Estimating the hydrological response of soil and water conservation structures: Is the Curve Number method applicable?

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Abstract

Land degradation combined with strongly seasonal and insufficient rainfall is a challenge to rainfed crop production and food security in the arid and semi-arid Ethiopian highlands. To reverse land degradation and ensure food security, soil and water conservation (SWC) structures, water harvesting and irrigation development have been implemented since 1980’s. However, the success of water harvesting reservoirs is limited due to insufficient inflows. There are no adaptable hydrological models which account for local conditions such as SWC structures for an optimized design of ongoing water harvesting reservoirs. As a result most of the constructed reservoirs were over-designed and less area was irrigated. The objective of this study is therefore, to apply the runoff curve number method on the measured rainfall-runoff data and to estimate runoff depth for the runoff plots treated with different SWC structures.

This study was conducted at Mayleba catchment located in Tigray at ca. 40 km to the west from the regional capital Mekelle. 21 large runoff plots (600 to 1000 m\textsuperscript{2}) were installed in cropland and rangeland and treated with different SWC structures: stone bunds, trenches and stone bunds with trenches and a control plot without SWC structures. Plot sites were selected on gentle (5\%), medium (12\%) and steep (16\%) slope gradients for both land use types. At the lower slope of each plot a 17.7 m\textsuperscript{3} collector trench was installed and lined by 0.5mm thick geomembrane to collect runoff. During the rainy season in 2010 to 2012 rainfall-runoff depths were measured and recorded. The rainfall depth was measured using manual rain gauges installed at each plot site. Depth of the water in the collector trench was measured and runoff volume was obtained using calibration curve developed for each collector trench. Measured rainfall-runoff data were divided into two-third for calibration and one-third for cross-validation of the CN method for each plot. 200 alternative subsamples were drawn randomly for the calibration and cross-validation. Using these alternative subsamples the corresponding maximum retention potential and CN values were obtained considering the initial abstraction ratio of 0.05. Model efficiency (ME) and relative root mean square error (RRMSE) were also calculated for cross-validation to evaluate the CN method. The result indicates that the CN values obtained for the runoff plots based on land use type, treatment practices, hydrological condition and hydrological soil group (HSG) of the national engineering handbook (NEH) ranges from 78 to 89 for all the plots in cropland and rangeland.
The median calculated CN values based on the measured rainfall-runoff data ranges from 34, for a plot treated with stone bunds and trenches in cropland, to 91 for a control plot in rangeland, while the corresponding ME ranges from -3.01 to 0.49. The CN values selected for plots based on NEH is overestimated by 21% compared to those calculated from measured rainfall-runoff data. The overestimation is particularly large for plots with SWC structures. Application of the CN method to estimate surface runoff is more reliable for plots on rangeland than the corresponding plots in cropland due to a high runoff production on rangeland plots. The CN method is less applicable for plots with more effective SWC structures as their ME is negative for most plots. Overestimation of the CN methods when using plot characteristics somehow explain why water harvesting structures are overdesigned.

**Keywords:** Curve number, stone bunds, trenches, rangeland, cropland, rainfall-runoff