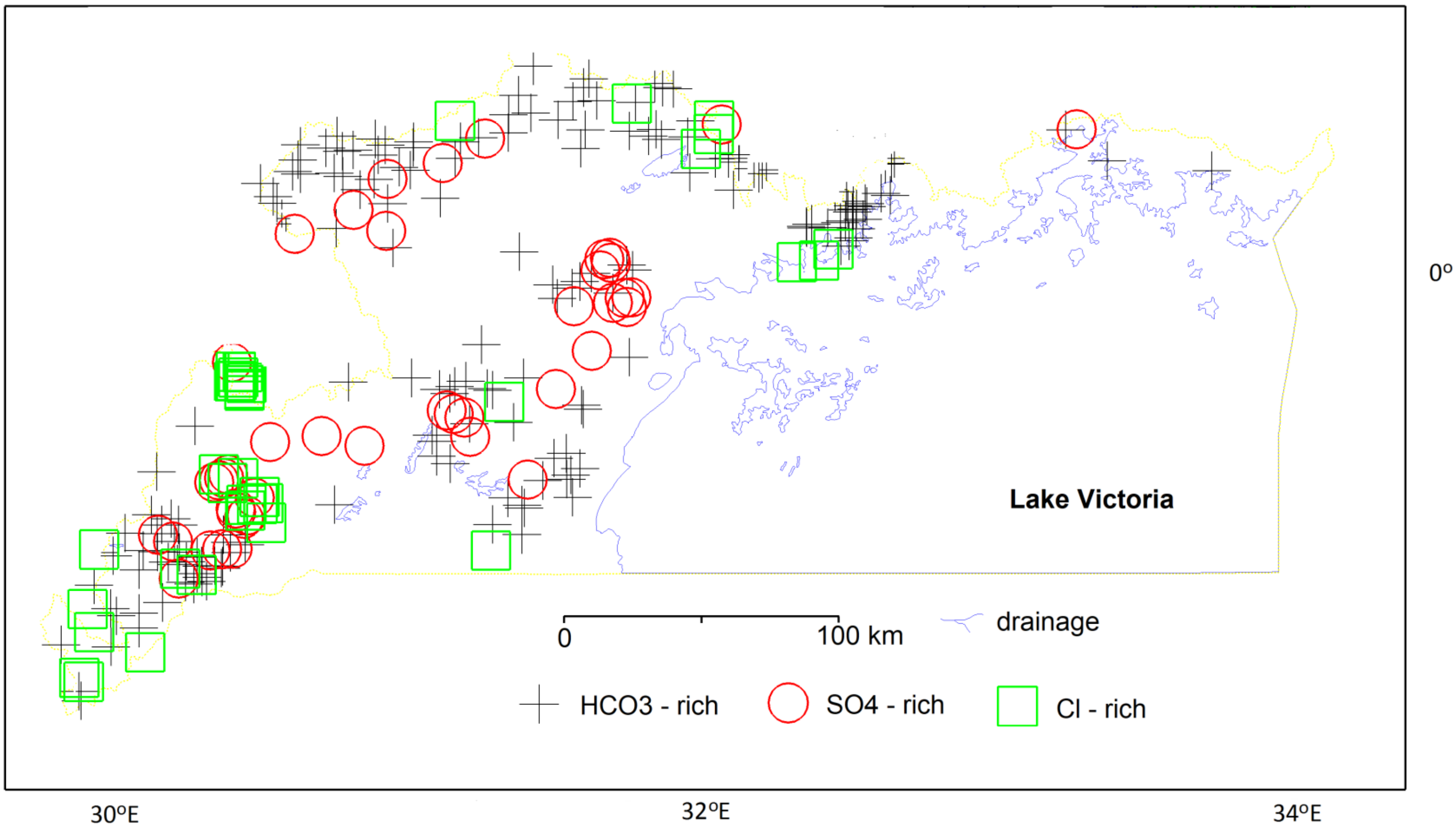
(a) estimated yield ($m^3 \cdot h^{-1}$) from groundwater sources

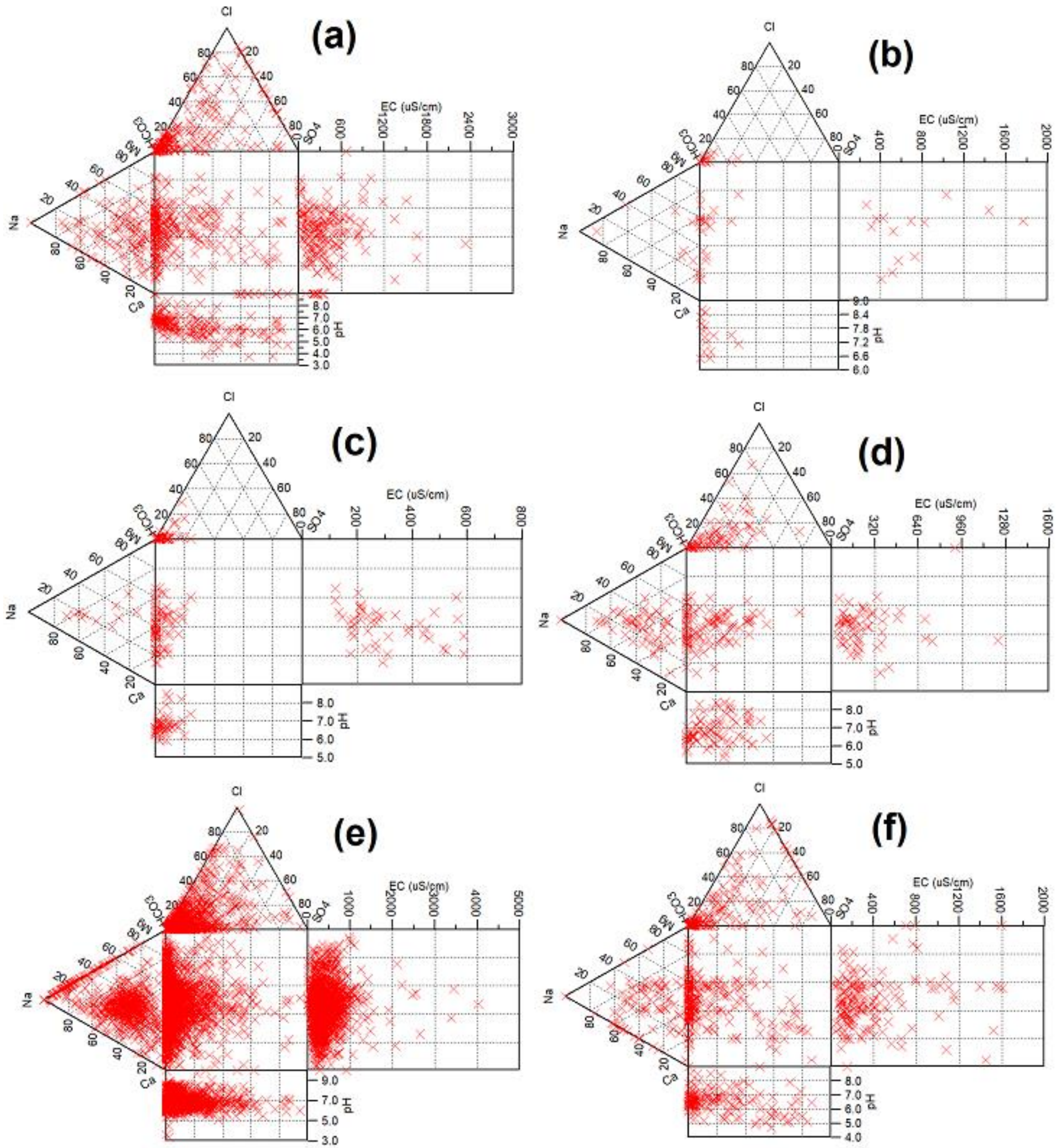
(b) estimated specific capacity ($m^2 \cdot d^{-1}$) on well completion

- predominance bicarbonate (HCO_3^-) anionic facies in 95% of samples;



- SO_4-rich and Cl-rich anionic facies associated with mineralized intrusions, volcanic eruptions, geothermal waters and wetlands (Lake Victoria Management Zone);

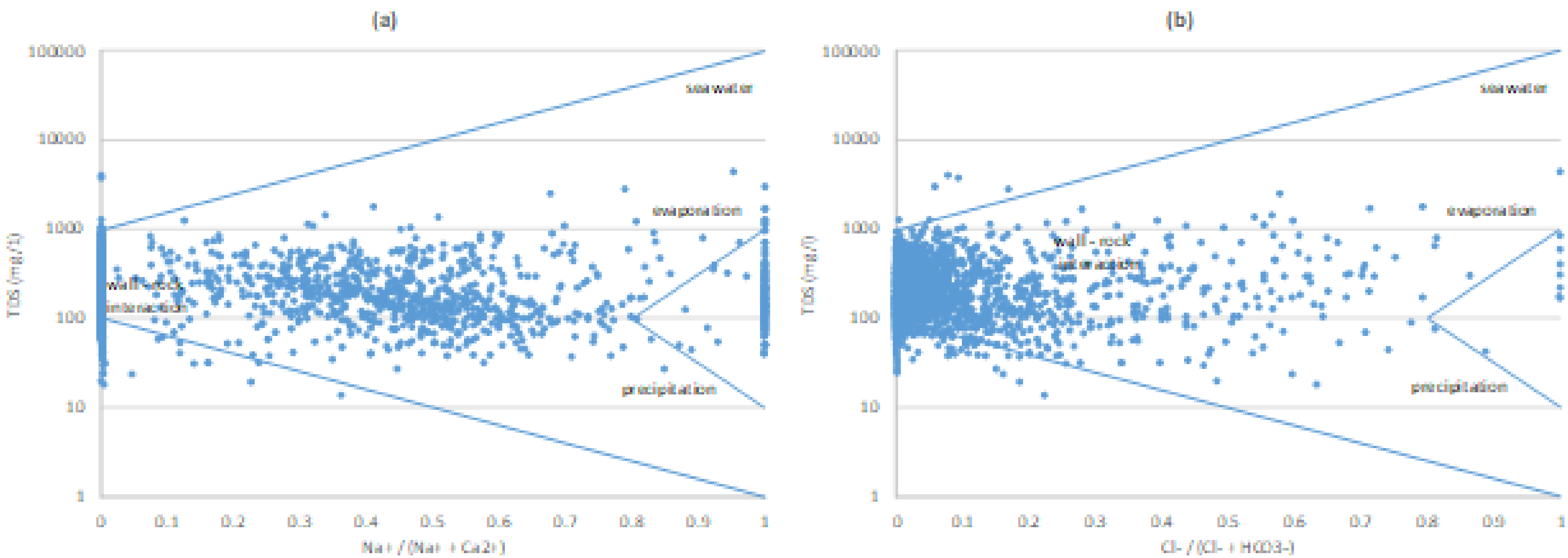




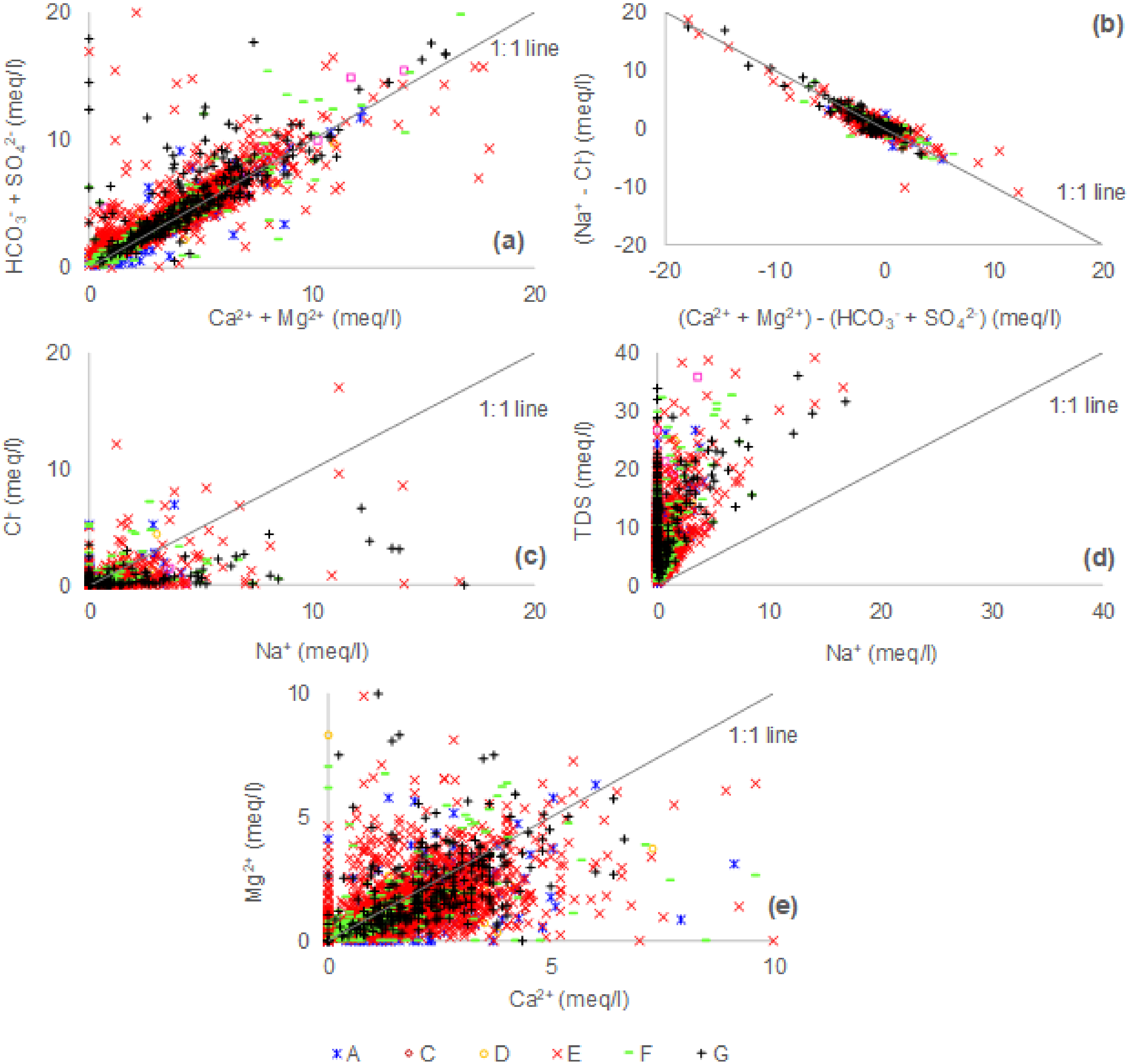
- extended Durov plots of groundwater samples indicate importance of cation-exchange processes where Na^{+} replaces Ca^{2+} and Mg^{2+};

  pH commonly (6-8) and EC <1000 $\mu S \cdot cm^{-1}$;

Gibbs (1970) plots of all groundwater samples show the dominance of water-rock interactions as controlling factors over evaporation and precipitation;



(a) TDS vs. $Na^+/(Na^+ + Ca^{2+})$; (b) TDS vs. $Cl^-/(Cl^- + HCO_3^-)$



groundwater chemistry dominated by silicate weathering - leading to problems of excessive Fe and Mn where weatherable minerals (e.g. micas) bearing these elements occur;

Summary

- at the time of drilling groundwater across Uganda is generally fresh with TDS <8% threshold exceedance of WHO (2011); pH is commonly neutral (6-8) and EC <1000 $\mu S \cdot cm^{-1}$;
- dominance of HCO_3 facies in groundwaters across all lithological categories (95%) reflecting localized flow conditions commonly found in these discontinuous aquifers;
- key hydrogeochemical controls include cation exchange and to a lesser extent evaporation and precipitation of salts;
- natural groundwater chemistry at well completion can be expected to support rising freshwater demand for irrigation, safe major chemical drinking water and industry;
- need to assess how human activity (e.g. land-use change) and effluent (e.g. faecal waste) impact on groundwater quality.


Thank you