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Combining hydrologic and groundwater modelling to characterize a regional aquifer system within a rift setting (Gidabo River Basin, Main Ethiopian Rift)

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The development of groundwater resources within the Ethiopian Rift is complicated by the strong physiographic contrasts between the rift floor and the highland and by the manifold hydrogeological setting composed of volcanic rocks of different type and age that are intersected by numerous faults. Hydrogeochemical and isotope data from various regions within the Ethiopian Rift suggest that the aquifers within the semi-arid rift floor receive a significant contribution of groundwater flow from the humid highland. For example, the major ion composition of groundwater samples from Gidabo River Basin (3302 km^2) in the southern part of the Main Ethiopian Rift reveals a mixing trend from the highland toward the rift floor; moreover, the stable isotopes of water, deuterium and O-18, of the rift-floor samples indicate a component recharged in the highland. This work aims to assess if the hydrological and hydrogeological data available for Gidabo River Basin is consistent with these findings and to characterize the regional aquifer system within the rift setting. For this purpose, a two-step approach is employed: First, the semi-distributed hydrological model SWAT is used to obtain an estimate of the spatial and temporal distribution of groundwater recharge within the watershed; second, the numerical groundwater flow model MODFLOW is employed to infer aquifer properties and groundwater flow components.

The hydrological model was calibrated and validated using discharge data from three stream gauging stations within the watershed (Mechal et al., Journal of Hydrology: Regional Studies, 2015, doi:10.1016/j.ejrh.2015.09.001). The resulting recharge distribution exhibits a strong decrease from the highland, where the mean annual recharge amounts to several hundred millimetres, to the rift floor, where annual recharge largely is around 100 mm and below. Using this recharge distribution as input, a two-dimensional steady-state groundwater flow model was calibrated to hydraulic heads measured in 72 wells. To account for the incomplete knowledge of the aquifer system several model set-ups differing in the number of transmissivity zones as well as in the implementation of fault zones, rivers, and model boundaries were evaluated using information criteria. The general pattern of the hydraulic-head distribution resulting from the plausible model set-ups agrees reasonably well with that obtained from the observations. Likewise the simulated baseflow is similar (though slightly higher) to that obtained by baseflow separation from measured discharge. The estimated transmissivity increases from the highland (in the order of 10-100 m^2/day) toward the rift floor (in the order of 100-1000 m^2/day). Although the rift-floor aquifers are mainly (65%) supplied by recharge from precipitation, groundwater flow from the highland (mountain block recharge) is found to provide a significant contribution (35%). At present, less than 1% of the groundwater flow is abstracted by pumping wells, suggesting a high potential for groundwater development both in the highland and the rift floor. With regard to the rift floor, potential effects of climate change on groundwater resources deserve further investigation, as the hydrological model suggests a high sensitivity of groundwater recharge to changes of precipitation and air temperature particularly within this part of the watershed.