Comment on ‘A transport-distance approach to scaling erosion rates: III. Evaluating scaling characteristics of MAHLERAN’

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Received 14 March 2008; Revised 15 July 2008; Accepted 3 March 2009

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The focus of Kinnell (1993) is sediment transport of particles traveling by raindrop-induced saltation within flowing water. The primary equation considered in Kinnell (1993) was:

\[ q_s(d) = k_s I u f[h,d] \] (1)

where \( q_s(d) \) is the rate sediment from an erodible surface \( s \) is discharged across a unit width of any arbitrary boundary as the result of the impacts of drops of size \( d \), \( k_s \) is the susceptibility of the eroding surface to erosion by rain-impacted flow, \( I \) is the rainfall intensity generated by drops of size \( d \), and \( f[h,d] \) is an empirical function that varies with flow depth \( h \) and drop size. This function is perceived to vary from zero when \( h = 0 \) to some peak value at a depth that is dependent on drop size before declining as flow depth increases further. There are number of physical reasons for this:

1. When flow depth is zero, particles are transported by raindrop splash not raindrop induced saltation within the flow. Consequently, although particles may be being transported across the downslope boundary of an area by splash, \( q_s(d) = 0 \) when \( h = 0 \).
2. The mass of material lifted into the flow decreases from an initially high value when the flow depth is low and little of the kinetic energy is dissipated in the flow, to zero in a very deep flow.
3. The downstream transport rate for particles moving by raindrop-induced saltation within the flow depends on the time the particles remain in the flow above the bed after each drop impact (Kinnell, 1990). That time depends on (a) the settling velocities of the particles and (b) how high the particles are lifted above the bed, and that height is initially restricted by the height of the water surface above the bed. As flow depth increases, more of the kinetic energy of the raindrop is dissipated in the water layer so that less is available to lift particles from the bed up into the flow. As a result, the factor controlling the height to which particles are lifted into the flow changes from the ceiling provided by the water surface to the energy available to produce particle uplift, a factor which decreases with flow depth.

The combination of the effect of flow depth on the mass of particles lifted into the flow together with the effect of flow depth on the height particles are lifted into the flow generates the peak in the relationship between \( f[h,d] \) and \( h \). Nothing was said in Kinnell (1993) about the mass of particles lifted into the flow peaking at flow depths of two drop diameters. Also, while the rate of detachment influences \( q_s(d) \), the flow depth–drop size functions described in Kinnell (1993) are empirical functions that do not imply the behavior of any one physical process.

In raindrop-induced saltation, particles are lifted into the flow by drop impact and fall back to the bed under the influence of gravity. The concentration of the particles moving by raindrop-induced saltation in a flow results from the balance between the rate of detachment and the rate of deposition (Hairsine and Rose, 1991). Thus, there is a strong inherent relationship between sediment concentration \( c_s(d) \) and the detachment rate. As noted earlier, when raindrops impact a layer of water, part of their energy is dissipated in the water and so detachment decreases as the depth of the water increases. It follows from Equation 1 that the \( c_s(d) \) is given by

\[ c_s(d) = k_s I u f[h,d] / h \] (2)
and, as shown in Kinnell (1993), \( f[h, d]/h \) decreases with \( h \) from a peak at \( h = 0 \). Contrary to the assertion that the function \( f[h, d] \) indicates that detachment peaks at two drop diameters, Equation 2 is consistent with the concept that detachment is greatest when there is no water on the surface and decreases as the depth of water increases. In reality, the peak in \( f[h, d] \) at a depth >0 is associated with effect of flow depth on the distance particles travel after each drop impact.

In theory, the mass of particles of size \( p \) discharged over a boundary is given by

\[
q_s[p, d] = X_{pd} F_d M_{pd}
\]

where \( X_{pd} \) is the distance particles of size \( p \) travel in the flow after the impact of each drop of size \( d \), \( F_d \) is the spatially average impact frequency of drop of size \( d \), and \( M_{pd} \) is the mass of \( p \) sized particles detached by each drop impact (Kinnell, 1990). Given the strong inherent relationship between detachment and sediment concentration mentioned earlier, \( M_{pd} \) increases as \( f[h, d]/h \) increases as \( h \) tends towards zero. In shallow flows, \( X_{pd} \) increases from zero with flow depth when flow velocity is held constant before decreasing after a drop size dependent flow depth is reached. As a result, the product of \( M_{pd} \) and \( X_{pd} \) increases from zero when flow depth is zero and peaks at a drop size dependent flow depth. The function \( f[h, d] \) accounts for this effect. The assertion that the peak produced by \( f[h, d] \) in Equation 1 is ‘an artifact of considering sediment concentration in the flow’ is completely incorrect.

In reality, detachment, the plucking of particles from the cohesive soil matrix, by raindrops impacting flows is usually not predicted well in many existing so-called process based models of rainfall erosion. Often, it is assumed that experiments on splash erosion give information about the form of the relationship between detachment and flow depth. However, this is not so. In experiments where sediment is collected after it has been splashed from an eroding surface, the amount of sediment collected is dependent on the ability of the transport process to move the detached material to the collection point. As flow depth increases, splash trajectories change so the distance particles are splashed decreases as flow depth increases. Ultimately, detachment may occur without producing splash transport. Consequently, there is a water depth dependent relationship between detachment and the amount of sediment splashed that is ignored in many of the approaches that attempt to model detachment and transport processes in rain impacted flows.

**References**


