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The role of a coarse surface layer in impeding evaporation from gravel bars

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The presence of a coarse surface layer (CSL) on bars in gravel bed rivers is expected to have an influence on evaporation rates from these surfaces and thereby on the water content in the underlying gravel-sand matrix. A statistically significant increase in soil water content in the presence of a CSL has recently been demonstrated in outdoor experiments by Meier and Hauer (2010). The authors argued that the CSL leads to a reduction in available energy for evaporation, decreases the advection of water vapour from the evaporating surface and reduces the supply of water from the underlying matrix to the evaporating surface. These findings are important because the germination of seeds and vegetative reproduction of riparian species on gravel bars are presumed to be driven by local soil moisture availability. Therefore local conditions of erosion-deposition which lead to the presence or absence of a CSL could be a crucial parameter for successful vegetation establishment on gravel bars.

We conducted a simple laboratory experiment to verify the findings of Meier and Hauer (2010) under more controlled conditions. In the experiment 6 cylindrical buckets with a surface area of 720 cm^2 and total volume of 19500 cm^3 were filled with a sand-gravel mixture to replicate the sediment composition in the Thur River, Switzerland (d_{50} = 8 mm). This site is part of the research project RECORD (www.record.ethz.ch), which focuses on river restoration issues. Three treatments were investigated, each with a CSL of different thickness (H = 0, 40 and 80 mm) with one replicate each, roughly corresponding to 2 and 4 layers of typical CSL gravel diameters in the Thur River. We also measured the temperature in the sediment matrix underneath the CSL. The samples were saturated over several days and subsequently gravitationally drained in order to retain water held only by capillary forces as the initial condition. The samples were then weighed daily for 47 days and the evaporation rates and the soil water content were computed and analyzed.

Our results support the findings of Meier and Hauer (2010). The average evaporation rate without a CSL was 1 mm/day, while for the treatments H = 40 and 80 mm it was 0.3 and 0.17 mm/day respectively. These changes were highly statistically significant (Kruskal-Wallis and T tests). At the end of the experiment after 47 days, the volumetric soil moisture retained in the sediment related to the fine matrix was only 5% without CSL while it was 18-22% with a CSL depending on the treatment. For comparison the porosity of the fine sediment matrix was 33%. We conclude that a CSL decreases evaporation rates and maintains higher soil moisture in the underlying sediment matrix due to its shielding effect but that the effectiveness of the CSL at a site far from the water table will depend on the interarrival time of rainfall (and flood inundation) which replenishes the soil moisture at that location. In ongoing laboratory experiments we are currently studying whether the shielding effect is significant for root growth of typical riparian species such as Salix by planting cuttings into different treatments and monitoring the evapotranspiration rates as well as the length and architecture of the root system which develops.