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The influence of forest roads on runoff generation and soil erosion – an assessment based on small scale rainfall simulation

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In the course of forestry operations such as pruning and harvesting, a dense network of forest roads and skid trails has to be established. Due to mostly insufficient soil protective measures, the frequent overpassing of previously undisturbed topsoil with heavy forestry equipment on skid trails generates severe soil compaction. On persistent forest roads, the constructional layout and fortification also cause an increase of soil density.

As a result of soil compaction, infiltration capacities are significantly reduced. Therefore, the affected areas tend to generate overland flow much quicker than undisturbed soil and differ considerably from the adjacent forest topsoil. As a consequence, decentral water retention on the watershed scale can be affected, if the road network is too dense and/or covers too much of the catchment's surface. Another consequence is the increase of soil erosion rates caused by erosive overland flows and the removal of vegetation cover on roads and skid trails. Again, the road and path surfaces differ significantly from adjacent forest soils where soil erosion rates normally tend to be equal or less than the soil renewal rates.

To quantify the influence of forest roads and skid trails on runoff generation and soil erosion rates in a forested catchment area, rainfall simulations were carried out. A small scale rainfall simulator with a plot area of 0,64 m^2 was used to simulate rainfall events with an intensity of 45 mm/h, a duration of 3 x 30 minutes and a kinetic energy of 4,6 J/m^2*mm. Overland flow and eroded material were collected in a high temporal resolution of 1 minute. The sampled roads and skid trails were differentiated and categorized according to their constructional layout. Beyond that, rutted and unrutted road areas were distinguished. To obtain a benchmark for natural soil characteristics, undisturbed forest soils were also examined.

The results show a significant influence of traffic induced soil compaction on the hydrological properties: On undisturbed sites, averagely 96% of the induced rainfall infiltrated. On skid trails, 75% infiltrated when there was no direct overpassing and only 40% in rutted zones where a direct compaction was existent. Persistent roads showed even more disturbed infiltration processes, as there was merely 14% - 7% measureable infiltration causing significant overland flow. Parallel to this, the soil erosion rates rose distinctly dependent on the degree of vegetation removal and the magnitude of the runoff coefficient. On undisturbed plots, only 4 g/m^2 were averagely collected, skid trails produced 16 g/m^2. On persistent roads, with almost no vegetation cover, 168 - 320 g/m^2 were eroded in 90 minutes.

The results indicate the connection between forestry operations and possible environmental hazards that can occur when soil protective measures are insufficient. Rainfall simulation was shown to be an effective method for the in-situ measuring of runoff generation and soil erosion on skid trails and forest roads.