Impact of surface water reservoirs in enhancing groundwater reserves in the highland of Northern Ethiopia, Tigray region

Tesfamichael G.Yohannes, F. De Smedt, Kristine Walraevens, Jan Nyssen, Jan Moeyersons, Jozef Deckers, Kindeya Gebrehwot, Hans Bauer

An intensive small scale reservoir construction campaign has been carried out by the regional state of Tigray in order to supplement the rain-fed subsistence agriculture in the region. The plan was to construct 500 reservoirs, each of them with a capacity in the order of 1 million m^3, in ten years. Today only about 70 reservoirs have been built throughout Tigray. However, most of these micro-dams did not meet the intended goal of supporting rain-fed agriculture through small scale irrigation schemes. Only a few reservoirs can hold sufficient water for irrigation in the planned areas. The main problem is known to be reservoir leakage. But the construction of these small reservoirs is thought to have supplemented the groundwater recharge in the basin, which can be witnessed by the occurence of base flow in rivers and increased discharge of some springs downstream of the reservoirs.

Although the water level in the reservoirs varies between the wet and dry seasons, it can be safely assumed that the local groundwater level is close to the water level in the reservoirs. Two reservoirs have been studied more in detail using diver (automatic data loggers) installations and nearby groundwater wells were sampled for hydrochemical interpretation. The intention is to understand the interaction of the reservoirs and groundwater using water level and hydrochemical measurements both on the reservoirs and the well. Tsinkanet reservoir and two nearby hand-dug wells were investigated from June 1 to November 30, 2006. The study shows that the reservoir level rises to full capacity after a single high rainfall event during the year and that such events are closely linked to the rainy season. During the dry season, sporadic rainfalls do not produce the same effect. This is probably due to dry soils which enhance infiltration in the ground and inhibit large surface run-off. The same is true for the first rainfall events in the wet season, and only when soils become sufficiently moist, rainfalls produced sufficient runoff to fill the reservoir. Afterwards from October to March, the water level in the reservoir decreases again, due to lack of rainfall, irrigation, and evaporation.

The evolution of the water levels in the wells is somewhat different from the water level of the reservoir. The water level in the wells, especially in well 2, fluctuates while the level of the reservoir is more constant. This points out that at least part of the groundwater reaching the wells is coming from another source than the reservoir. Hence, this can only be recharge from precipitation in the vicinity of the wells. In addition, it is observed that, at the end of the rainy season, the water level in the wells decreases long before that of the reservoir, which indicates that groundwater is flowing out to other areas, most likely along the river valley downstream of the reservoir, which is observed to flow most of the year.

The data also show that the groundwater fluctuations are larger and the response to rainfall is faster in well 2 than in well 1. This can possibly be related to soil texture in the vicinity of the wells. Well 2 is located beneath sandy soils which have a high rate of percolation, while well 1 is located beneath clay or silty clay soils which are less pervious. It has been observed that groundwater levels in the area reach the surface towards the end of the rainy season, while the reservoir becomes full much earlier. Moreover, the groundwater levels in the wells continue to decline after the end of the rainy season while the reservoir level remains constant for months. This observation, together with the fact that the wells are shallow (3 to 4 m), leads to the conclusion that the wells are tapping a perched groundwater recharged locally by precipitation. Hence, there is no interaction between the wells and the reservoir in the Tsinkanet area.

Water samples collected from the reservoir and the nearby wells to investigate the hydrochemical relationship show the major ion composition, both for the Tsinkanet and the Rubafeleg reservoirs (located some 20 km to the ESE, on the Atsbi Horst). The first apparent difference between water samples from the two sites is that the concentration of most major ions (HCO_3^-, Ca^{2+}, Mg^{2+}, Cl^-, and

SO_4^{2-}) and electrical conductivity (EC), is higher for samples from Rubafeleg than those from Tsinkanet. Possible reasons for these differences could be related to geological characteristics of the catchments and the wells, and the groundwater residence time. The geology of the Rubafeleg catchment is mainly weathered and fractured metavolcanics and metavolcanoclastics which favors increased concentration of dissolved ions in the groundwater and to some extent in the surface runoff. Moreover, the Rubafeleg reservoir is continuously fed by base flow from the perennial main stream. Hence, surface runoff and base flow from the catchment to the reservoir bring relatively higher concentration of dissolved ions. On the other hand, the groundwater sample was taken from a borehole of about 50 m deep. Considering the low hydraulic conductivity of the metamorphic rock, groundwater at this depth is likely to have relatively higher residence time in the aquifer which results in higher concentration of dissolved ions. On the contrary, the geology of Tsinkanet catchment is dominantly sandstone which has high hydraulic conductivity and less potential to supply dissolved ions. Hence, low concentration of dissolved ions is observed in both the groundwater and the lake, compared to that of Rubafeleg.

Groundwater at Tsinkanet was sampled from about 4 m deep hand dug well in a sandstone aquifer. The concentration of dissolved ions for the groundwater is found to be less than that of the lake water. This is mainly because the silica dominated sandstone aquifer (Enticho Sandstone) has low potential to supply dissolved ions, and has high hydraulic conductivity which decreases the residence time of groundwater. The higher concentration of dissolved ions in the lake water compared to the groundwater at Tsinkanet could either be because of the small exposures of metavolcanic rocks upstream, higher evaporation rate of the lake water, domestic effluents from the Senkata town (which is located at the upstream part of the catchment), or due to combination of the three. It is also possible that aquatic organisms have contributed to the concentration of dissolved ions in the lake.

The very low concentration of phosphate in groundwater compared to the lake water at Tsinkanet indicates that groundwater recharge is very local with less accumulation of ions from fertilizers and animal feedlots, while the lake receives these ions from all over the catchment through surface runoff. It is also possible that phosphate is supplied through domestic wastes from Senkata town, which joins the lake water.