Comment on “A New Splash and Sheet Erosion Equation for Rangelands”

Wei et al. (2009) report on the development of a new equation to account for splash and sheet erosion \( (D_{ss}) \) in rangelands,

\[
D_{ss} = K_{ss} I^{1.052} q^{0.592} \tag{1}
\]

where \( K_{ss} \) is a splash and sheet erosion coefficient, \( I \) is rainfall intensity and \( q \) is runoff rate. As noted by Wei et al., this equation differs from the basic interrill erosion model used in WEPP,

\[
D_{ss} = K_{i} I q \tag{2}
\]

where \( K_{i} \) is the interrill erodibility factor. Arguably, the need to develop this new equation comes from (a) the fact that data used to derive Eq. [2] was taken exclusively from experiments on croplands where conditions differ from rangelands in terms of their basic characteristics and management, (b) the spatial distribution and heterogeneity of vegetation under rangeland conditions are quite different from croplands, and (c) the baseline freshly tilled bare-of vegetative-cover condition makes no sense for rangelands soils. In addition, most cropland interrill plots are small (approx 0.6 m by 1.2 m) while rangeland surfaces are often rocky, covered by plant residue, evidence of animal activity, and patchy vegetation and so require a larger representative plot to measure and model splash and sheet erosion. The data set used to develop Eq. [1] was generated from rainfall simulator experiments using two rainfall intensities on 3.06 m wide by 10.7 m long plots in 49 rangeland sites in the USA. At 23 of the locations, 2 replicate plots were used. At the other 26 locations, 6 replicate plots were used.

When sediment is discharged with the outflow from a rectangular eroding area, the rate sediment is discharged \( (q_s, \text{ mass/width/time}) \) is given by

\[
q_s = (q L) c_s \tag{3}
\]

where \( L \) is the length of the area and \( c_s \) is the sediment concentration, the mass of sediment discharged in the flow per unit volume of the volume of water discharged. There is no distinction as to the transport processes involved in causing the sediment to be discharged in the flow in respect to this equation. In the case of the rangelands experiments, splash erosion contributes sediment to that subsequently discharged by rain-impacted flow. From Eq. [1], the Wei et al. model indicates that

\[
c_s = K_{ss} I^{1.05} q^{-0.41} \tag{4}
\]

so that sediment concentrations are perceived to vary directly with rainfall intensity and inversely with the runoff rate. In rain-impacted flows, detachment and transport processes are highly dependent on the dissipation of raindrop kinetic energy, and it is well known that more of the raindrop energy is dissipated in the water layer as flow depth increases, leading to a decline in \( c_s \). Because the depths of flow on longer slopes tend to be in the ranges where declines in \( c_s \) caused by the flow dissipating raindrop energy are appreciable, the decline in \( c_s \) with \( q \) associated with the Wei et al. model seems reasonable. In addition, Wei et al. provide data which show that the model is effective in accounting for \( D_{ss} \) values associated with rainfall simulator experiments on 6 m long grassland range plots in Arizona (their Fig. 5), and more effective than Eq. [2] in a test on 15 plots (their Fig. 6) randomly selected from the original data set.

Although Eq. [1] seems to be an appropriate equation for modeling the combined effect of splash erosion and erosion by rain-impacted flow in rangelands, concern exists about the manner by which the model was developed. It was developed using dependencies between \( D_{ss} \), \( I \) and \( q \) expressed as

\[
D_{ss} = c_1 I^{e_1} \tag{5}
\]

\[
D_{ss} = c_2 q^{e_2} \tag{6}
\]

\[
q = c_3 I^{e_3} \tag{7}
\]

Regression analysis was undertaken using data collected when \( q \) reached a steady value after the onset of the simulated rainfall at the intensity \( I \) to determine the values of \( c_1 \), \( c_2 \), \( c_3 \), \( e_1 \), \( e_2 \), and \( e_3 \) for each location. The means of \( e_1 \), \( e_2 \), and \( e_3 \) were then calculated. Given that,

\[
D_{ss} = c_2^2 c_3^3 e_2^2 e_3^2 \tag{8}
\]

Wei et al. adjusted the mean values of \( e_1 \), \( e_2 \), and \( e_3 \) so that the product of \( e_2 \) and \( e_3 \) equalled \( e_1 \). Equation [1] has the general form

\[
D_{ss} = K_{ss} I^{e_4} q^{e_5} \tag{9}
\]

and, according to Wei et al., the ratio of \( e_4 \) to \( e_5 \) should equal the ratio of \( e_1 \) and \( e_2 \). The values of \( e_4 \) and \( e_5 \) were calculated using the adjusted means of \( e_1 \) and \( e_2 \) with Eq. [1] the result.

According to Wei et al., the approach to developing an equation of \( D_{ss} \) from \( q \) and \( I \) based on the relationship between \( q \) and \( I \) is important because developing models based on the assumption that \( I \) and \( q \) are independent of each other is not an optimum method since there are strong interactions between rainfall and the runoff response (Huang, 1995). Wei et al. illustrated the interactions between runoff
Despite the significant correlation coefficients produced by Eq. [7], the approach adopted by Wei et al. fails to deal with the fact that six different plots are involved at locations such as B190, and that spatial variation in plot characteristics resulted in plots that were not good replicates of each other. The excess rainfall rate is given by the difference between $I$ and the infiltration rate ($I_s$). When the runoff rate reaches a steady value, as in the experiments being considered, $I_s$ is steady and the time of concentration of runoff has been reached so that the runoff rate is given by

$$q = I - I_s \quad \text{[10]}$$

It is apparent from the data for location B190 (Fig. 2), that $I_s$ varied greatly between rainfall “events” on any given soil at any given location. $I_s$ varied between the plot replicates, and with rainfall intensity, and these variations influenced the relationships between $q$ and $I$ obtained by Wei et al. When, as is the case of B190, $I_s$ increases appreciably with $I$, $c_3 < 1.0$. If $I_s$ is appreciably greater than zero and does not vary or increases with $I$, then $c_3 > 1.0$. Wei et al. observed $c_3$ to vary between 0.219 and 6.21. In using the average value of 1.731 Wei et al. failed to give any real consideration of how $q$ and $I$ influenced $D_{ss}$ on individual plots.

Also, the role of $I$ in Eq. [1] needs to be considered in terms of the effect of raindrop impact in generating sediment in the flow rather than how rainfall produces runoff. Consequently, while Eq. 1 appears to be an improvement over the basic WEPP interrill erosion model (Eq. [2]), the manner in which it was derived is not as appropriate as one where $I$ and $q$ are considered to be independent of each other with respect to the determination of $D_{ss}$.

REFERENCES