Realistic prediction of infiltration-excess overland flow occurrence under contrasting land-cover conditions in the Nepalese Middle Hills

Background

Rainfall paritioning into infiltration excess overland flow (IOF) and water infiltrating into the soil to sustain vegetation and groundwater recharge is a key ecohydrological process. A widely used approach to predict IOF occurrence as a function of land cover involves comparing top-soil saturated hydraulic conductivities (K_{sat}) and rainfall intensities of specific intervals. Comparisons against measured IOF are rare, however, while infiltration tests involving ponding may overestimate actual infiltration rates. This work presents data on rainfall intensity, surface- and near-surface K_{sat}, wet-season soil moisture levels as well as measured and modeled IOF for a highly degraded pasture and a natural mixed broad-leaved forest in the Middle Hills of Central Nepal where water is at a premium due to a long dry season.

Methods

Overland flow was measured during the 2011 monsoon (20 June – 9 September) using a single runoff plot (5 m x 15 m) per land-cover type. Runoff was collected in a gutter funneling the water into a first 190 L collector equipped with a seven-slot divider allowing 1/7th of the spill-over to a second 180 L drum. Water levels in the two collectors were measured continuously by pressure transducers.

A disc permeameter was used to measure surface K_{sat} and a Talsma constant-head well permeameter for near-surface (0.05–0.15 m) K_{sat} (Fig. 1).

The Spatially Variable Infiltration Model (SVIM; Yu et al., 1998) was applied to model IOF. SVIM employs an infiltration parameter I_{max} derived from measured short-term rainfall intensities *(P)* and IOF (Fig. 2). I_{max} represents the spatially integrated maximum rate of infiltration across the plot. IOF rates as a function of variations in P are given by:

$$IOF = P - I_{max}\,(1 - e^{-P/I_{max}})$$

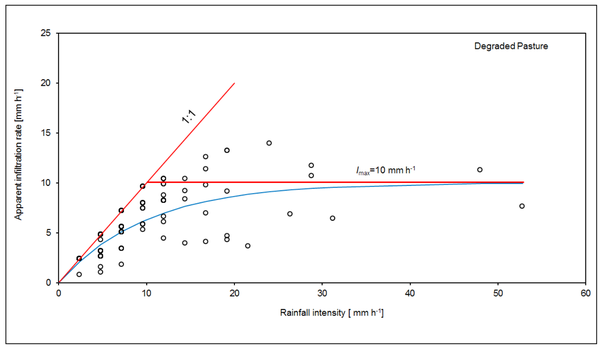

Figure 2: Relationship between apparent infiltration rate and rainfall intensity for the degraded pasture.

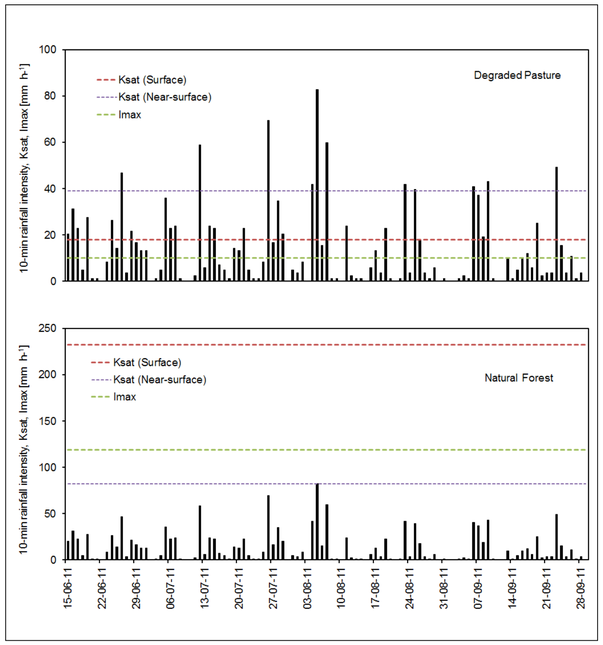

Figure 3: Ten-minute rainfall intensity patterns versus (near-) surface Ksat and observation-based Imax in degraded pasture and natural forest.

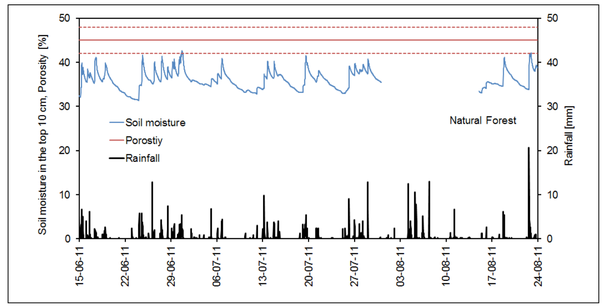

Figure 5: Top-soil moisture dynamics in the natural forest at the height of the rainy season.

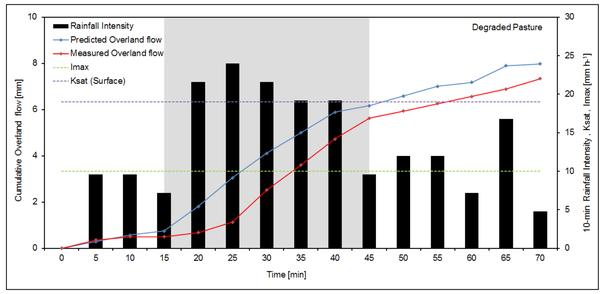

Figure 6: Measured and predicted IOF using SVIM in the degraded pasture (rainfall event of 16.4 mm).

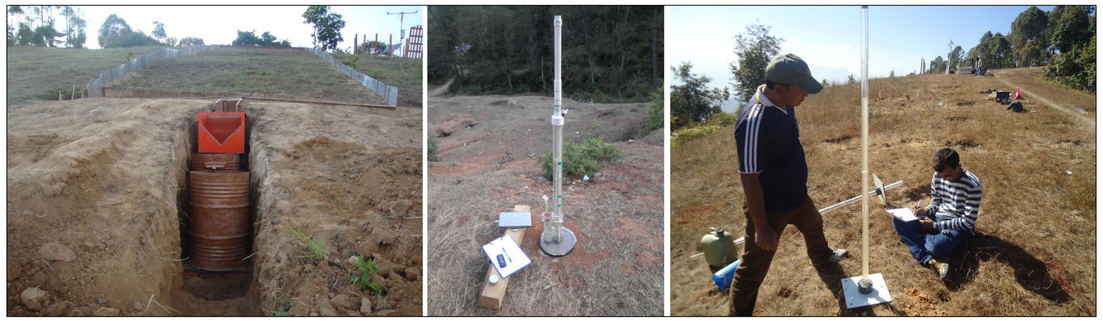

Figure 1: Runoff plot in degraded pasture (left), disc permeameter (centre) and constant-head well permeameter (right).

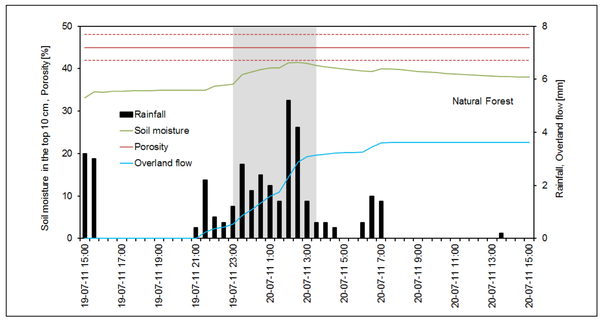

Figure 4: Saturation-excess overland flow occurrence in the natural forest during a 38 mm rainfall event.

Conclusions

- Wet-season overland flow totals were 187 mm (21.3% of rainfall) in the degraded pasture vs. 18 mm (2.5%) in the natural forest even though surface K_{sat} in the forest exceeded 10-min rainfall intensities at all times.
- Actual K_{sat} during the rainy season appeared reduced by 45–50% compared to infiltration test results obtained during the dry season.
- Peak volumetric moisture contents in the natural forest at the height of the monsoon were close to soil porosity (i.e. saturation) suggesting occasional saturation-excess overland flow.
- The SVIM model was able to predict IOF in the degraded pasture reasonably well.

References

Yu, B., Cakurs, U., Rose, C.W., 1998. An assessment of methods for estimating runoff rates at the plot scale. Transactions of the ASAE, 41(3), 653 – 551.

Authors

Chandra Prasad Ghimire [1], *, L.A. (Sampurno) Bruijnzeel [2], Mike Bonell [3]

[1] Faculty of Geo-Information and Earth Observation (ITC), University of Twente, Enschede, The Netherlands

[2] Department of Geography, King's College London, United Kingdom

[3] Deceased, formerly with UNESCO-HELP Centre, University of Dundee, Dundee, United Kingdom

*Corresponding author at: Chandra Prasad Ghimire (c_ghimire@yahoo.com)

UNIVERSITY OF TWENTE.

KING'S College LONDON

UNESCO

ITC