Groundwater Models to Support Rural Water Development in Tanzania's Internal Drainage Basin (Kiteto and Simanjiro Districts)

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Background

•Groundwater is the largest and most widely distributed freshwater resource in Africa and is vital for sustaining communities during dry seasons.[1,2,3]

•In rural Tanzania, groundwater Development is difficult because of uncertainties in geology, the existence of low-quality saline water in local areas, and lack of data.[4,5]

•Computer models are a tool for understanding groundwater systems and can be integrated in groundwater development efforts in rural Tanzania.[6]

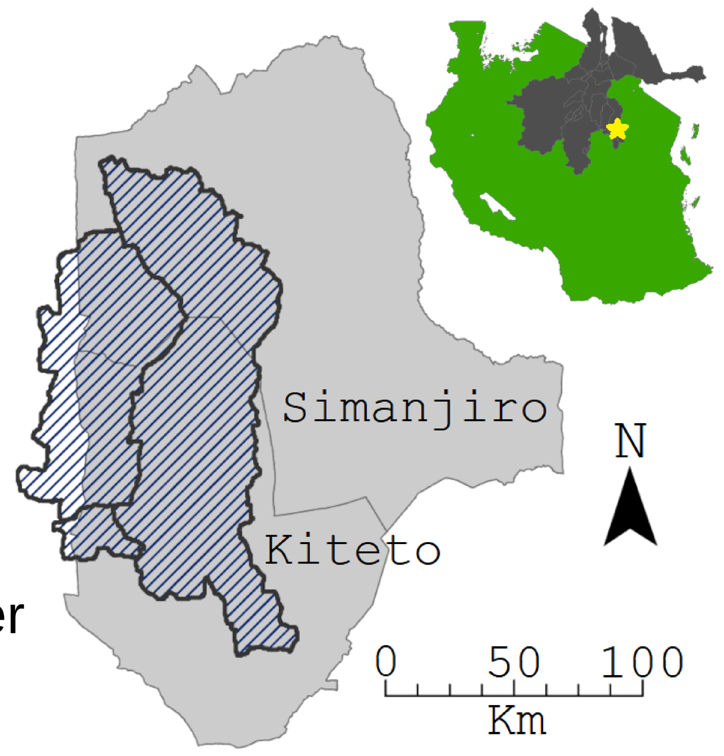

Figure 1. Map of modeled subbasins (blue hatched areas) and the Kiteto and Simanjiro Districts (gray shaded areas). Inset shows Internal Drainage Basin (dark gray infill) within Tanzania and extending into Kenya.

Objective

•Determine groundwater residence times to assess renewability.

•Develop maps of depth to water (Figure 7) and flow patterns for water resource managers.

•Provide model as a management tool for in-country collaborators.

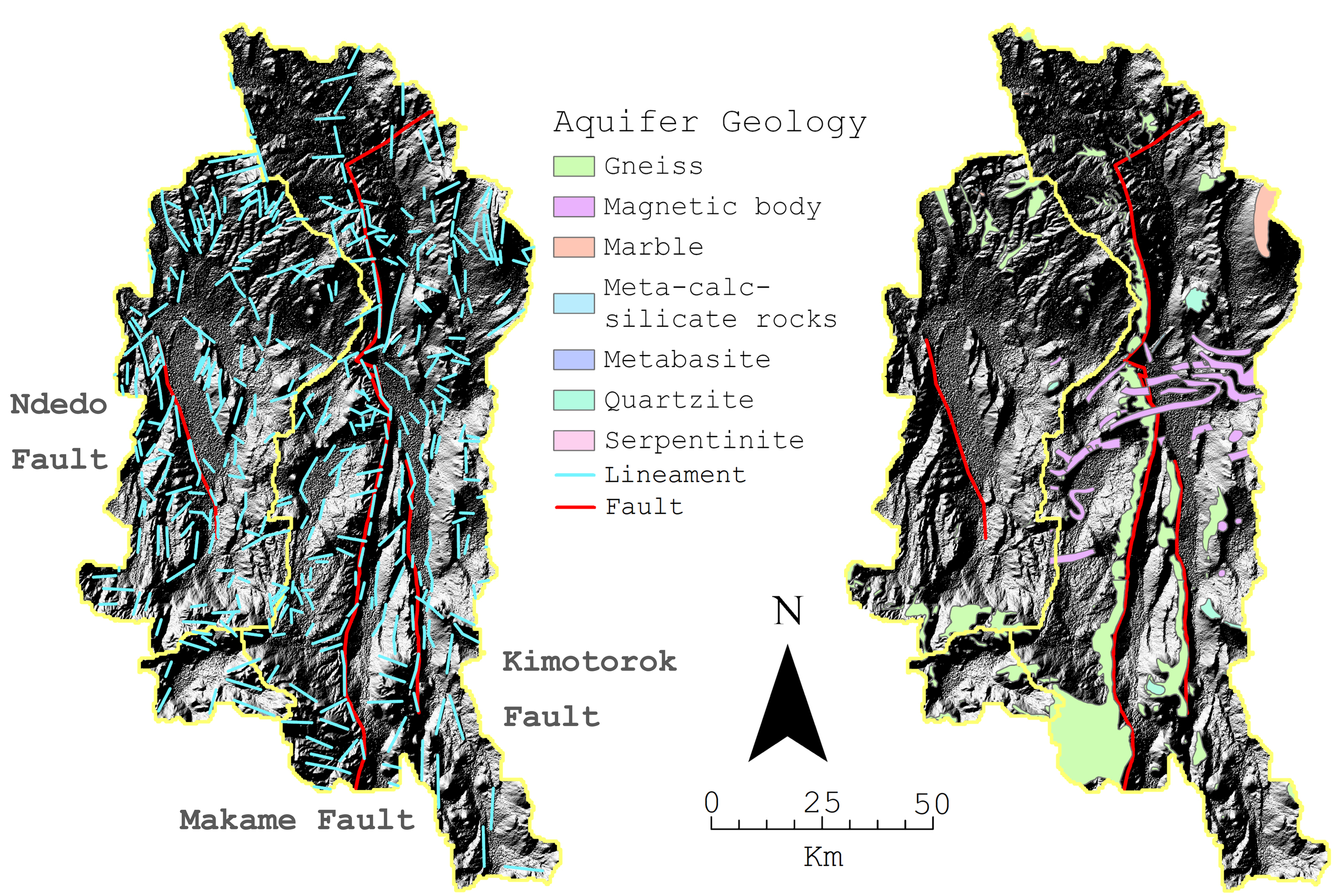

Figure 2. Shaded relief map of the study area including major faults (red), lineaments (cyan, left) and major aquifer geologic bodies (right). Geologic bodies were derived from the Geological Map of Tanzania[7]. Unmapped bodies are gneiss of the Usagaran System intermittently covered by a thin veneer of red sand[8,9].

Methods

•Groundwater model was created in MODFLOW. Grid is 1 km^2 and it increases to a maximum of 64 km^2 within the outer basins (Figure 4).

•Recharge was estimated using the Thornthwaite-Mather water balance approach and varied to find a best-fit with existing water level observations.

•Other parameters that were varied to find a best-fit include hydraulic conductivities of the aquifer, faults, and aquifer thickness.

•Root-mean-square error was used to approximate best-fitness (Figure 5).

•The flux-weighted distribution of residence time from MODPATH was determined for the best-fit model (Figure 6).

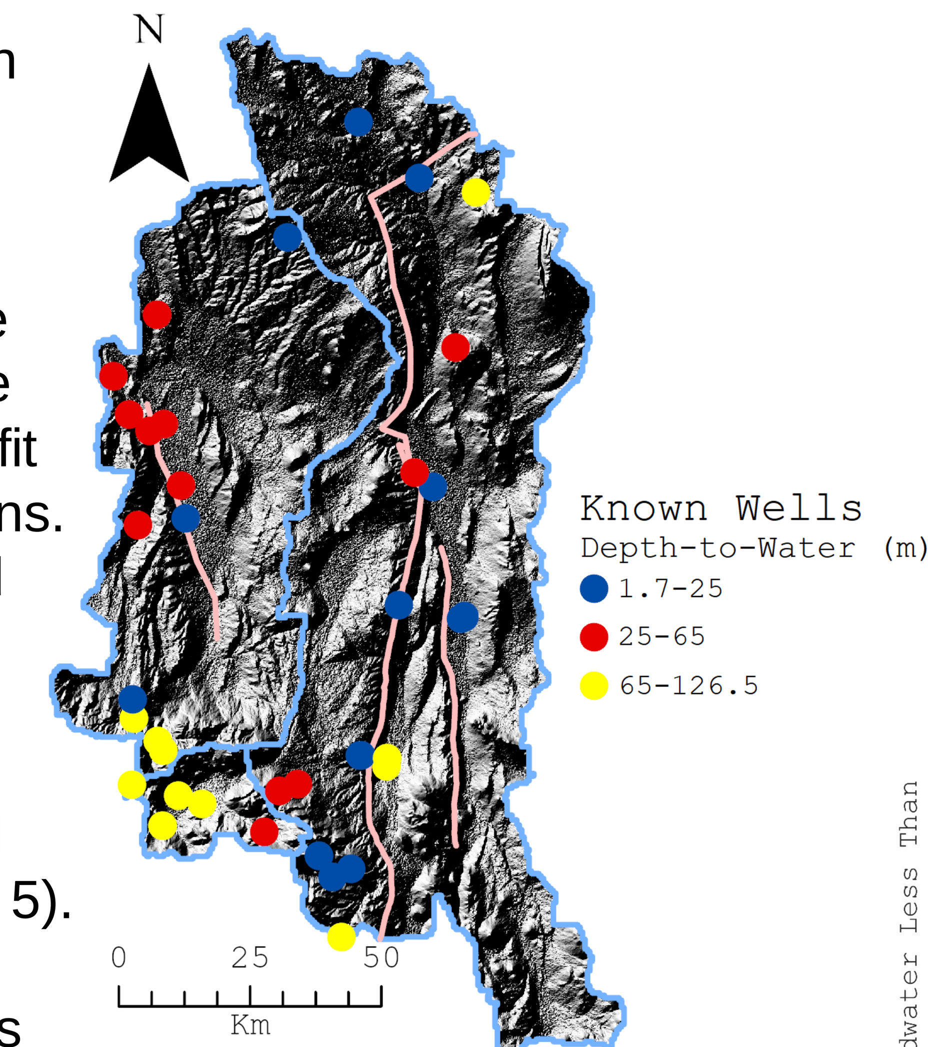

Figure 3. Depth-to-water in meters of 69 known well locations. Depth-to-water generally falls within one of three ranges. Major faults in pink.

Results/Discussion

•The best fitting model was found to have a homogeneous hydraulic conductivity of 1x10^{-6} m/s, with a fault conductivity of 1x10^{-7} and a recharge 50% greater than estimated. Recharge was underapproximated due to the higher percentage of recharge occurring during intense rainfall events (Figure 5).

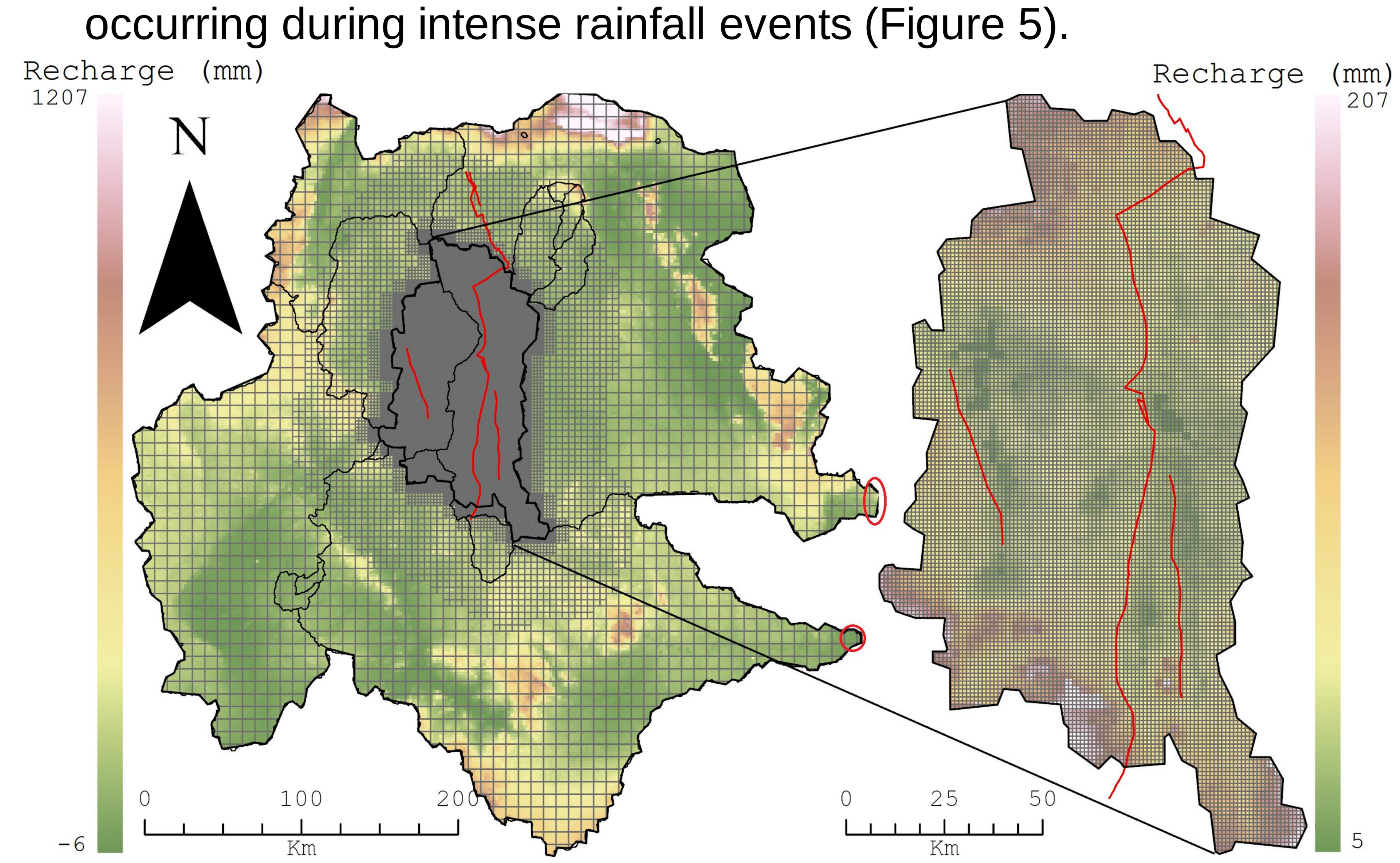

Figure 4. 30-year average annual recharge calculated by the Thornthwaite-Mather method. Scaled for the regional model (left) and study area (right). Red lines represent major regional faults. Light lines represent basin boundaries, The boundaries of the outer basins is represented as a no-flow boundary; the circled areas are constant head boundaries with a head level at the surface.

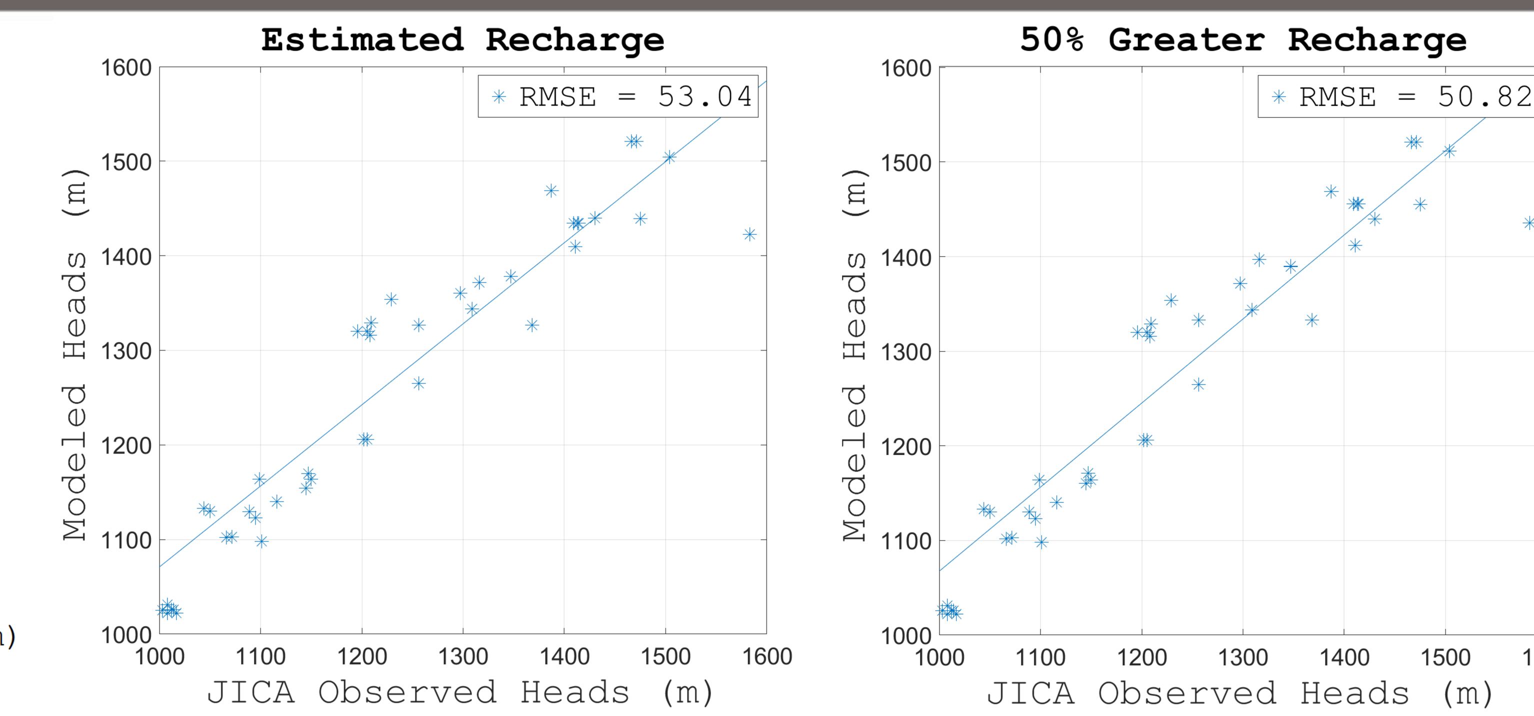

Figure 5. RMSE plots for recharge as predicted by the Thornthwaite-Mather approach (left), and for a recharge 50% greater (right). Well locations are shown in Figure 3.

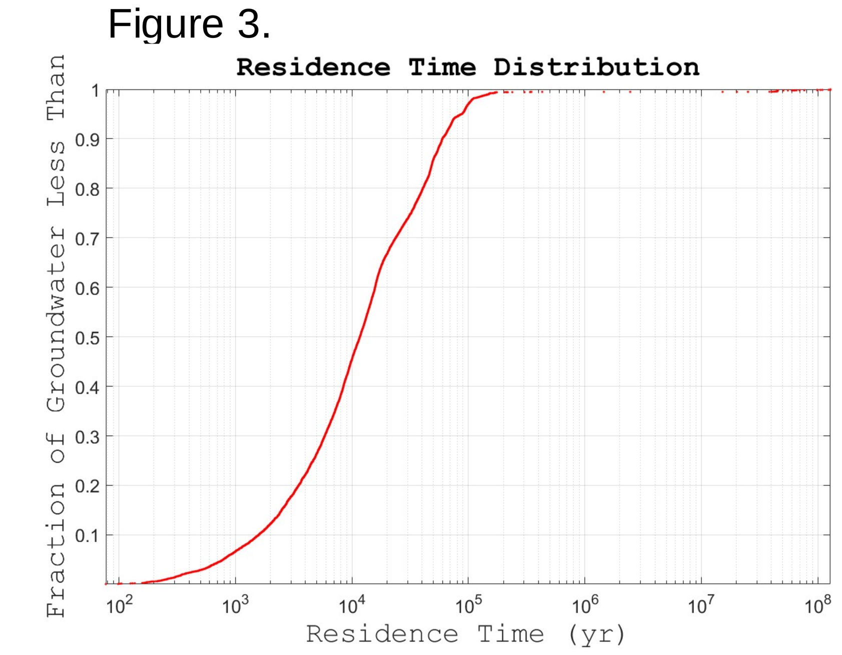

Figure 6. Residence time distribution as predicted by the best-fitting model. The median residence time is 10,000 years, indicating slow renewal of groundwater.

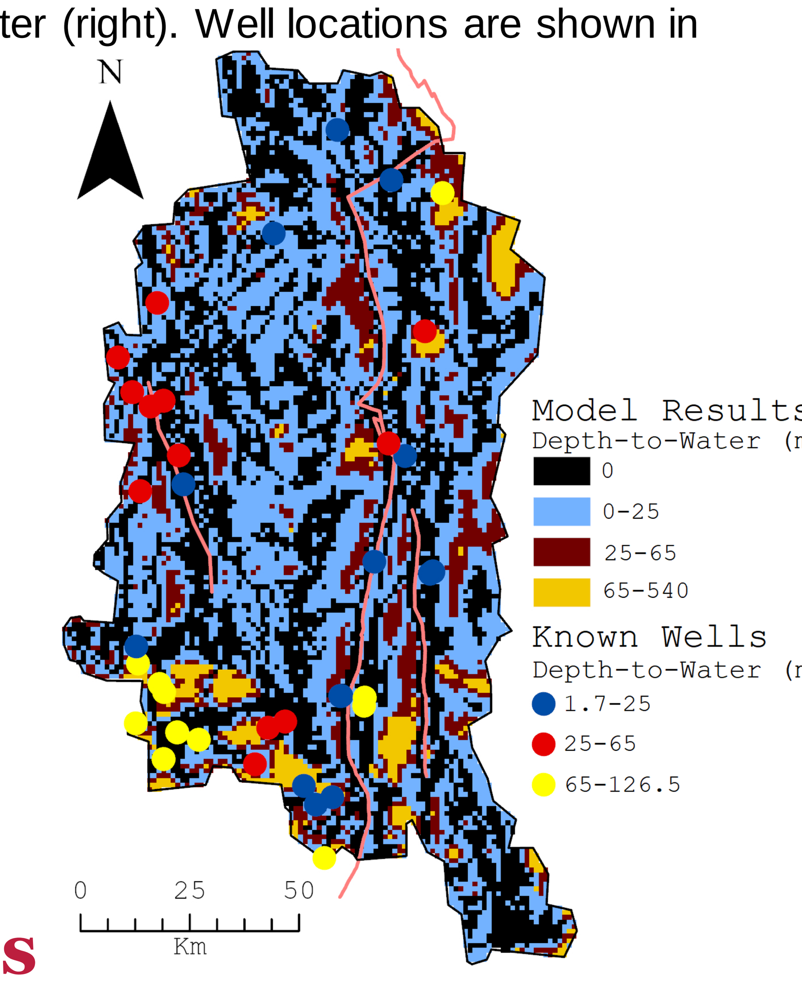

Figure 7. Best-fit modeled depth-to-water results. The land surface is more water-logged than expected, but model development is still ongoing.

Preliminary Conclusions

•Faults play an important role in compartmentalizing sections of the aquifer.

•Simulated groundwater levels match observations consistently, but the surface is still too saturated in some areas of the model (Figure 7).

•95% of groundwater within the basin evaporates or enters wetlands; only 5% flows to adjacent basins.

Future Work

Next steps include further model refinement, preparation of the results in a manuscript for peer-review, and meetings to share the model product with groundwater managers in Tanzania.

Acknowledgments

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