Investigation of the Impact of Stone Bunds on Erosion and Deposition Processes Combining Conventional and Tracer Methodology in the Gumara Maksegnit Watershed, Northern Highlands of Ethiopia

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Ethiopia is one of the most populous countries in Africa, with over 85% of the total population dependent on agriculture. Massive deforestation in the past and missing soil and water conservation (SWC) measures cause severe soil erosion problems in the northern highlands of Ethiopia. Different SWC methods are supposed to prevent ongoing land degradation. A common technique used is the construction of stone bunds. Though the expected effect is a reduction of surface runoff and soil loss, their behaviour and effectiveness is not always clear, and their performance seems to be strongly dependant on their age.

Thus, the purpose of this research was to evaluate the impact of graded stone bunds on surface runoff and sediment yield by using conventional and tracing approaches at different field scales. In June 2015 two controlled field experiments were set up in the Gumara-Maksegnit watershed in Northern Ethiopia. Three consecutive runoff plots of 20 x 4 m (length and width, respectively) along the maximum slope direction were established (Klik et al., 2015; Figure 1). Each was separated from the downstream one by a stone bund. The experimental setup allowed the measurement of surface runoff along each stone bund and the measurement of overflow over the lowest stone bund. To assess the pathway and the spatial distribution of the sediments, different tracers (Magnetite, Hematite and Goethite) were applied in a 40 cm wide strip at the top of each one of the plots following the procedure described in Guzmán et al. (2015).

The second tracer experiment was conducted on the same hillslope. It consisted of a 20 m long hillslope without borders in which a 4 m long and 40 cm wide Magnetite strip was placed at the top, also according to Guzmán et al. (2015). Soil samples parallel to the stone bund (above and below) were taken along a distance of 16 m to assess the soil movement/deposition.

At the end of August 2015, soil samples of the 0-2 cm depth were taken in a 1.5 x 1.5 m grid within the area of the cascade and the hillslope, respectively. Tracer concentrations of soil and sediment samples in both trials were analysed. Runoff and sediment were collected in weekly intervals from July to September.

Measurements from the runoff plots showed high variability of runoff along the stone bunds (side flow; Figure 2). The amount of side flow ranged between 35 mm (stone bund 1) and 150 mm (stone bund 2). Overflow depth over stone bund 1 was estimated at 26 mm. This was derived by a separate erosion plot study (Wakolbinger et al., 2016). Based on the high side flow of 150 mm at stone bund 2 we assumed that there was no water overtopping stone bund 2. This led to an overflow of 31 mm at stone bund 3 and a flow depth of 70 mm along the stone bund.

Soil loss measurements were highly correlated to runoff. Highest soil translocation along the stone bund was observed at stone bund 3 and lowest at stone bund 1. Based on the obtained data it was not possible to determine how much of this sediment was deposited along the stone

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bund/contour and which part was transported to the gully system. Net soil loss from the cascade experiment of an 80 m long hillslope with the three stone bunds was 6.5 t ha^{-1}, which is greater than the 3.8 t ha^{-1} soil loss from a 20 m long hillslope with just one stone bund (Wakolbinger et al., 2016). This suggests that at the existing slope steepness a distance of about 20 m between bunds created an accumulation of runoff and sediment yield with each consecutive stone bund.

Spatial distribution of magnetite concentrations in the cascade and hillslope experiments is shown in Figures 3 and 4. The results show that the magnetite moved from the top of the hillslope over stone bund 1 but there was (nearly) no dislocation below stone bund 2. This is an indication that stone bund 2 was not overtopped by runoff. In the hillslope experiment (Figure 4) the applied tracer was moved further away from the strip where it was applied. This can be attributed to higher runoff as this hillslope was not bordered at the top and, therefore, allowed run-on from areas above the investigation site. Nevertheless, the data obtained from both experiments show similar distribution patterns with high deposition rates along the stone bund.

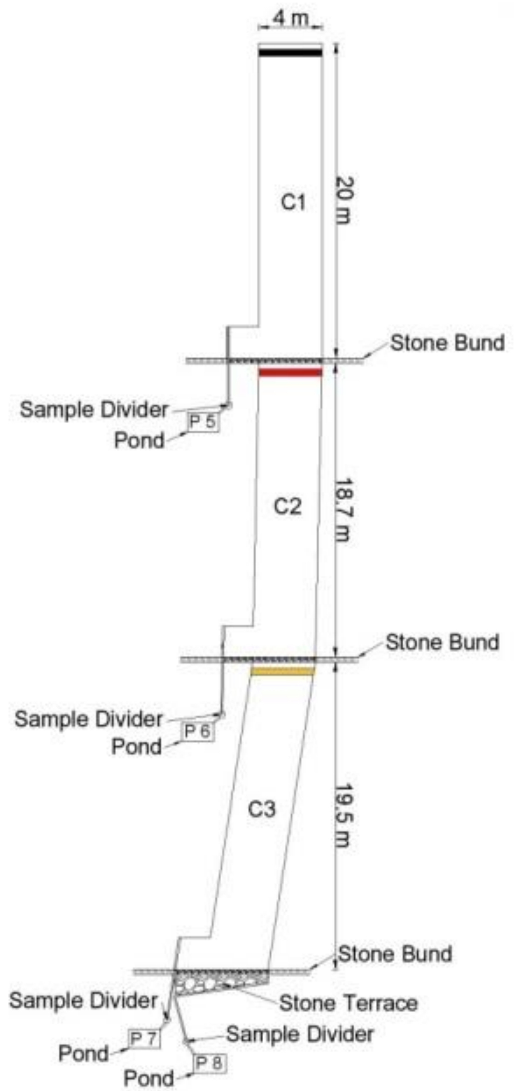

Figure 1. Plot layout of the cascade experiment.

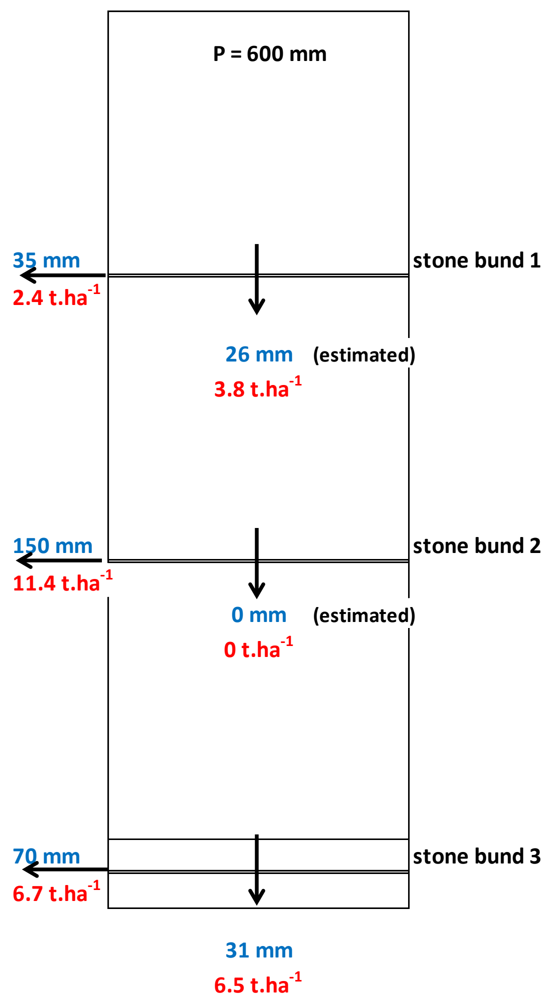

Figure 2. Runoff and soil loss results of the cascade experiment.

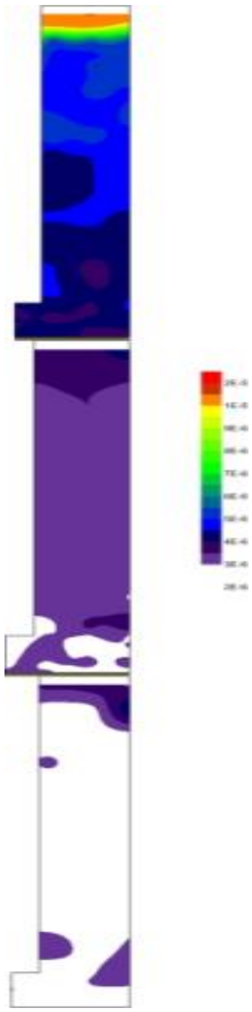

Figure 3. Spatial distribution of magnetite concentration along cascade experiment.

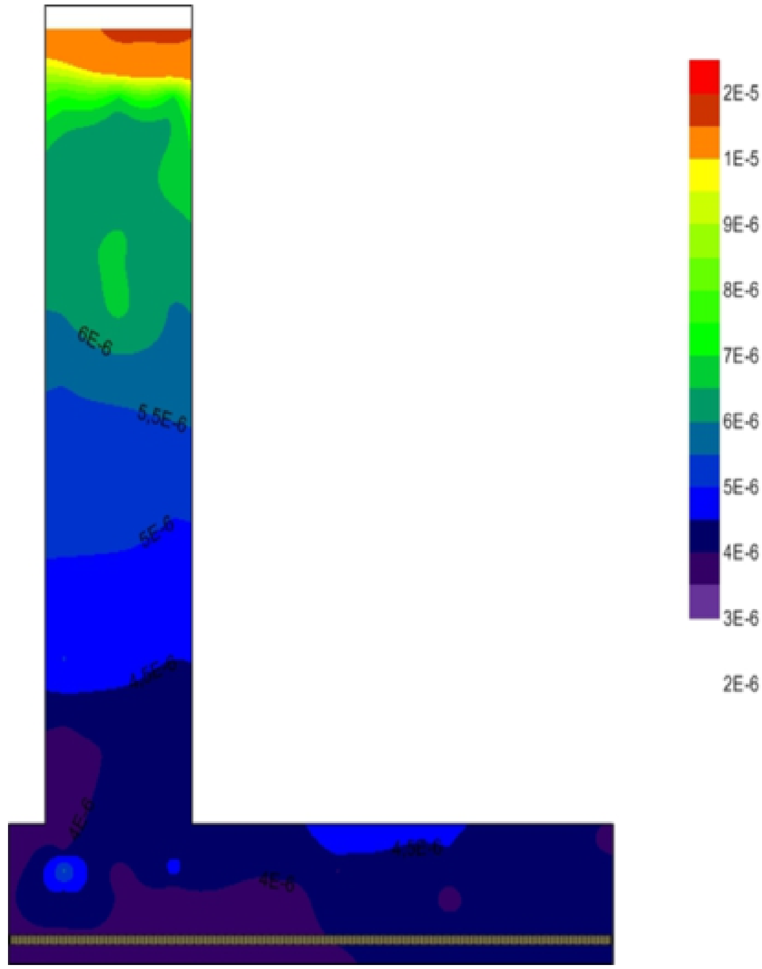

Figure 4. Spatial distribution of magnetite concentration along hillslope experiment.

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