ALTERNATIVE APPROACHES FOR DETERMINING THE USLE-M SLOPE LENGTH FACTOR FOR GRID CELLS

Peter I. A. Kinnell*

Abstract

Erosion within a grid cell depends on cell size and the size of the area that is upslope of the cell. The factor accounting for slope length when the USLE-M is applied to predicting erosion in grid cells needs to (a) equal the universal soil loss equation (USLE) slope length factor for the cell when the area above the cell is completely pervious and (b) be directly related to the Desmet and Govers slope length factor when runoff is generated uniformly over the whole area. The procedure for calculating the slope length factor proposed previously fails to meet the second criteria. Alternative approaches which consider the contribution of the upslope area to the determination of the slope length factor to vary when the ratio of the runoff coefficient of the upslope area varies from that of the cell are described and shown to meet both criteria. The approach where the slope length factor is based on the ratio of the runoff coefficients for the upslope area and the upslope area plus the cell produces slope length factor values that lie within theoretically acceptable boundaries.

KINNELL AND RISSE (1998) showed that the ability of the USLE (Wischmeier and Smith, 1978) to account for event soil loss could be improved by multiplying the USLE event erosion factor by the runoff coefficient for the event \(Q_{e} \) (the amount of runoff per unit quantity of rain on an area). The version of the USLE using this modification of the USLE erosion factor is called the USLE-M. While the USLE-M is an empirical model, the event erosion factor has some physical basis. It was developed from the concept that erosion is directly related to the product of runoff volume and sediment concentration and the suggestion that the sediment concentration for an event is directly related to (a) the average amount of rainfall for kinetic energy per unit quantity of rain and (b) effect of rainfall intensity which could be accounted for by \(I_{30} \) the maximum 30-min rainfall intensity.

As shown by Kinnell and Risse (1998), the modification of the USLE event erosion factor used in the USLE-M requires changes to be made to all USLE factors that influence runoff when the new erosion index is used. In modeling erosion within catchments or watersheds, it is common to represent the catchment or watershed by a grid of square cells in which factors like slope gradient, soil erodibility, and crop management are uniform in any given cell. In the case of applying the USLE-M to such grid cells where the event erosivity factor is given by the product of the runoff ratio \(Q_{Re} \) the volume of the water flowing out of the cell during the event divided by the volume of rain falling on the cell) and \(E_{30} \) (the product of event kinetic energy and the maximum 30-min intensity), Kinnell (2001) proposed that the slope length factor for a cell with coordinates \(ij \) that applies during Event \(e \) \(L_{(Me,ij)} \) could be expressed by

\[
L_{(Me,ij)} = F \frac{Q_{Ce,ij}}{Q_{Re,ij} A_{ij} D^{m+1}} \frac{A_{ij,m+1} + D^{m+2} x_{ij}}{22.13} \quad (22.13)
\]

where

\[
F = \frac{Q_{Ce,ij}}{1 + A_{ij,m+1}} \frac{(1 - Q_{Ce,ij})}{(1 + A_{ij,m+1} D^{m})^{2}} \quad (22.13)
\]

and \(A_{ij,m+1} \) is the area \((m^{2})\) contributing to flow into the cell with coordinates \(ij \), \(D \) is the length \((m)\) of the sides of the grid cell, \(x_{ij} \) a factor that is dependent on flow direction relative to grid cell orientation and \(m \) is the slope length exponent defined for use with the RUSLE (Renard et al., 1997). The variable \(m \) varies with slope gradient. The terms \(A_{ij,m+1} + D^{m+1} \) \(A_{ij,m+1} + D^{m+2} x_{ij} \) and \(22.13 \) result from a slope length factor for applying the USLE to grid cells developed by Desmet and Govers (1996) on which Eq. [1] is based. \(Q_{Ce,ij} \) is the runoff coefficient for the whole area that contributes to runoff out of the cell during an event (hence the use of the subscript \(e \)) and is given by \(Q_{e,ij}/B_{ij} \) where \(Q_{e,ij} \) is the runoff per unit area from the area that includes the cell and \(B_{ij} \) as rainfall amount per unit area during the event. Likewise, \(Q_{Ce,ij} \) is the runoff coefficient for the area upslope of the cell and is given by \(Q_{e,ij}/B_{ij} \) where \(Q_{e,ij} \) is runoff per unit area for the area upslope of the cell. The \(Q_{Re,ij} \) is the runoff ratio for the cell. In the case of runoff coefficients \(Q_{Ce} \), \(Q_{e} \), and \(B_{ij} \) apply to the same area and so take on values from 0 to 1 when runoff is generated by infiltration excess. However, the runoff ratio for a cell \(Q_{Re,ij} \) is given by the volume of runoff discharged from the cell per unit volume of rainfall falling on that cell. The volume of runoff discharged from the cell is given by \(Q_{e,ij} + A_{ij,m+1} + Q_{e,ij,cell} D^{2} \) and because a large proportion of that volume may come from upslope, \(Q_{Re,ij} \) can take on values much \(>1 \).

In the context of this paper, the runoff ratio for the cell \(Q_{Re,ij,cell} \) is determined by dividing the volume of the water flowing out of the cell during the event by the volume of rain falling on the cell. Because the volume of runoff from the cell comes from both the cell and the upslope area, the runoff ratio can have values greater than 1.0. In contrast, the runoff coefficient for a cell \(Q_{Ce,ij,cell} \) is given by the volume of water discharged from the cell that is derived from rainfall falling on the cell divided by the volume of rain falling on the cell. For runoff produced by infiltration excess, \(Q_{Ce,ij,cell} \) will not exceed 1.0.

Abbreviations: RUSLE, revised universal soil loss equation. USLE, universal soil loss equation.
As noted above, the USLE-M was developed from the concept that erosion is directly related to the product of runoff volume and sediment concentration and the suggestion that the sediment concentration is directly related to (a) the average amount of rainfall for kinetic energy per unit quantity of rain and (b) effect of rainfall intensity which could be accounted for by $i_{v1}$. As a consequence of this, $L_{\text{UMLMj}}$ accounts for the effect of upslope area on the sediment concentration associated with erosion in the cell. In terms of the USLE-M, it follows from Desmet and Govers (1996) that when runoff is generated uniformly over an area, event soil loss from a cell with coordinates $i,j$ ($Y_{i,j}$) for bare fallow ($C_{\text{UMLMj}} = 1.0$) on a 9% slope ($S = 1.0$) and cultivation up and down the slope ($P_{\text{UMLMj}} = 1.0$) is given by

$$Y_{i,j} = \frac{Q_{\text{UMLMj-all}}(A_{\text{ij-in}} + D^2)E_{I30}}{B_i(A_{\text{ij-in}} + D^2)} \left(\frac{A_{\text{ij-in}} + D^2}{D^m + x_{ij}^m} \right)^{22.13} K_{\text{UMLMj}}$$

where $K_{\text{UMLMj}}$ is the soil erodibility in the cell during the event. Because the term $Q_{\text{UMLMj-all}}(A_{\text{ij-in}} + D^2)/B_i$ $(A_{\text{ij-in}} + D^2)$ equals $Q_{\text{Cj}}$, Eq. [3a] can be written as

$$Y_{i,j} = \frac{Q_{\text{Cj}}(A_{\text{ij-in}} + D^2)^{m+1} - A_{\text{ij-in}}^{m+1}}{D^m x_{ij}^m} K_{\text{UMLMj}}$$

Given that the erodibility index for the cell is given by the product of $E_{I30}$ and $Q_{\text{Cj}}$ (Kinnell, 2001), it follows from Eq. [3] that

$$L_{\text{UMLMj}} = \frac{Q_{\text{Cj}}(A_{\text{ij-in}} + D^2)^{m+1} - Q_{\text{Cj}} - A_{\text{ij-in}}^{m+1}}{Q_{\text{Cj}} - A_{\text{ij-in}}^{m+1}} K_{\text{UMLMj}}$$

when runoff is generated uniformly over an area. Equation [1] is a modification of Eq. [4]. In Eq. [1], $Q_{\text{Cj}}$ has been replaced by $Q_{\text{Cj}} - A_{\text{ij-in}}^{m+1}$ to account for the fact that the runoff coefficient for the area including the cell may be different to that of the upslope area. $F$ appears in Eq. [1] because without $F$, Eq. [1] overpredicts the slope length effect when $Q_{\text{Cj}} = 0$ (Kinnell, 2001). When $Q_{\text{Cj}} = 0$, $L_{\text{UMLMj}}$ should equal $(D/22.13)^m$.

Figure 1 shows how $L_{\text{UMLMj}}$ values given by Eq. [1] and [4] vary with the total area contributing to runoff out of a cell as that total area increases when $D = 30\ m$, $m = 0.5$ and both $Q_{\text{Cj}}$ and $Q_{\text{Cj}} - A_{\text{ij-in}}^{m+1}$ the runoff coefficient for the cell, are equal to 0.6. While, without $F$, Eq. [1] overpredicts the slope length effect when $Q_{\text{Cj}} = 0$, it can be seen from Fig. 1 that, when runoff is generated uniformly over the area, Eq. [1] does not give the same result as Eq. [4] when, in reality, it should. Consequently, a new approach needs to be developed to overcome this problem. Two alternatives are considered here.

**Theory**

As noted above, Eq. [4] is valid when runoff is generated uniformly over the area. Logically, Eq. [4] is not valid when the runoff coefficient for the cell ($Q_{\text{Cj}}$) differs markedly from that of the upslope area ($Q_{\text{Cj-in}}$). As noted earlier, the value for $L_{\text{UMLMj}}$ when $Q_{\text{Cj-in}} = 0$ must be given by $(D/22.13)^m$. As can be seen from Fig. 2, Eq. [1] produces this value but Eq. [4] produces a value that is less than required and the values $L_{\text{UMLMj}}$ for Eq. [4] do not vary with $Q_{\text{Cj-in}}$.

As with Eq. [1], alternative approaches for determining $L_{\text{UMLMj}}$ can be based on a modification of the Desmet and Govers (1996) equation. The Desmet and Govers equation extends the equation for the slope length factor for Segment $i$ developed for the USLE and the RUSLE (Renard et al., 1997)

$$L_i = \frac{\lambda^m - \lambda_i^{m+1}}{(\lambda - \lambda_i)22.13}$$

where $\lambda$ is the length of slope to the bottom of the segment and $\lambda_i$ is the length of slope to the top of the segment, to grid cells by replacing $\lambda$ and $\lambda_i$ with the respective contributing areas ($A_{\text{ij-in}} + D^2$ and $A_{\text{ij-in}}$) divided by cell width ($D$) to give

$$L_{ij} = \frac{(A_{\text{ij-in}} + D^2)^{m+1} - A_{\text{ij-in}}^{m+1}}{D^m x_{ij}^m}$$

For a rectangular area one cell wide, the value of $A_{\text{ij-in}}/D$ is the same as $\lambda_i$ and the value of $(A_{\text{ij-in}} + D^2)/D$ is the same as $\lambda$, so that Eq. [5] and [6] produce the same slope length factor value with a rectangular area one cell wide.

Equation [5] is based on a mass balance approach where soil passing into the segment from upslope varies directly with erosion in the upslope area and the length of upslope area ($\lambda_i$) and the soil passing out of the segment varies directly with erosion in the area that includes the segment and the length of slope to the bottom of the segment ($\lambda$). According to Kinnell (2001), applying this approach to the USLE-M in grid cells gives

$$L_{\text{UMLMj}} = \frac{Q_{\text{Cj}}(A_{\text{ij-in}} + D^2)^{m+1} - Q_{\text{Cj-in}} - A_{\text{ij-in}}^{m+1}}{Q_{\text{Cj-in}} - A_{\text{ij-in}}^{m+1}} K_{\text{UMLMj}}$$

Equation [7] equals Eq. [4] when $Q_{\text{Cj-in}} = Q_{\text{Cj}}$, and consequently, meets the criteria for applying the USLE-M when runoff is produced uniformly over the whole area and when $A_{\text{ij}} = 0$ but not when $Q_{\text{Cj-in}} = 0$ when $A_{\text{ij-in}} > 0$. (Kinnell, 2001) introduced the factor $F$ to overcome this problem. However, in effect, $A_{\text{ij-in}}$ should equal zero when $Q_{\text{Cj-in}} = 0$ and the failure of Eq. [7] to meet the criteria for the $Q_{\text{Cj-in}} = 0$ results from the failure to set $A_{\text{ij-in}} = 0$ when $Q_{\text{Cj-in}} = 0$.

In an area where runoff is produced uniformly, the volume of water flowing across a unit width of a boundary is directly related to the upslope area divided by the width of the boundary. Using the contributing area divided by the cell width approach when the area is not rectangular assumes that the effect of the above cell area on the slope length factor is independent of the volume of water inflow per unit cell width rather than the length of flow in the above cell area. It follows from this that if $Q_{\text{Cj-in}}$ is less than $Q_{\text{Cj-in-eff}}$, then the effective value of $A_{\text{ij-in}} (A_{\text{ij-in-eff}})$ should be less than $A_{\text{ij-in}}$ in the context of determining $L_{\text{UMLMj}}$ (Fig. 3). Likewise, if $Q_{\text{Cj-in}}$ is greater than $Q_{\text{Cj-in-eff}}$, then $A_{\text{ij-in-eff}}$ should be greater than $A_{\text{ij-in}}$. Under these circumstances,

$$L_{\text{UMLMj}} = \frac{Q_{\text{Cj-in-eff}} (A_{\text{ij-in-eff}} + D^2)^{m+1} - Q_{\text{Cj-in-eff}} - A_{\text{ij-in-eff}}^{m+1}}{Q_{\text{Cj-in-eff}} - A_{\text{ij-in-eff}}^{m+1}} K_{\text{UMLMj}}$$

where

$$Q_{\text{Cj-in-eff}} = \frac{(Q_{\text{Cj-in}} D^2) + (Q_{\text{Cj}} - A_{\text{ij-in}} A_{\text{ij-in}})}{(A_{\text{ij-in-eff}} + D^2)}$$

In the context of the combination of Eq. [8] and [9], the primary criteria for $A_{\text{ij-in-eff}}$ are that it equal (a) $A_{\text{ij-in}}$ when $Q_{\text{Cj-in}} = Q_{\text{Cj-in-eff}}$ and (b) zero when $Q_{\text{Cj-in}} = 0$. In addition,
it can be argued that if $Q_{Ce,i,j-in}$ is half $Q_{Ce,i,j-cell}$, then $A_{i,j-in}^{eff}$ should equal half $A_{i,j-in}$ and so on. These conditions are met by

$$A_{i,j-in}^{eff} = A_{i,j-in} Q_{Ce,i,j-in}^{Q_{Ce,i,j-cell}}$$  \[10\]

In effect, Eq. [10] considers that runoff entering a cell is produced from an area whose size is that required to produce that runoff given a runoff coefficient equal to that of the cell so that $Q_{Ce,i,j-cell}$ takes on a value equal to $Q_{Ce,i,j-in}$. Thus, the combination of Eq. [8], [9], and [10] calculates $L_{UMe,i,j}$ on the basis of a total area whose runoff coefficient is equal to that of cell $i,j$. In this way, the approach to determining $L_{UMe,i,j}$ maintains the perception of runoff being produced uniformly over the whole area.

Figure 4 shows how $L_{UMe,i,j}$ values produced by Eq. [8] vary with $Q_{Ce,i,j-in}$ when Eq. [10] is used in comparison with the values produced by Eq. [1] and [4]. It can be seen that the approach has positive features in terms that $L_{UMe,i,j}$ varies non-linearly from the value given by $(D/22.13)^{m}$ when $Q_{Ce,i,j-in} = 0$ to the value given by Eq. [4] when $Q_{Ce,i,j-in} = Q_{Ce,i,j-cell}$. The approach also produces $L_{UMe,i,j}$ values that are between those produced by Eq. [1] and [4] when $Q_{Ce,i,j-in} > Q_{Ce,i,j-cell}$ and $Q_{Ce,i,j-cell} = 0.6$.

As noted above, the approach maintains the perception that runoff is produced uniformly over the whole area used to determine $L_{UMe,i,j}$ and assumes that the runoff coefficient for that area is that of the cell. Thus $L_{UMe,i,j} = 0$ when $Q_{Ce,i,j-cell} = 0$ despite the fact that erosion can occur when $Q_{Ce,i,j-cell} = 0$. $Q_{Ce,i,j-cell} = 0$ can occur when the cell has an infiltration rate that is higher than the upslope area and runoff from upslope still occurs even though the rainfall rate is less than the infiltration rate for the cell. Also, Eq. [10] will produce very large values of $A_{i,j-in}^{eff}$ and low values of $L_{UMe,i,j}$ whenever $Q_{Ce,i,j-cell}$ is very much less than $Q_{Ce,i,j-in}$. Thus, the effect on $L_{UMe,i,j}$ produced by Eq. [8] under these conditions may generate an unrealistic erosion result. For example, in the case of the newly cultivated
The flow of water over the downstream boundary does not vary (Fig. 9). In contrast to when Eq. [10] is used, with Eq. [11], when Eq. [11] shows how $Q_{ci,j-m} > Q_{ci,j-cell}$.

An alternative to Eq. [10],

$$A_{i,j-m} = A_{i,j} \times \frac{Q_{ci,j-m}}{Q_{ci,j-cell}} \quad [11]$$

also meets the primary criteria for $A_{i,j-m}$ being equal to (a) $A_{i,j}$ when $Q_{ci,j-m} = Q_{ci,j-cell}$ and (b) zero when $Q_{ci,j-m} = 0$. In the case of Eq. [11], as with Eq. [10], $A_{i,j-m} < A_{i,j}$ when $Q_{ci,j-m} < Q_{ci,j-cell}$ and $A_{i,j-m} > A_{i,j}$ when $Q_{ci,j-m} > Q_{ci,j-cell}$ but $A_{i,j-m}$ will not tend toward infinity when $Q_{ci,j-cell}$ tends to zero and $L_{UMe,j}$ will not equal zero when $Q_{ci,j-cell} = 0$. Figure 5 shows how $L_{UMe,j}$ varies with $Q_{ci,j-cell}$ when Eq. [11] is used when $Q_{ci,j-cell} = 0.6$ in comparison with when Eq. [10] is used. In contrast to when Eq. [10] is used, with Eq. [11], $L_{UMe,j}$ lies close to the value for when $Q_{ci,j-cell} = Q_{ci,j-cell}$ except at low values of $Q_{ci,j-cell}$.

As noted earlier, cell erosion is directly related to the product of $Q_{ci,j-cell}$ and $L_{UMe,j}$. Figure 6 shows the product of $Q_{ci,j-cell}$ and $L_{UMe,j}$ produced using Eq. [10] and [11] when $Q_{ci,j-cell}$ is held constant. Erosion should not vary significantly when the flow of water over the downstream boundary does not vary with $Q_{ci,j-cell}$ when $Q_{ci,j-cell}$ is held constant. Figure 6 shows that erosion predicted using Eq. [11] varies little with $Q_{ci,j-cell}$ while that predicted using Eq. [10] is not close to reality except when $Q_{ci,j-cell}$ is close to $Q_{ci,j-cell}$. Using Eq. [11] predicts erosion rates that are close to those predicted when $L_{UMe,j}$ is determined using Eq. [4] except at low values of $Q_{ci,j-cell}$ when $Q_{ci,j-cell}$ varies with $Q_{ci,j-cell}$ (Fig. 7). By design, using either Eq. [10] or [11] will predict the appropriate erosion rates when $Q_{ci,j-cell} = 0$ and when $Q_{ci,j-cell} = Q_{ci,j-cell}$ but Eq. [10] does not predict erosion values that lie within theoretically acceptable limits.

**Discussion**

Of the two approaches considered, the approach where $A_{i,j-m}$ varies with $Q_{ci,j-cell}$ (Eq. [11]) rather than $Q_{ci,j-cell}$ (Eq. [10]) provides $L_{UMe,j}$ values which can be applied when $Q_{ci,j-cell} = 0$. Consequently, the combination of Eq. [8], [9], and [11] provides the more appropriate method for determining the slope length effect for use when the USLE-M is applied to grid cells.

In effect, Eq. [8] is the product of $L_{ij}$ given by Eq. [6] with $A_{i,j-m}$ replaced by $A_{i,j-m-eff}$.

$$L_{ij} = \frac{(A_{i,j-m-eff} + D^m)^{m+1} - A_{i,j-m-eff}^{m+1}}{D^{m+1} \times X_{ij}^{2.13}} \quad [12]$$

and the ratio of $Q_{ci,j-cell}$ to $Q_{ci,j-cell}$. Figure 8 shows how the $L_{ij}$ for the outlet 30-m cell varies with $Q_{ci,j-cell}$ when Eq. [12] is applied to the 0.9-ha total area considered here when $A_{i,j-m-eff}$ is determined using Eq. [11]. In the context of Eq. [8] being the product of $L_{ij}$ values determined by Eq. [12] and the ratio of $Q_{ci,j-cell}$ to $Q_{ci,j-cell}$, $L_{UMe,j}$ values tend to be directly related to the $L_{ij}$ values determined by Eq. [12] as $Q_{ci,j-cell}$ varies when $A_{i,j-m-eff}$ is determined using Eq. [11] except when $Q_{ci,j-cell}$ tends toward zero because the ratio of $Q_{ci,j-cell}$ to $Q_{ci,j-cell}$ varies little with $Q_{ci,j-cell}$ except when $Q_{ci,j-cell}$ toward zero (Fig. 9).

![Fig. 4. Relationships between $L_{UMe,j}$ for a 0.09-ha cell and $Q_{ci,j-cell}$ produced by Eq. [1], [4], and [8] with Eq. [15] when $A_{i,j-m} + D^m = 0.9$.](image)
It should be noted that the determination of $L_{\text{LUMe}}$ (Re.) does not consider the form of the hillslope profile in which a grid cell lies or the actual erosion that occurs in the upslope area. The approach considers only the slope gradient of the cell and the slope lengths of the cell and upslope areas. That is standard for determining what is commonly known as erosion in a cell or segment. However, the total mass of soil loss, which is calculated by multiplying the total area by the average erosion rate over that total area, may differ from the mass of soil actually passing across the downstream boundary of a cell. This is because deposition may occur in the cell, particularly when a hillslope is concave, and the USLE, RUSLE (as implemented in the computer program RUSLE 1) and USLE-M models do not account for deposition. In terms of looking at the impact of land management on the health of rivers and streams, sediment delivery to channels in a watershed or catchment is the ultimate focus of the modeling exercise and requires the use of a sediment transport model to control the movement of sediment when deposition occurs. The concept involved is illustrated in Fig. 10. This is recognized in the computer program RUSLE 2 (Foster et al., 2003) that produces two outputs—“erosion”, which is the output that would occur if all the sediment available for transport is transported to the bottom of the hill-slope, and “sediment delivery”, which takes account of deposition on the amount of sediment discharged from.
the bottom of the hillslope. RUSLE 2 models erosion and sediment delivery in a one-dimensional system. The issue addressed here is “erosion” in a two-dimensional system.

Conclusions

Kinnell (2001) proposed an equation (Eq. [1]) for determining the slope length factor for applying the USLE-M in grid-cells. This equation was a modification of the one proposed by Desmet and Govers (1996) for determining the slope length factor for applying the USLE/RUSLE in grid cells and considered that the effect of variations of runoff from the area upslope of a cell was dependent on the runoff coefficient of that upslope area. That equation has been found to be deficient in terms of determining the value of the slope length factor when runoff is uniformly produced over the whole area. A new method of determining the slope length factor has been developed (Eq. [8] with Eq. [9] and [11]) which has the required characteristics for applying the USLE-M to erosion in grid cells.

Symbols

$\lambda_i$, length of slope to the bottom of the segment $i$.
$\lambda_{i+1}$, length of slope to the top of the segment $i$.
$A_{i+j}$, area of upslope area of cell with coordinates $i,j$.
$A_{i+j-eff}$, effective area of upslope area when runoff not uniformly generated over the area contributing to runoff out of cell with coordinates $i,j$.
$B_e$, amount of rain falling during an rainfall event.
$C_{i+1}$, crop management factor for applying the USLE-M to a grid cell with coordinates $i,j$ for a rainfall event.
$E$, event kinetic energy.
$D$, length of cell sides.
$I_{30}$, maximum rainfall intensity measured using a 30-min time frame.

$K_{U(Me)}$, USLE-M soil erodibility factor for cell with coordinates $i,j$ for a rainfall event.

$L_{ij}$, slope length factor for applying the USLE to a grid cell with coordinates $i,j$.

$L_{U(Me)ij}$, slope length factor for applying the USLE-M to a grid cell with coordinates $i,j$ for a rainfall event.

$m$, slope length exponent defined for use with the RUSLE.

$P_{U(Me)}$, support practice factor for applying the USLE-M to a grid cell with coordinates $i,j$ for a rainfall event.

$Q_{Ce}$, Runoff coefficient volume of runoff per unit volume of rain for rain falling on the same area during a rainfall event.

$Q_{Ce}$, runoff per unit area.

$Q_{Ce,ij,all}$, runoff per unit area from the area that includes the cell with coordinates $i,j$.

$Q_{Ce,ij,all}$, runoff coefficient for upslope area plus cell with coordinates $i,j$ for a rainfall event.

$Q_{Ce,ij,eff}$, effective runoff coefficient for an area including cell with coordinates $i,j$ for a rainfall event assuming that the area is given by the sum of $A_{ij,all}$ and $D^2$.

$Q_{Ce,ij,up}$, runoff coefficient for upslope area to cell with coordinates $i,j$ for a rainfall event.

$Q_{Be,ij,cell}$, runoff ratio for cell with coordinates $i,j$—volume of runoff from cell per unit volume of rain falling on cell during a rainfall event. Volume of runoff from cell includes water running into the cell from upslope.

$S$, USLE slope gradient factor.

$x_{ij}$, coefficient that adjusts for width of flow at the center of the cell. It has a value of 1.0 when the flow is toward a side and $\sqrt{2}$ when the flow is toward a corner.

$Y_{ij}$, soil loss from a cell with coordinates $i,j$.

References


