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Land cover effects on thresholds for surface runoff generation in Eastern Madagascar

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Reforestation and natural regrowth in the tropics are promoted for a wide range of benefits, including carbon sequestration, land rehabilitation and streamflow regulation. However, their effects on runoff generation mechanisms and streamflow are still poorly understood. Evaporative losses (transpiration and interception) likely increase with forest regrowth, while infiltration rates are expected to increase and surface runoff occurrence is, therefore, expected to decrease. As part of a larger project investigating the effects of land use on hydrological processes in upland Eastern Madagascar, this presentation reports on a comparison of the thresholds for surface runoff generation at a degraded grassland site, a young secondary forest site (5–7 years; LAI 1.83) and a mature secondary forest site (ca. 20 years; LAI 3.39). Surface runoff was measured on two (young and mature secondary forest) or three (degraded site) 3 m by 10 m plots over a one-year period (October 2014–September 2015). Soil moisture was measured at four (degraded site) to six depths (both forests), while perched groundwater levels were measured in piezometers installed at 30 cm below the soil surface. Soil hydraulic conductivity was measured in situ at the surface and at 10-20 and 20-30 cm depths at three locations in each plot. Porosity, moisture content at field capacity and bulk density were determined from soil cores taken at 2.5–7.5, 12.5–17.5 and 22.5–27.5 cm depth.
The porosity and texture of the different plots were comparable. The hydraulic conductivity of the soil differed between the different land uses and declined sharply at 20-30 cm below the soil surface. Total surface runoff during the study period was 11% of incident rainfall at the degraded site vs. 2% for the two secondary forest sites. Maximum monthly runoff coefficients were 22%, 3.5% and 2.7% for the degraded site, the young forest site and the mature forest site, respectively, but individual event runoff coefficients could be as high as 45%, 12%, and 10%, respectively. Initial analyses indicate that a threshold rainfall amount was required before surface runoff occurs. Comparison of surface runoff occurrence with perched groundwater levels and soil moisture data showed that surface runoff was generated once the top-soil (0–20 cm) became saturated because of impeded drainage to the low hydraulic conductivity deeper layers. Thresholds for saturation overland flow generation were higher at the two forested sites compared to the degraded grassland due to their greater percolation to deeper layers, faster shallow lateral flow, and larger available storage in the top layers. The detailed analyses of the soil moisture and rainfall thresholds for surface runoff generation and their temporal variation will be used to develop a bucket-based conceptual model for runoff generation at these upland tropical sites.

Key words: Runoff plot, rainfall threshold, soil moisture, saturation overland flow, secondary forest, soil hydraulic conductivity, Madagascar, p4ges project