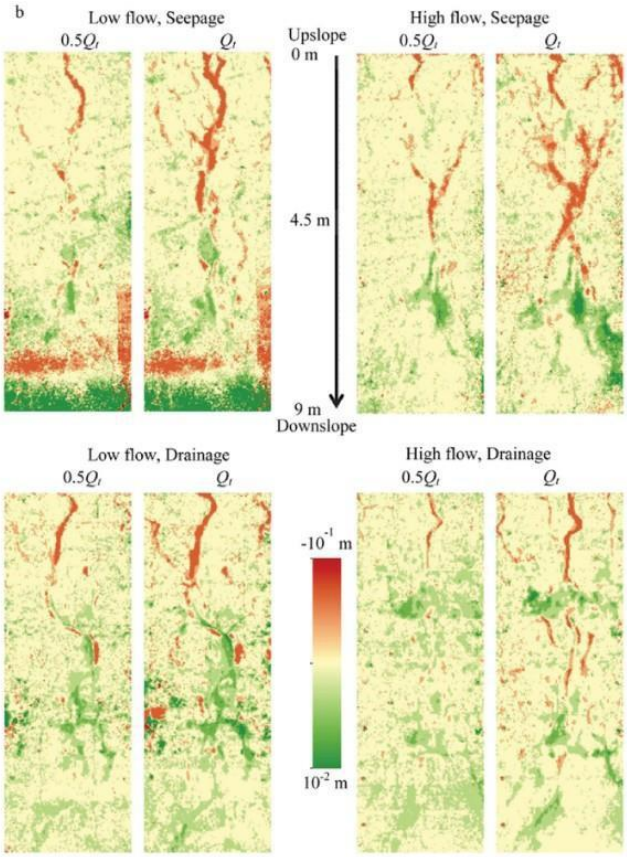
SUBSURFACE HYDROLOGIC EFFECTS ON SEDIMENT DEPOSITION

Zhaoxia Li, Huazhong Agricultural University, Wuhan, CHINA, zxli@mail.hzau.edu.cn
Sayjro Nouwakpo, University of Nevada, Reno, Nevada, snouwakpo@cabnr.unr.edu
Chi-hua Huang, USDA-ARS, W. Lafayette, Indiana, chi-hua.huang@ars.usda.gov

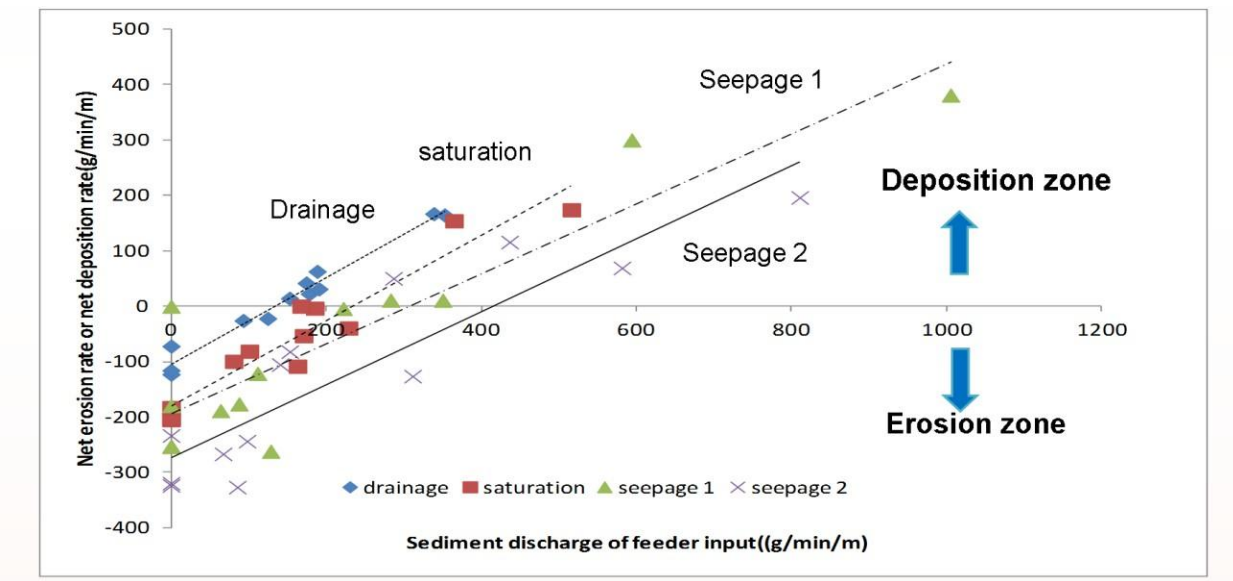
EXTENDED ABSTRACT

Quantification of soil erosion processes has been traditionally focused on soil detachment and sediment transport while efforts in quantifying sediment deposition process are relatively minor. Although soil erosion has been considered as a surface hydrologic process governed by the mechanics and hydraulics of the rainfall and surface flow, there are increasing numbers of literature evidences showing effects of subsurface hydrology on soil erosion processes, some recent examples: Fox et al., 2007; Chu-Agor et al., 2008; Nouwakpo et al., 2010. There are many components of the sub-surface hydrology that may or may not have any impacts on soil erosion. The specific component we are interested in is the near-surface hydraulic gradient which controls whether surface water flows into, i.e., downward drainage, or out of the soil surface (upward seepage). These findings show that as the near-surface hydraulic gradient is shifted from a natural gravity drainage condition to an upward seepage (artesian) condition, soil erosion is greatly enhanced. The question is whether the change in the near-surface hydraulic gradient affects the sediment deposition process.

In a recently published paper from a rainfall simulation study conducted in a laboratory 3.7-m (w) by 9.7-m (l) soil box, we observed the further advancement of the deposition zone when the soil box was free drained as compared to when the box was set to seepage (Nouwakpo and Huang, 2012). This is illustrated here where the deposition areas, shown in green, appeared further into the upper edge of the soil box under drainage (lower graphs) vs. under seepage (upper graphs) (reference here). This graph also shows deeper and more pronounced rills (darker red color) under the seepage condition. The net sediment delivery measured at box outlet supported prior findings of a higher sediment delivery under the seepage condition. Although we have visual evidences of soil profile drainage may have enhanced the development of sediment deposition areas, we need quantitative results to support this observation.



We designed another soil box system specifically to quantify sediment deposition. The box system contains a sediment source box that feeds runoff into a 5-m long rill channel which has water table control to set the rill channel to free drainage, saturation or seepage. The sediment source box and the rill channel have their own programmable rainfall simulator such that the amount of runoff from source box and the study channel can be separately controlled. By regulating the amount of sediment from the source box, the rill channel can have net erosion when the feed sediment at the top of the rill channel is less than the discharged sediment at the outflow end of the channel. Net deposition in the rill channel occurs when the inflow feed sediment is greater than the outflow sediment. For the results shown in this presentation, the rainfall intensities for the feeder box and rill channel were kept constant while the subsurface hydrology of the rill channel was set to one of the following: free drainage, saturation, low seepage (240 ml/m2/min) and high seepage (480 ml/m2/min). For each hydrologic treatment, the amount of feed sediment was varied, by varying the fraction of the feeder box surface covered by a furnace filter, from zero to a maximum rate that the feeder box could generate. Hence, the rill channel went through a transition from net erosion with low sediment feed to net deposition with high sediment feed.



The graph shows the sediment feed rate (x-axis) and net erosion or deposition (y-axis), which is the difference between the feeder input to the rill channel and the rill channel output. As the subsurface hydrology of the rill channel is shifted from drainage, to saturation and seepage, the results show increased erosion and decreased deposition. In other words, soil drainage not only reduces soil erosion, it also enhances sediment deposition. Conversely, saturation and seepage conditions will enhance soil erosion and hinder sediment deposition.

Our results present some challenges in the current thinking of soil erosion processes. If we define the equilibrium sediment discharge as the crossing point from net erosion to net deposition, then this amount increases as the rill channel is shifted from drainage to seepage regime. In our case, the erosion-deposition crossing varies from ~130 to 410 g/m^2/min when the subsurface hydrology changes from drainage to seepage.

In the current erosion model concept, the equilibrium sediment discharge, when neither erosion nor deposition occurs, can be considered the sediment transport capacity, or Tc. However, current concept of Tc is solely based on surface hydraulics and sediment characteristics. In this study, the same soil was used in the feeder box and rill channel, and the same rainfall rate was maintained, hence surface hydraulics and sediment properties were invariant. The challenging question is what is Tc?

The second challenge in current erosion modeling concept is the calculation of sediment deposition. Currently, sediment deposition is based on surface flow hydraulics, sediment characteristics (mainly, size distribution) and sediment concentration. Again, in our research, the sediment property and surface flow hydraulics are somewhat constant. But we show the seepage condition has much greater sediment concentration but much less sediment deposition. Again, this is a deficiency in current sediment deposition equation.

In summary, we have quantified sediment deposition in a rill channel and found the amount of deposition is highly dependent on the subsurface hydrology. Our results show that current process-based erosion modeling concept where erosion and deposition equations based solely on surface flow hydraulics and sediment properties is deficient. It requires a major rethinking on how to incorporate the surface hydrology to properly quantify erosion, deposition, and sediment transport processes on the landscape.

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