# CHAPTER 5. COVER-MANAGEMENT FACTOR (C)

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The C factor is used within both the Universal Soil Loss Equation (USLE) and the Revised USLE (RUSLE) to reflect the effect of cropping and management practices on erosion rates, and is the factor used most often to compare the relative impacts of management options on conservation plans. The C factor indicates how the conservation plan will affect the average annual soil loss and how that soil-loss potential will be distributed in time during construction activities, crop rotations, or other management schemes.

As with most other factors within RUSLE, the C factor is based on the concept of deviation from a standard, in this case an area under clean-tilled continuous-fallow conditions. The soil loss ratio (SLR) is then an estimate of the ratio of soil loss under actual conditions to losses experienced under the reference conditions. Work by Wischmeier (1975) and Mutchler et al. (1982) indicated that the general impact of cropping and management on soil losses can be divided into a series of subfactors. Within RUSLE, this technique is used as modified by Laflen et al. (1985) and Weltz et al. (1987). In this approach the important parameters are the impacts of previous cropping and management, the protection offered the soil surface by the vegetative canopy, the reduction in erosion due to surface cover and surface roughness, and in some cases the impact of low soil moisture on reduction of runoff from low-intensity rainfall. As used in RUSLE, each of these parameters is assigned a subfactor value, and these values are multiplied together to yield a SLR.

An individual SLR value is thus calculated for each time period over which the important parameters can be assumed to remain constant. Each of these SLR values is then weighted by the fraction of rainfall and runoff erosivity (EI) associated with the corresponding time period, and these weighted values are combined into an overall C factor value.

## USE OF TIME-VARYING OR AVERAGE ANNUAL VALUES

For areas such as pasture or rangeland that have reached a relative equilibrium, the parameters used in computing SLR values may change very slowly with time, so calculated SLR values will also change little. In these cases, it may prove adequate to calculate a C factor based on a single average SLR representing the entire year. RUSLE provides this option to simplify calculations, but this capability must be used with caution, as the result will no longer reflect changes in the climate's erosive potential through the year.

In almost all cropland scenarios and in many cases where rangeland or pasture are being managed, the crop and soil parameters change with time due to either specific management practices or natural cyclic effects such as winter knockdown and spring growth. This demands that the SLR values be calculated frequently enough over the course of a year or a crop rotation to provide an adequate measure of how they change. This is especially important because the erosion potential is also changing with time, as indicated by the EI distributions discussed in chapter 2. The calculated average annual soil loss should be high if a cropping or management scheme happens to leave the soil susceptible to erosion at a time of high rainfall erosivity. USLE incorporated this effect into calculations of SLR values based on crop-growth stages (Wischmeier and Smith 1978). These values were usually assigned based on tillage type, elapsed time since a tillage operation, canopy development, and date of harvest.

Following the lead of the USLE approach, RUSLE calculations are based on a 15-day time step. This means that SLR values are calculated every 15 days throughout the year, and that the important parameters are assumed to remain constant during those 15 days. In order to maintain a total of 24 periods in a year, the first 15 days of each month are placed in one period, and the remainder in another. Period lengths thus range from 13 days for the second period in February to 16 days for the second period in any month having 31 days.

If a management operation occurs within the period, the parameters can no longer be assumed constant; the half-month period is then broken into two segments and two SLR values are calculated. These segments can in turn be broken into smaller time increments by other management operations. A recalculation of the SLR can therefore be forced by either of two occurrences. The first is the end of a half-month period, because conditions are presumed to

have changed sufficiently to require new calculations. The other occurrence is any field operation or sudden climatic change that affects the soil/vegetation/ residue system, thereby changing the value of the SLR. These are handled by dividing the entire time period of interest into time *segments*. Each segment is bracketed by two *events*, which are defined as either a field operation or the beginning of a new half-month period. A segment can therefore range in length from 0 days (if two events occur on the same day) to a 16-day maximum if a month has 31 days and there are no field operations within a period. A zero-length segment is kept track of for accounting purposes, but requires no SLR calculation because there is no associated EI.

Calculations of the SLR for the average annual and time-varying approaches are the same and require the same input parameters; the difference lies in how often the calculation is performed. In the time-varying approach, the SLR value is calculated at a date in the middle of each time segment, and this value is then weighted by the percentage of EI associated with that segment. In the average annual approach, everything is assumed constant, so the calculation is made once.

## COMPUTATION OF HALF-MONTH CLIMATE VARIABLES

Calculation of the time-varying SLR requires values for the rainfall, average air temperature, and fraction of total EI associated with each of the half-month periods throughout the year. This forces additional calculations in order to get smooth half-month values when the available data are supplied on a monthly basis.

Known: M, (M-1), and (M+1), which are monthly values for the month of interest (M), the previous month (M-1), and the subsequent month (M+1).

Wanted: $P_1$ and $P_2$, which are calculated values of the variable for the first and second half-month periods in the month, respectively.

For the temperature variables,

$$P_1 = 2 \cdot M \left( \frac{.75(M-1)+.25(M+1)}{(M-1)+(M+1)} \right) ;$$

$$P_2 = 2 \cdot M \left( \frac{.25(M-1)+.75(M+1)}{(M-1)+(M+1)} \right) \qquad [5\text{-}1]$$

This works out so that the average of the two period temperatures is equal to the monthly average. For rainfall,

$$P_1 = M \left( \frac{.75(M-1)+.25(M+1)}{(M-1)+(M+1)} \right) ;$$

$$P_2 = M \left( \frac{.25(M-1)+.75(M+1)}{(M-1)+(M+1)} \right) \qquad [5\text{-}2]$$

This leaves the sum of the two period rainfalls equal to the monthly rainfall.

## COMPUTATION OF SOIL-LOSS RATIOS

Based on new descriptions of cropping and management practices and their influence on soil loss (Laflen et al. 1985), soil-loss ratios are computed as

$$SLR = PLU \cdot CC \cdot SC \cdot SR \cdot SM \qquad [5\text{-}3]$$

where SLR is the soil-loss ratio for the given conditions, PLU is the prior-land-use subfactor, CC is the canopy-cover subfactor, SC is the surface-cover subfactor, SR is the surface-roughness subfactor, and SM is the soil-moisture subfactor.

Each subfactor contains cropping and management variables that affect soil erosion. Individual subfactors in equation [5-3] are expressed as functions of one or more variables, including residue cover, canopy cover, canopy height, surface roughness, below-ground biomass (root mass plus incorporated residue), prior cropping, soil moisture, and time.

RUSLE uses a CROP database to store the values required to calculate the impact on soil loss of any vegetation within the management plan. These user-defined sets of values specify the growth characteristics of the vegetation, the amount of residue the vegetation will produce, and the characteristics of that residue. The program uses that information to calculate the change with time of the variables listed above and their impact on the subfactors. RUSLE contains another database to store user-supplied information defining the impacts of management operations on the soil, vegetation, and residues, and uses that information to modify the variables accordingly. The relationships of these databases to the subfactor calculations are explained in more detail in the following sections. Published values used in defining some basic crop and operation database sets are shown in tables 5-1 through 5-7. These values are not suitable for all conditions and will need to be adjusted accordingly. This adjustment can be readily accomplished within the RUSLE program by use of procedures described in chapter 7, using estimates as described in appendix D.

The RUSLE program contains a third database that represents the climate for the area of interest. This is important to the C-factor calculations in two ways: first,

the EI distribution within the database set is used to weight each SLR value in calculating the overall C-factor value. Second, the set also contains temperature and rainfall data, which are needed to calculate the rate of residue decomposition. Note that the climatic data are not used to modify the crop growth characteristics, because these are already defined in the crop database.

In addition to the databases, the RUSLE program contains a module that is important to several of the subfactor calculations. This is a subroutine that calculates the rate of residue decomposition as a function of residue characteristics and climate variables. Based on work by Stott et al. (1990) and Stott and Barrett (1991), this is derived as a first-order rate equation, and is calculated as

$$M_e = M_b \exp(-a D) \qquad [5\text{-}4]$$

where $M_e$ is residue mass at end of a time period, $M_b$ is mass at beginning of the period, D is period length in days, and

$$a = p \cdot [\text{minimum of } (W, F)] \qquad [5\text{-}5]$$

where p is a coefficient depending on residue characteristics (taken from the CROP database), and W and F are precipitation and temperature factors defined subsequently. The database sets provided with the RUSLE program contain empirically derived values of p for specific crops; new values of p must be found either by experimentation or by modifying existing values to reflect known differences in decomposition rates. See appendix D for more information on this modification. The decomposition relationships continue with

$$W = \frac{R}{R_o} \qquad [5\text{-}6]$$

and

$$F = \frac{2\left(T_a + A\right)^2 \cdot \left(T_o + A\right)^2 - \left(T_a + A\right)^4}{\left(T_o + A\right)^4} \qquad [5\text{-}7]$$

where R is rainfall in the half-month period, $R_o$ is minimum average half-month rainfall required for optimum decomposition, $T_a$ is average temperature in the half-month period, $T_o$ is optimum temperature for decomposition, and A is a coefficient used to describe the shape of the decomposition response to temperature. Calibration of these constants against decomposition data yields the values $R_o = 2.6$ in, $T_o = 90$ °F, and $A = 46$ °F. These values provide decomposition rates that seem to accurately reflect data from various regions of the United States, including the Pacific Northwest, Texas, Indiana, and Mississippi. The corresponding values of the crop decomposition constant p are shown in table 5-1. There are not sufficient data to distinguish between the decomposition rates of residue under surface and subsurface conditions, so the values shown in table 5-1 can be used for both. These values can be changed when further tests yield more complete information on p values for surface and subsurface conditions. The program treats the two values separately to allow for these changes.

Because SLR values are for half-month periods, they are calculated for the average residue level during the period, which is defined as

$$M_a = \left[\frac{M_b}{a\ D}\right]\left[\ 1 - \exp(-a\ D)\right] \qquad [5\text{-}8]$$

where $M_a$ is average residue mass during the time period, and the other terms are as defined above. Note that D may be up to 16 days but can be smaller if the half-month period is divided by one or more management operations. Note also that the units of mass need not be specified as long as they are consistent. The RUSLE program calculates residue mass in units of ($lb \cdot acre^{-1}$).

The RUSLE program separately calculates the amount of residue both on the surface and within the soil, and decomposes each according to climatic conditions and residue characteristics. It also accounts for additions of residue to the surface by harvests, senescence, or other management operations, and for incorporation of residue by tillage operations.

The calculations within RUSLE include three additional assumptions concerning residue incorporation and decomposition. First, it is assumed that residue incorporation cannot occur within a soil depth of less than 2 in, regardless of the depth of tillage defined for the field operation. Next, it is assumed that the residue is evenly incorporated throughout the depth of tillage. Finally, it is assumed that all subsurface residue will decompose at the same rate, without regard for the depth to which it is buried. While these assumptions are of limited validity, they provide an appropriate simplified basis on which to make the calculations.

The effectiveness of both surface and incorporated residues in controlling erosion rates has been found to depend on the mechanism by which the soil tends to erode. In general, soils that erode primarily through the formation of rills are substantially more protected by both surface and buried residues than are soils that erode primarily through sheet erosion in the interrill areas. Examples of soils that rill easily include those with naturally weak structure and those whose structure has been destroyed by disturbance and are in an unconsolidated state. Consolidated soils, or those with good structure, usually have a low ratio of rill to interrill erosion.

For permanent pasture or rangeland, the amounts of canopy cover, surface and subsurface residues, and root mass are relatively constant when compared to the widely varying amounts seen with most agronomic crops. This is especially true for permanent pasture or grassland, where the changes in residue and root mass are likely to be a small fraction of the total masses. If the assumption of constant values for these variables is thought to be adequate, RUSLE allows for calculation of the SLR values based on their average annual values. In this case, there are assumed to be no residue additions or decomposition. The program does allow for some disruption by tillage or other practices on a one-time basis and calculates an exponential decay of this effect.

**Prior-Land-Use Subfactor (PLU)**

The prior-land-use subfactor (PLU) expresses (1) the influence on soil erosion of subsurface residual effects from previous crops and (2) the effect of previous tillage practices on soil consolidation. The relationship is of the form

$$PLU = C_f \cdot C_b \cdot \exp[( -c_{ur} \cdot B_{ur} ) + ( c_{us} \cdot B_{us} / C_f^{c_{uf}} )] \qquad [5\text{-}9]$$

where PLU is the prior-land-use subfactor (which ranges from 0 to 1), $C_f$ is a surface-soil-consolidation factor, $C_b$ represents the relative effectiveness of subsurface residue in consolidation, $B_{ur}$ is mass density of live and dead roots found in the upper inch of soil (lb · acre$^{-1}$ · in$^{-1}$), $B_{us}$ is mass density of incorporated surface residue in the upper inch of soil (lb · acre$^{-1}$ · in$^{-1}$), $c_{uf}$ represents the impact of soil consolidation on the effectiveness of incorporated residue, and $c_{ur}$ and $c_{us}$ are calibration coefficients indicating the impacts of the subsurface residues.

The variable $C_f$ expresses the effect of tillage-induced surface density changes on soil erosion. Tillage operations tend to break soil aggregate bonds, increasing the potential for erosion. This is reflected in the lower erosion rates associated with the undisturbed soils of rangeland or no-till systems. Based on the work of Dissmeyer and Foster (1981), the value of $C_f$ for freshly tilled conditions is 1.0. If the soil is left undisturbed, this value decays exponentially to 0.45 over 7 yr, or over some other length of time specified by the user. The impact of a field operation on this factor is determined by the portion of the surface disturbed. For example, if a planting operation disturbs only 30% of the surface that had already consolidated to the point where $C_f = 0.6$, then 70% of the field would have a value of $C_f = 0.6$, and the disturbed 30% would have a value of $C_f = 1.0$; the overall value would be $[(70\%)(0.6) + (30\%)(1.0)]/(100\%) = 0.72 = C_f$.

The $B_u$ variables are used to calculate the impact on erosion rates of live and dead roots and incorporated residue. The effectiveness of such materials can take two forms. First, roots and residue can control erosion directly by physically binding soil particles together and by acting as mechanical barriers to soil and water movement. Second, roots and residue exude binding agents and serve as a food source for microorganisms that produce other organic binding agents. These serve to increase soil aggregation and thereby reduce its susceptibility to erosion.

It is the subsurface biomass (incorporated residue and roots) near the surface that is most effective in resisting erosion, so the values of $B_u$ are in terms of biomass density (lb · acre$^{-1}$ · in$^{-1}$) in the top inch of soil. The depth of soil that has these biomass densities will be defined by the pattern of field operations. If the most recent operation affects 100% of the surface and has a disturbance depth of 6 in, the $B_u$ values will be the subsurface biomass densities to a depth of 6 in. It is assumed in RUSLE that residue cannot be mixed into a soil depth of less than 2 in, which makes this the least depth to which the $B_u$ values can apply.

The surface residue is assumed to be evenly incorporated into the soil to the depth of tillage, and the root mass at that depth is also assumed to be mixed in.

Inputs provide information on root mass to a depth of only 4 in, but the assumption of no roots below this will lead to incorrect dilution of the residue if mixing occurs to a depth greater than 4 in. RUSLE therefore includes the assumption that the soil depth of 4-8 in contains a root mass equal to 80% of that in the layer at 0-4 in. Note here that soil layers are defined not by soil characteristics or morphology, but by where the roots grow and how deeply the soil is disturbed.

This concept of the $B_u$ values and soil layers can best be clarified with an example, beginning with 6,000 lb · acre$^{-1}$ of surface residue and 1,000 lb · acre$^{-1}$ of root mass in the top 4 in. This gives $B_{ur}$ = 1,000/4 = 250 lb · acre$^{-1}$ · in$^{-1}$ throughout the top 4 in, a biomass density of (1,000 · 0.8)/(8-4) = 200 lb · acre$^{-1}$ · in$^{-1}$ for the layer at 4-8 in, and $B_{us}$ = 0 because no surface residue has been buried. Assume then a field operation that disturbs 100% of the surface, leaves 70% of the surface residue on the surface, and has a tillage depth (and therefore an incorporation depth) of 6 in. Following the operation, there are two soil layers; the top layer is from the surface down to 6 in, below which is a layer from 6 to 8 in. The top layer has a total root mass of (250 · (4-0)) + (200 · (6-4)) = 1,400 lb · acre$^{-1}$, or $B_{ur}$ = 1,400/6=233 lb · acre$^{-1}$ · in$^{-1}$, while the bottom layer still has a root mass density of 200 lb · acre$^{-1}$ · in$^{-1}$. The top layer also contains (6,000 · 0.3) = 1,800 lb · acre$^{-1}$ of incorporated surface residue, leaving (6,000 · 0.7) = 4,200 lb · acre$^{-1}$ on the surface, and yielding $B_{us}$ = 1,800/6 = 300 lb · acre$^{-1}$ · in$^{-1}$. If this is followed immediately with another tillage that disturbs 100% of the surface, leaves 75% of the residue on the surface, and has a tillage depth of 2 in, we end up with three soil layers: one from 0-2 in, one from 2-6 in, and one from 6-8 in. The top layer has a total root mass of 233 · 2 = 466 lb · acre$^{-1}$ and a total incorporated residue of (300 · 2) + (4,200 · 0.25) = 1,650 lb · acre$^{-1}$, resulting in $B_{ur}$ = 466/2 = 233 lb · acre$^{-1}$ · in$^{-1}$ and $B_{us}$ = 1,650/2 = 825 lb · acre$^{-1}$ · in$^{-1}$. The layers at 2-6 and 6-8 in will still have root mass biomass densities of 233 and 200 lb · acre$^{-1}$ · in$^{-1}$, and incorporated biomass densities of 300 and 0 lb · acre$^{-1}$ · in$^{-1}$, respectively.

The RUSLE program keeps track of the biomass in each soil layer, continuously adjusting the root mass and subsurface residue to account for additions and decomposition.

Additional complications arise when a field operation does not disturb 100% of the surface, because the residue incorporation and mixing will vary over the field. The program needs to account for the fact that some portions of the field will be protected by additional subsurface biomass, while other portions will not. As it handles the field operation for $B_{ur}$, the program calculates three values: one overall without considering spatial variability, one for just those areas with

the added incorporation and mixing, and one for the areas without the additional incorporation and mixing. Equation [5-9] is used to calculate the PLU values associated with each of these last two densities, which are then weighted by the associated surface fraction and added. This average PLU value is put back into equation [5-9] to calculate an equivalent weighted $B_{ur}$. This is divided by the first overall $B_{ur}$, which yields an adjustment ratio. Until it is changed by the next tillage operation, this ratio is used to adjust the calculated overall $B_{ur}$ (which changes with residue decay and root growth); $B_{ur}$ is multiplied by the ratio before it is put into equation [5-9]. This simplifies calculations during the time between operations by requiring only calculation of the overall $B_{ur}$, and by accounting for spatial variability with the adjustment ratio. If this procedure is followed, an operation that disturbs 100% of the surface simply yields an adjustment ratio of 1.0. A similar adjustment is used for $B_{us}$.

As an example of this adjustment, assume that an operation disturbs 20% of the surface, that in the disturbed area $B_{ur} = 500$ lb · acre$^{-1}$ · in$^{-1}$, in the undisturbed area $B_{ur} = 200$ lb · acre$^{-1}$ · in$^{-1}$, and that the overall $B_{ur} = 260$ lb · acre$^{-1}$ · in$^{-1}$. If the first two values are put back into equation [5-9] with an assumed $c_{ur} =$ 0.0014 acre · in · lb$^{-1}$, the weighted average PLU is PLU = (0.2 · 0.497) + (0.8 · 0.756) = 0.70. This corresponds to an equivalent density of 251 lb · acre$^{-1}$ · in$^{-1}$, which yields an adjustment ratio of 251 / 260 = 0.97. This indicates that in this case the uneven residue incorporation is only slightly less effective at controlling erosion than if it were incorporated evenly.

The coefficients $C_b$, $c_{ur}$, $c_{us}$, and $c_{uf}$ describe the relative effectiveness of subsurface biomass in reducing erosion. These were calibrated using information from Van Liew and Saxton (1983), values from table 5 and 5-D in Agriculture Handbook 537 (Wischmeier and Smith, 1978), and an extensive data set collected from a broad series of no-till experiments. This analysis yields $C_b$ = 0.951, $c_{ur}$ = 0.00199 acre · in · lb$^{-1}$, $c_{us}$ = 0.000416 acre · in · lb$^{-1}$, and $c_{uf}$ = 0.5. For soils that erode primarily as a result of rainfall and snowmelt on frozen or thawing soils (such as many in the Northwest Wheat and Range Region), subsurface residue has been found to be even more effective, yielding $c_{ur}$ = 0.00398 acre · in · lb$^{-1}$, $c_{us}$ = 0.000832 acre · in · lb$^{-1}$, and $c_{uf}$ = 0.5.

The amount of incorporated residue is calculated from the additions of residue to the surface and its subsequent burial by tillage operations. The total subsurface biomass is made up of this incorporated surface residue ($B_{us}$ in equation [5-9]), and the total live and dead root mass ($B_{ur}$ in equation [5-9]). The program keeps track of the live roots as described later, and adds this amount to the root residue when the vegetation is killed. The root residue is decayed through use of the decomposition subroutine.

The impact of surface residue on soil organic matter is described by adding a portion of the decayed surface residue mass to the root-mass residue. Based on analysis of no-till erosion data, this fraction is defined as 0.5.

The amount of live roots in the top 4 in is usually taken directly from the CROP database set. The user is responsible for supplying these values, but estimates of root mass at various times in the growing season for selected agronomic crops are given in table 5-2, and suggested values for pasture and meadow crops are shown in table 5-3. In addition, the program assumes that the soil layer at 4-8 in will contain a root mass concentration equal to 80% of that in the top 4 in. This assumption is required to reflect the mixing of soil layers by tillage operations and the resulting redistribution of root mass.

For many rangeland conditions, values of live root mass are not available. Weltz et al. (1987) developed data for estimating root biomass on rangelands. The effective below-ground root biomass ($B_b$) is given as

$$B_b = B_a \cdot n_i \qquad [5\text{-}10]$$

where $B_a$ is total average annual site production potential (lb · acre$^{-1}$), and $n_i$ is the ratio of effective root mass to annual site production potential. Suggested values of $n_i$ for many plant communities in western U.S. rangelands and eastern pastures are found in table 5-4. Estimates of $B_a$ can be made using standard production potential techniques, or by use of such guides as Natural Resources Conservation Service (NRCS) range-site descriptions.

On croplands, the amount of above- and below-ground biomass present at a given time depends on initial mass of the residue, root mass, fraction of crop residue incorporated by field operations, and decomposition rate of residue and roots. If the initial residue mass at harvest is not known, it can be estimated by multiplying the grain yield by the residue-to-yield ratio (table 5-1). The percentages of residue cover left on the soil surface after various field operations are shown in table 5-5. These values may vary considerably, depending on crop type, implement speed, and soil and residue conditions. If more than one type of residue cover exists on the surface, this percentage of each of the residues will be left after the field operation.

**Canopy-Cover Subfactor (CC)**

The canopy-cover subfactor expresses the effectiveness of vegetative canopy in reducing the energy of rainfall striking the soil surface. Although most rainfall intercepted by crop canopy eventually reaches the soil surface, it usually does so

with much less energy than does rainfall that strikes the ground without having been intercepted. The intercepted raindrops fracture into smaller drops with less energy, or drip from leaf edges, or travel down crop stems to the ground. The canopy-cover effect is given as

$$CC = 1 - F_c \cdot \exp(-0.1 \cdot H) \qquad [5\text{-}11]$$

where CC is the canopy-cover subfactor ranging from 0 to 1, $F_c$ is fraction of land surface covered by canopy, and H (ft) is distance that raindrops fall after striking the canopy.

This relationship was given graphically by Wischmeier and Smith (1978) and is shown in figure 5-1 for several heights. It is based on the assumptions that the rainfall fraction intercepted by the canopy is equal to the fraction of the land surface beneath the canopy, and that any rainfall intercepted will leave the canopy at a height H (ft) with a mean drop diameter of 0.1 in. Although Quinn and Laflen (1983) found that stem flow was quite significant and that drop sizes differed from those assumed by Wischmeier and Smith, they did find that the relationship given in equation [5-11] was satisfactory for corn. Others have noted the different effects of various kinds of crops (Armstrong and Mitchell 1987, 1988; Finney 1984; Haynes 1940). Values for $F_c$ and H for each crop are defined by the user. Some suggested values for several crops are listed in table 5-2.

**Surface-Cover Subfactor (SC)**

Surface cover affects erosion by reducing the transport capacity of runoff water (Foster 1982), by causing deposition in ponded areas (Laflen 1983), and by decreasing the surface area susceptible to raindrop impact. It is perhaps the single most important factor in determining SLR values. Surface cover includes crop residue, rocks, cryptogams, and other nonerodible material that is in direct contact with the soil surface (Simanton et al. 1984, Box 1981, Meyer et al. 1972). The effect of surface cover on soil erosion is given by

$$SC = \exp\left[ -b \cdot S_p \cdot \left( \frac{0.24}{R_u} \right)^{0.08} \right] \qquad [5\text{-}12]$$

where SC is the surface-cover subfactor, b is an empirical coefficient, $S_p$ is percentage of land area covered by surface cover, and $R_u$ is surface roughness (in) as defined by equation [5-16].

The b value indicates the effectiveness of surface cover in reducing soil erosion. Laflen et al. (1980) and Laflen and Colvin (1981) found that b values ranged from 0.030 to 0.070 for row crops, and Dickey et al. (1983) found b values of 0.024-0.032 in a rainfall-simulation study on small grains. Within the Northwestern Wheat and Range Region, b values greater than 0.050 have been found for small grains. Simanton et al. (1984) recommended a b value of 0.039 for rangeland conditions with the impact of subsurface biomass removed. The relationship given in equation [5-12] is shown in figures 5-2 and 5-3 for several values of $R_c$ and b.

Even though experimental data reflect a wide variance in b values, additional analyses using modeling techniques have indicated that the selection of an appropriate b value can be made more accurately if the dominant erosion process is known. When rill erosion is the primary mechanism of soil loss (such as for irrigation or snowmelt or for highly disturbed soils), b values should be about 0.050. Fields dominated by interrill erosion have a b value of around 0.025. For typical cropland erosion conditions, a b value of 0.035 is suggested. For rangeland and permanent pasture communities, the b value depends on the general type of vegetation.

The percentage of land area covered by residue can be estimated from residue weight by use of the relationship developed by Gregory (1982), as follows:

$$S_p = \left[ 1 - \exp\left( -\alpha \cdot B_s \right) \right] \cdot 100 \qquad [5\text{-}13]$$

where $S_p$ is percent residue cover, $\alpha$ is the ratio of the area covered by a piece of residue to the mass of that residue (acre $\cdot$ lb$^{-1}$), and $B_s$ is the dry weight of crop residue on the surface (lb $\cdot$ acre$^{-1}$). Typical values for $\alpha$ are given in table 5-1. Percent residue covers for various residue weights from the use of equation [5-13] are illustrated in figure 5-4. If more than one type of residue is present, the resulting total surface cover is calculated by modifying equation [5-13] as

$$S_p = \left\{ 1 - \exp\left[ - \sum_{i=1}^{N} \left( \alpha_i \, B_{si} \right) \right] \right\} \cdot 100 \qquad [5\text{-}14]$$

where N is number of residue types and $\alpha_i$ is ratio of the area covered to the mass of that residue for each type encountered.

Within RUSLE, rather than entering a value for $\alpha$, the program asks for residue weights associated with specific values of residue cover and calculates the corresponding $\alpha$ value. The program asks for residue weights at 30%, 60%, and 90% surface cover. Only one of these needs to be entered to calculate an $\alpha$ value. If more than one weight is entered, the program will calculate an $\alpha$ value for each and then average them.

**Surface-Roughness Subfactor (SR)**

Surface roughness has been shown to directly affect soil erosion (Cogo et al. 1984), and to indirectly affect it through the impact on residue effectiveness, implied in equation [5-12]. In either case, this is a function of the surface's random roughness, which is defined as the standard deviation of the surface elevations when changes due to land slope or nonrandom tillage marks (such as dead furrows, traffic marks, and disk marks) are removed from consideration (Allmaras et al. 1966). A rough surface has many depressions and barriers. During a rainfall event, these trap water and sediment, causing rough surfaces to erode at lower rates than do smooth surfaces under similar conditions. Increasing the surface roughness decreases the transport capacity and runoff detachment by reducing the flow velocity.

Roughness and cloddiness of soils also affect the degree and rate of soil sealing by raindrop impact. Soils that are left rough and cloddy typically have higher infiltration rates. Soils that are finely pulverized are usually smooth, seal rapidly, and have low infiltration rates (Sumner and Stewart 1992).

Values of random roughness vary, depending on the type and degree of surface disturbance. Typical values are given in table 5-5 for cropland and table 5-6 for rangeland conditions. These core values may be modified as described in appendix D. Roughness conditions for a given field operation may vary, depending on previous tillage, implement speed, and field conditions.

The impact of surface roughness on erosion is defined by a baseline condition, which sets SR equal to 1 for unit plot conditions of clean cultivation smoothed by extended exposure to rainfall of moderate intensity. These conditions yield a random roughness of about 0.24 in. This makes it possible to get SR values of greater than 1 for practices in which the soil is very finely pulverized and smoothed to a smaller random roughness, as might be the case for some rototilling operations or for repeated cultivations of silt loam soils under dry fallow conditions. For conditions in which repeated disturbance leaves a rougher surface (for example, for continuous cattle-grazing), this final roughness value of 0.24 can be replaced. Chapter 7 describes how this is done.

Except in these cases of fine pulverization, it is assumed that the roughness left after field operations is smoothed by the effects of raindrop impact, approaching a random roughness of 0.24 in as the cumulative rainfall increases. This smoothing is modeled by expanding on the relationship described by Onstad et al. (1984)

$$D_r = \exp\ [1/2\ (-0.14 \cdot P_t) + 1/2\ (-0.012 \cdot EI_t)] \qquad [5\text{-}15]$$

where $D_r$ is the dimensionless roughness decay coefficient, $P_t$ is the total inches of rainfall since the most recent operation that disturbed the entire surface, and $EI_t$ is the total EI amount since that same operation. The value of $D_r$ ranges exponentially from a value of 1.0 for a surface that has experienced no rainfall to a value approaching 0.0 for a surface that has experienced extensive rainfall and has lost most of its roughness.

If the initial roughness is defined as $R_i$ (in inches), the surface roughness just before the current tillage operation ($R_u$) can be defined as

$$R_u = 0.24 + [D_r\ (R_i - 0.24)] \qquad [5\text{-}16]$$

where $R_u$ is in inches. Since many field operations affect only a portion of the surface, $R_u$ is also the roughness of the portion of the field that is undisturbed by the current field operation.

For that portion of the surface that is affected by the field operation, the resulting roughness has been found to be a function of subsurface biomass present in the top 4 in of soil. This relationship is described by

$$R_a = 0.24 + (R_t - 0.24)\{0.8\ [1 - \exp(-0.0012\ B_u)] + 0.2\} \qquad [5\text{-}17]$$

where $R_a$ is the roughness after biomass adjustment (in), $R_t$ is the original tillage roughness based on the assumption of ample subsurface biomass such as that found with high-yielding midwestern corn (in), and $B_u$ is total subsurface biomass density in the top inch of soil ($lb \cdot acre^{-1} \cdot in^{-1}$). $B_u = B_{ur} + B_{us}$ as defined for equation [5-9]. Researchers in the Northwestern Wheat and Range Region indicate that the strong relationship of tillage roughness to subsurface biomass does not hold for their conditions (D.K. McCool, personal communication 1994). In that area of the country, equation [5-17] is not used, leaving simply $R_a = R_t$.

This adjusted tillage roughness is then combined with that of the undisturbed portion of the surface as

$$R_n = R_a F_d + R_u F_u \qquad [5\text{-}18]$$

where $R_n$ is the net roughness following the field operation (in). $F_d$ and $F_u$ are the fractions of the surface disturbed and undisturbed, respectively, so their sum equals one.

Similarly, the decay coefficient must be adjusted to reflect the fact that only a portion of the field was disturbed. This is done using the relationship

$$D_e = D_r F_u + 1.0 F_d \qquad [5\text{-}19]$$

where $D_e$ is the equivalent roughness decay coefficient. Under the assumption that the ratio $EI_t/P_t$ before the operation equals that after, the $P_t$ and $EI_t$ values corresponding to the equivalent roughness decay coefficient are

$$P_t = -2 \cdot \ln(D_e) \Big/ \left[0.14 + 0.012 \left(\frac{EI_{t,b}}{P_{t,b}}\right)\right]; \qquad [5\text{-}20]$$
$$EI_t = EI_{t,b} \cdot P_t/P_{t,b}$$

where the subscript b indicates the value before the operation.

These values for the decay coefficient and corresponding precipitation and EI describe a point on a new roughness decay curve, asymptotic to zero at infinite amounts of precipitation, and with a new initial roughness at $P_t = 0$. This new initial roughness $R_i$ (in) is calculated from

$$R_i = 0.24 + \frac{(R_n - 0.24)}{D_e} \qquad [5\text{-}21]$$

thereby completely describing the decay curve.

As the computer program steps through each time segment in the rotation, the total rainfall and EI since tillage ($P_t$ and $EI_t$) are incremented by the amounts in that segment. The value of the roughness decay coefficient for that segment is then calculated by use of equation [5-15], and the current surface roughness is calculated by equation [5-16].

The surface random roughness is affected not only by the soil clods resulting from tillage, but also by the vegetation. If a site is clean-tilled and then left without human intervention, two things will happen: (1) the tillage roughness will decrease as defined previously, and (2) as the years go by, the vegetation will trend toward its climax community, with attendant roughness caused by protruding roots, soil mounded around old basal areas, rocks, and so on.

RUSLE assumes that the formation of this vegetative roughness follows a typical sigmoidal growth curve increasing from the minimum soil roughness ($r_{min}$, with a default of 0.24 in) to the total roughness when the soil is fully consolidated ($r_{max}$) over the time required for consolidation ($t_{con}$). At any time after disturbance ($t_d$), the relationship will be

$$r_{nat} = r_{min} + \left[ \frac{(r_{max} - r_{min})}{1 + \exp \dfrac{\left(0.5 - \dfrac{t_d}{t_{con}}\right)}{0.1}} \right] \qquad [5\text{-}22]$$

where $r_{nat}$ is the roughness caused by the community (in). For each time period the program calculates $r_{nat}$, and compares its value to $R_u$ as calculated for that same period. If $r_{nat}$ is larger, then $R_u$ is set equal to $r_{nat}$. In general, this will only occur if the site has not been disturbed for quite some time.

The surface roughness subfactor is then

$$SR = \exp[-0.66(R_u - 0.24)] \qquad [5\text{-}23]$$

**Soil-Moisture Subfactor (SM)**

Antecedent soil moisture has a substantial influence on infiltration and runoff and hence on soil erosion. In general, antecedent moisture effects are an inherent component of continuous-tilled fallow plots, and these effects are reflected in variation in soil erodibility throughout the year. In most of the continental United States, soil moisture is usually high during susceptible crop stages in spring and early summer, when much of the erosion occurs. Hence the

antecedent soil moisture on cropped plots parallels that on the continuous-tilled fallow plots from which soil-erodibility factors are derived, so no adjustment is made for changes in soil moisture.

In the nonirrigated portions of the Northwestern Wheat and Range Region (Austin 1981) (including eastern Oregon, eastern Washington, and Idaho), soil moisture during critical crop periods depends on crop rotation and management. Winter wheat may be seeded after a previous crop of winter wheat, or after a more shallow-rooted crop, or after summer fallow. When a full year of fallow is used in the rotation, part of the moisture stored over the previous winter is retained in the soil profile. This is particularly true when an effective mulch system is used: either a loose soil and residue mulch in conjunction with a rodweeder, or an untilled residue mulch with direct stubble seeding. These systems are in contrast to continuous cropping, in which soil moisture is at or below the wilting point in the fall before the fall and winter precipitation. Addition of a soil-moisture subfactor (SM) is suggested for this region of the Northwestern Wheat and Range Region (McCool, personal communication 1994). SM reflects these dry fall conditions and the increase in soil moisture over the winter. The soil moisture decrease over the summer depends on the crop rooting depth and soil depth, and the soil moisture replenishment depends on the precipitation amount and soil depth.

When the soil profile is at or near field capacity, SM is 1.0 (such as on April 1 of fig. 5-5), indicating response equivalent to that of a continuous-fallow plot. When the profile is near wilting point to a 6-ft depth, the SM value is 0 (as on September 1 in fig. 5-5), indicating that no runoff and erosion are expected. This assumes that infiltration is not limited by surface conditions. SM increases over the winter from October 1 to March 31. Suggested replenishment-rate relationships are given in figure 5-6. Growing-season (April 1 to July 31) depletion rates for typical crops appear in table 5-7. These relationships and values are typical and may need adjustment for shallow-soil conditions or other considerations.

## COMPUTATION OF C FACTOR

Once the SLR's have been calculated for each time interval, they are multiplied by their corresponding percentage of annual EI (Wischmeier and Smith 1978) as seen in table 2-1. These values are then summed and divided by the total percentage of annual EI value for the entire time period being investigated, as

$$C = \left(SLR_1\ EI_1 + SLR_2\ EI_2 + \ldots\ SLR_n\ EI_n\right) / EI_t \qquad [5\text{-}24]$$

where C is average annual or crop value, $SLR_i$ is the value for time period i, $EI_i$ is percentage of the annual or crop EI occurring during that time period, n is number of periods used in the summation, and $EI_t$ is sum of the EI percentages for the entire time period.

For those systems where conditions are not rapidly changing (such as for rangeland, or continuous pasture or meadow), the PLU, CC, SC, and SR subfactor values are assumed to be annual averages, and are simply multiplied together to yield the overall C-factor value. If the assumption of nearly steady-state conditions does not hold, the weighted procedure used for cropland is more appropriate.

# COMPUTATION OF C FACTORS FOR SINGLE DISTURBANCES AND FOR ROTATIONS

RUSLE technology can be used to estimate erosion under two very different sets of circumstances. The first circumstance is the one-time disturbance of an area, such as for a construction site, a rangeland under an improvement plan, or a disturbed forest site. In this case, the soil/vegetation/residue system is drastically disturbed but is then allowed to reconsolidate and return to more stable conditions.

The other general circumstance under which RUSLE can be used is a normal cropping rotation, in which the soil/vegetation/residue system is disturbed repeatedly in a cycle of one or more years. For example, a conventionally tilled corn-soybean rotation would have the same field operation (for example, planting of corn) at roughly the same time of year (perhaps May 15) every second year.

For the situation of a single disturbance, proper use of the RUSLE program requires definition of all the important soil/vegetation/residue parameters immediately after the disturbance. This process is described in more detail in chapter 7. For a crop rotation, matters are somewhat more complicated, because the disturbance is usually not so severe and the previous crops and field operations can still have a significant impact. The RUSLE program handles this by running three times through the calculations for the entire rotation, and by returning the calculated SLR values on only the third time through. This procedure allows the system to stabilize and minimizes the impact of the assumed initial conditions on the resulting SLR values.

## COMPUTATION OF C FACTORS FOR HILLSLOPES UNDER STRIPCROPPING OR BUFFER STRIPS

For management schemes such as those modeling stripcropping and buffer strips, the vegetation and cropping schemes cause the SLR values to vary not only with time but also with position on the hillslope. For example, in a stripcropping scheme with alternating strips of conventionally tilled corn and good sod-forming grass, at any time half of the field would be under each crop.

The impact of such a scheme on the movement of runoff and the deposition of sediment is taken into account in the P factor (see ch. 6), but this does not account for the protection given the soil by the important parameters within the C factor: things such as random roughness, root mass, surface residue cover, and canopy cover. These must still be represented through the C factor.

This is done by calculating an individual C factor for each strip, and then weighting these by their area on the hillslope. For example, in any true stripcropping rotation scheme, each strip is rotated through the same pattern, so we need make only one C-factor calculation. On the other hand, for buffer strips, we can calculate a C factor for the buffer strips themselves and then calculate a C factor for the cropped areas between the buffer strips. We then calculate an overall C factor by multiplying each of the C factors by the percentage of the hillslope under that practice.

## ACKNOWLEDGMENT

The authors acknowledge the kind assistance of Jim Cropper, NRCS, Chester, PA, for his extensive work in developing the CROP database information for forage crops.

Table 5-1.
Parameter values of typical crops[1]

| Crop | Residue/yield ratio[2] | Surface p[3] | $\alpha$[4] (acre · lb$^{-1}$) | Residue at 30% cover[5] (lb · acre$^{-1}$) | Yield | Row spacing[6] (in) | Plant population[6] (plants acre$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Alfalfa | 0.15 | 0.020 | 0.00055 | 650 | 6 ton · acre$^{-1}$ | (drilled) | 180,000 |
| Bromegrass | 0.15 | 0.017 | 0.00055 | 650 | 5 ton · acre$^{-1}$ | 7 (drilled) | 330,000 |
| Corn | 1.00 | 0.016 | 0.00038 | 950 | 130 bu · acre$^{-1}$ | 30 | 25,000 |
| Cotton | 1.00 | 0.015 | 0.00022 | 1,600 | 900 lb · acre$^{-1}$ | 38 | 35,000 |
| Oats | 2.00 | [7]0.008 | 0.00059 | 600 | 65 bu · acre$^{-1}$ | 7 (drilled) | 890,000 |
| Peanuts | 1.30 | 0.015 | 0.00030 | 1,200 | 2,600 lb · acre$^{-1}$ | 36 | 558,000 |
| Rye | 1.50 | [7]0.008 | 0.00055 | 650 | 30 bu · acre$^{-1}$ | (drilled) | 890,000 |
| Sorghum | 1.00 | 0.016 | 0.00036 | 1,000 | 65 bu · acre$^{-1}$ | 30 | 41,000 |
| Soybeans | 1.50 | 0.025 | 0.00059 | 600 | 35 bu · acre$^{-1}$ | 30 | 110,000 |
| Sunflowers | 1.50 | 0.016 | 0.00024 | 1,500 | 1,100 lb · acre$^{-1}$ | 30 | 20,000 |
| Tobacco | 1.80 | 0.015 | 0.00036 | 1,000 | 2,200 lb · acre$^{-1}$ | 48 | 6,000 |
| Wheat (spring) | 1.30 | [7]0.008 | 0.00059 | 600 | 30 bu · acre$^{-1}$ | 7 (drilled) | 890,000 |
| Wheat (winter) | 1.70 | [7]0.008 | 0.00059 | 600 | 45 bu · acre$^{-1}$ | 7 (drilled) | 890,000 |

[1] Values in table are taken from Alberts et al. (1989), Ghidey et al. (1985), Gregory (1982), Gregory et al. (1985), Larson et al. (1978), National Research Council (1975), USDA (1990), and USDA-SCS (1991).

[2] Weight ratio of crop residue at harvest to crop yield,

[3] A constant that controls the exponential decomposition rate or surface residue from this crop. There are not enough data to justify different values for subsurface decay p values, so default values in program show identical decay rates for surface and buried residue. This can be changed by user.

[4] Ratio of area covered by a piece of residue to its mass.

[5] Mass of residue required to cover 30% of the surface area, corresponding to given value of $\alpha$.

[6] Not currently used in program; is simply an aid in defining cropping patterns and likely residue levels

[7] Use 0.017 for the Northwestern Wheat and Range Region, or for small grain cover killed in the vegetative state.

Table 5-2.
Typical values of root mass, canopy cover, and canopy-droplet-fall-height for row crops and small-grain crops

| | Root mass in upper 4 in of soil ($lb \cdot ac^{-1}$) | | | | | | Land surface covered by canopy (%) | | | | | | Canopy-droplet-fall-height (ft) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of days after planting | Corn[1] | Soybeans[2] | Cotton[3] | Sorghum[4] | Winter small grain[5,6] | Spring small grain[5,7] | Corn | Soybeans | Cotton | Sorghum | Winter small grain | Spring small grain | Corn | Soybeans | Cotton | Sorghum | Winter small grain | Spring small grain |
| 15 | 50 | 20 | 30 | 50 | 30 | 100 | 5 | 5 | 5 | 5 | 5 | 10 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 30 | 180 | 50 | 60 | 180 | 120 | 300 | 10 | 20 | 15 | 10 | 20 | 35 | 0.5 | 0.2 | 0.2 | 0.5 | 0.2 | 0.3 |
| 45 | 350 | 90 | 90 | 350 | 300 | 500 | 50 | 40 | 35 | 50 | 35 | 60 | 1.0 | 0.5 | 0.5 | 1.0 | 0.2 | 0.8 |
| 60 | 530 | 180 | 180 | 530 | 320 | 700 | 80 | 70 | 55 | 80 | 35 | 90 | 1.7 | 1.0 | 1.0 | 1.5 | 0.2 | 1.3 |
| 75 | 840 | 360 | 310 | 800 | 320 | 900 | 100 | 100 | 85 | 100 | 35 | 100 | 2.5 | 1.3 | 1.4 | 2.0 | 0.2 | 1.5 |
| 90 | 1060 | 360 | 360 | 1060 | 320 | | 100 | 100 | 100 | 100 | 35 | | 3.0 | 1.6 | 1.8 | 2.2 | 0.2 | |
| 105 | 1060 | 360 | 360 | | 320 | | 100 | 90 | 100 | | 35 | | 3.0 | 1.6 | 1.8 | | 0.2 | |
| 120 | 1060 | 360 | 360 | | 320 | | 100 | 50 | 60 | | 35 | | 3.0 | 1.6 | 1.8 | | 0.2 | |
| 135 | 1060 | 360 | 360 | | 320 | | 100 | 35 | 20 | | 35 | | 3.0 | 1.6 | 1.8 | | 0.2 | |
| 150 | 1060 | | | | 320 | | 90 | | | | 35 | | 3.0 | | | | 0.2 | |
| 165 | 1060 | | | | 320 | | 70 | | | | 35 | | 3.0 | | | | 0.2 | |
| 180 | | | | | 340 | | | | | | 40 | | | | | | 0.5 | |
| 195 | | | | | 400 | | | | | | 60 | | | | | | 1.0 | |
| 210 | | | | | 660 | | | | | | 90 | | | | | | 1.3 | |
| 225 | | | | | 1000 | | | | | | 100 | | | | | | 1.5 | |
| 240 | | | | | 1200 | | | | | | 100 | | | | | | 1.5 | |

[1] 125 bu/ac yield, 30 in rows, 120 d, adjust duration of full canopy for different lengths of growing season
[2] 35 bu/ac yield, 30 in rows, full season
[3] 750 lbs/ac lint yield, 30 in rows, solid seeded
[4] 65 bu/ac yield, 30 in rows
[5] These are specific to areas with a spring and summer precipitation regime, a winter dormant period, and are not applicable to the Northwest Wheat and Range Region, adjust period of dormancy and growth of crop during dormant period according to growth patterns typical of region
[6] 45 bu/ac yield
[7] 60 bu/ac yield

Table 5-3.
Typical values for established forage stands[1]

| Common name | Root mass in top 4 in (lbs·acre$^{-1}$) | Canopy cover just prior to harvest (%) | Effective fall height (ft) | Average annual yield (tons·acre$^{-1}$) |
|---|---|---|---|---|
| Grasses: | | | | |
| Bahiagrass | 1,900 | 95 | 0.1 | 4 |
| Bermudagrass, coastal | 3,900 | 100 | 0.2 | 8 |
| Bermudagrass, common | 2,400 | 100 | 0.1 | 3 |
| Bluegrass, Kentucky | 4,800 | 100 | 0.1 | 3 |
| Brome grass, smooth | 4,500 | 100 | 0.1 | 5 |
| Dallisgrass | 2,500 | 100 | 0.1 | 3 |
| Fescue, tall | 7,000 | 100 | 0.1 | 5 |
| Orchardgrass | 5,900 | 100 | 0.1 | 5 |
| Timothy | 2,900 | 95 | 0.1 | 5 |
| Legumes: | | | | |
| Alfalfa | 3,500 | 100 | 0.2 | 6 |
| Clover, ladino | 1,400 | 100 | 0.2 | 3 |
| Clover, red | 2,100 | 100 | 0.1 | 4 |
| Clover, sweet | 1,200 | 90 | 2.0 | 2 |
| Clover, white | 1,900 | 100 | 0.1 | 2 |
| Lespedeza, sericea | 1,900 | 100 | 0.5 | 3 |
| Trefoil, birdsfoot | 2,400 | 100 | 0.3 | 4 |

[1]These values are for mature, full pure stands on well-drained nonirrigated soils with moderate-to-high available water-holding capacity. These values hold for species shown only within their range of adaptation. Except for biennials, most forages do not attain a fully-developed root system until end of second growing season. Root mass values listed can be reduced by as much as half on excessively drained or shallow soils and in areas where rainfall during growing season is less than 18 in. The values listed are from Bennett and Doss (1960), Denison and Perry (1990), Doss et al. (1960), Holt and Fisher (1960), Kramer and Weaver (1936), Lamba et al. (1949), MacDonald (1946), and Pavlychenko (1942).

Table 5-4.
Parameter values for estimating below-ground root mass in western U. S. rangelands

| Vegetation type | Ratio of root mass in upper 4 in to total root mass | | Ratio of root mass to above-ground biomass | | Ratio of effective root mass to annual site production potential [1]($n_i$) |
|---|---|---|---|---|---|
| | Best estimate | Range | Best estimate | Range | |
| Southern mixed grass prairie | 0.50 | NA[2] | 4.0 | NA | 1.1 |
| Northern mixed grass prairie | 0.34 | 0.22-0.77 | 30.0 | 0.64-119.6 | 1.5 |
| Tallgrass prairie | 0.74 | 0.73-0.75 | 7.4 | 0.23-20.3 | 0.3 |
| Shortgrass prairie | 0.41 | 0.24-0.64 | 3.2 | 1.12-10.7 | 1.0 |
| Desert grasslands | 0.60 | 0.36-0.73 | 3.4 | 2.0-4.9 | 2.7 |
| Southeastern grasses and forbs | 0.40 | 0.23-0.68 | 0.7 | 0.4-1.5 | 5.6 |
| Cold desert shrubs | 0.46 | NA | 5.0 | 4.09-11.0 | 3.25 |
| Sandy shinnery oak with herbaceous interspaces | 0.45 | 0.20-0.70 | 5.5 | 3.44-18.6 | 0.9 |
| Southern desert shrubs | 0.56 | 0.20-0.72 | 2.5 | 0.20-18.4 | 2.84 |
| Chaparral | [3]0.13 | 0.08-0.30 | 0.8 | 0.30-1.9 | 6.5 |
| California annual grassland | 0.33 | NA | 3.0 | NA | 1.2 |
| Pasture, bunchgrass | NA | NA | NA | NA | 0.8 |
| Pasture, sod-forming grass | NA | NA | NA | NA | 1.3 |
| Pasture, weeds | NA | NA | NA | NA | 0.5 |

[1]Based on calibration against WEPP plot erosion data.
[2]NA = Data are not available.
[3]Root crowns and burls were excluded from root-biomass calculations.

Table 5-5.
Parameter values of typical cropland field operations

| Field operations[1] | Random roughness[2] (in) | Residue left on surface[3,4] (%) | Depth of incorporation[5] (in) | Soil surface disturbed (%) |
|---|---|---|---|---|
| Chisel, sweeps | 1.2 | 70 | 6 | 100 |
| Chisel, straight point | 1.5 | 60 | 6 | 100 |
| Chisel, twisted shovels | 1.9 | 45 | 6 | 100 |
| Cultivator, field | 0.7 | 75 | 3 | 100 |
| Cultivator, row | 0.7 | 80 | 2 | 85 |
| Cultivator, ridge till | 0.7 | 40 | 2 | 90 |
| Disk, 1-way | 1.2 | 30 | 4 | 100 |
| Disk, heavy plowing | 1.9 | 35 | 6 | 100 |
| Disk, tandem | 0.8 | 50 | 4 | 100 |
| Drill, double disk | 0.4 | 90 | 2 | 85 |
| Drill, deep furrow | 0.5 | 70 | 3 | 90 |
| Drill, no-till | 0.4 | 80 | 2 | 60 |
| Drill, no-till into sod | 0.3 | 90 | 2 | 20 |
| Fertilizer applicator, anhydrous knife | 0.6 | 80 | 2 | 15 |
| Harrow, spike | 0.4 | 80 | 2 | 100 |
| Harrow, tine | 0.4 | 85 | 2 | 100 |
| Lister | 0.8 | 20 | 4 | 100 |
| Manure injector[5] | 1.5 | 50 | 6 | 40 |
| Moldboard plow | 1.9 | 5 | 8 | 100 |
| Mulch treader | 0.4 | 75 | 2 | 100 |
| Planter, no-till | 0.4 | 85 | 2 | 15 |
| Planter, row | 0.4 | 90 | 2 | 15 |
| Rodweeder | 0.4 | 90 | 2 | 100 |
| Rotary hoe | 0.4 | 85 | 2 | 100 |
| Vee ripper | 1.2 | 80 | 3 | 20 |

[1]See American Society of Agricultural Engineers Standards 414 and 477.
[2]Zobeck and Onstad 1987.
[3]Stott and Barrett 1991.
[4]Percentage of before-operation cover for nonfragile residue. Values will be lower for fragile residues.
[5]The depth in which 75% of the residue is buried.

Table 5-6.
Roughness values for rangeland field conditions

| Condition | Random roughness (in) |
|---|---|
| California annual grassland | 0.25 |
| Tallgrass prairie | 0.30 |
| Clipped and bare | 0.60 |
| Pinyon/Juniper interspace | 0.60 |
| Cleared | 0.70 |
| Natural shrub | 0.80 |
| Seeded rangeland drill | 0.80 |
| Shortgrass, desert | 0.80 |
| Cleared and pitted | 1.00 |
| Mixed grass, prairie | 1.00 |
| Pitted | 1.10 |
| Sagebrush | 1.10 |
| Root-plowed | 1.30 |

Table 5-7.
Growing-season soil-moisture depletion rates for use in calculation of soil moisture subfactor for use in the Northwestern Wheat and Range Region.

| Crop | Depletion rate |
|---|---|
| Winter wheat and other deep-rooted crops | 1.00 |
| Spring wheat and barley | 0.75 |
| Spring peas and lentils | 0.67 |
| Shallow-rooted crops | 0.50 |
| Summer fallow | 0.00 |

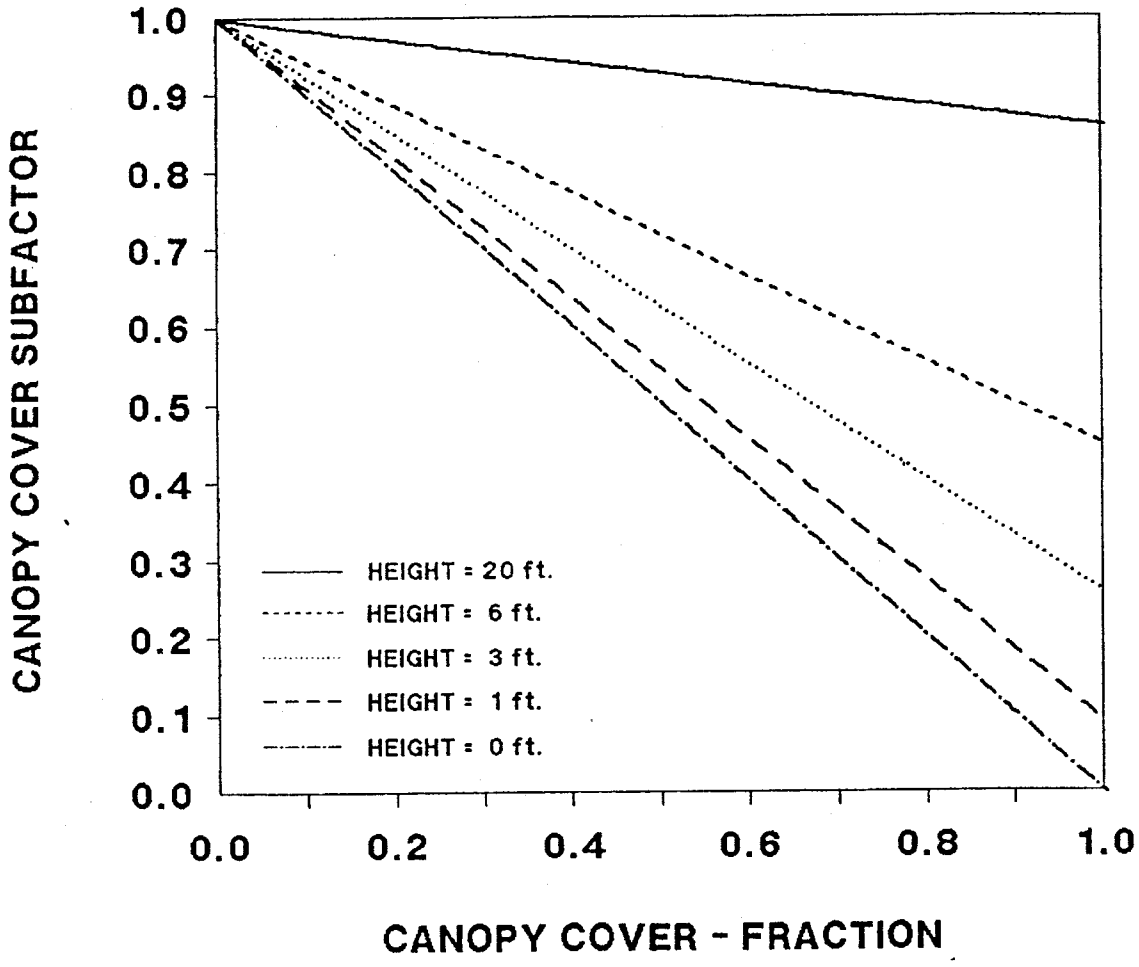


Figure 5-1.
Effect of canopy cover and canopy height on the canopy-cover subfactor

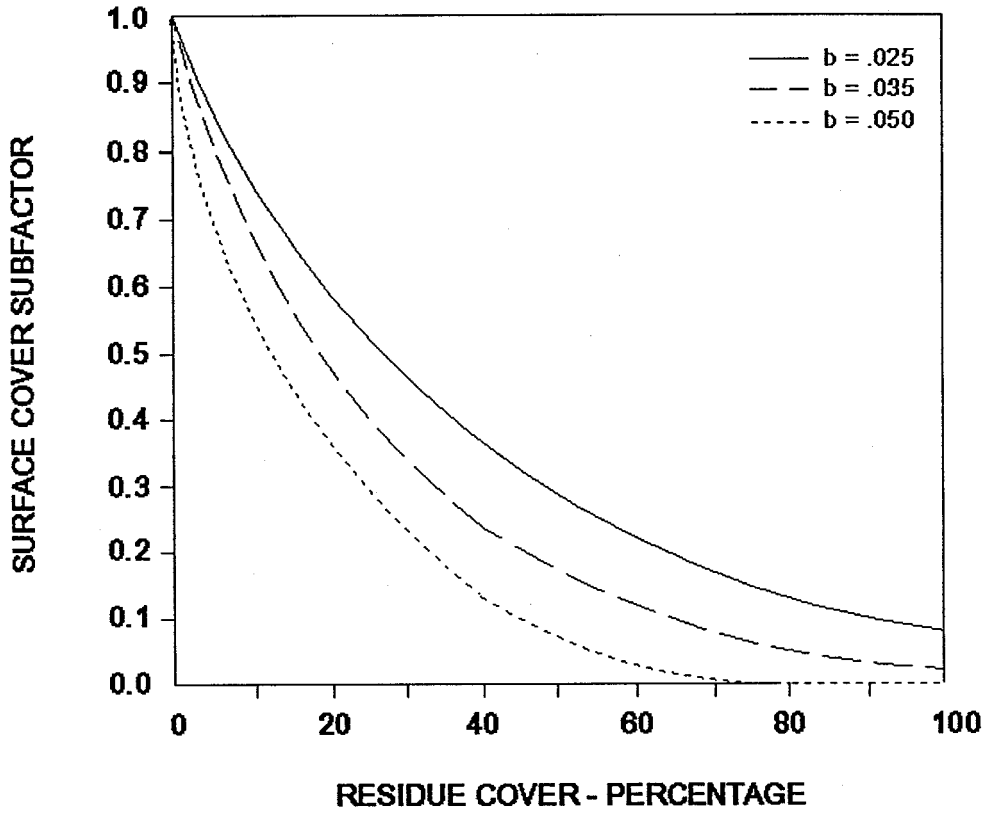


Figure 5-2.
Effect of residue cover and b values on the surface-cover subfactor for smooth field surfaces

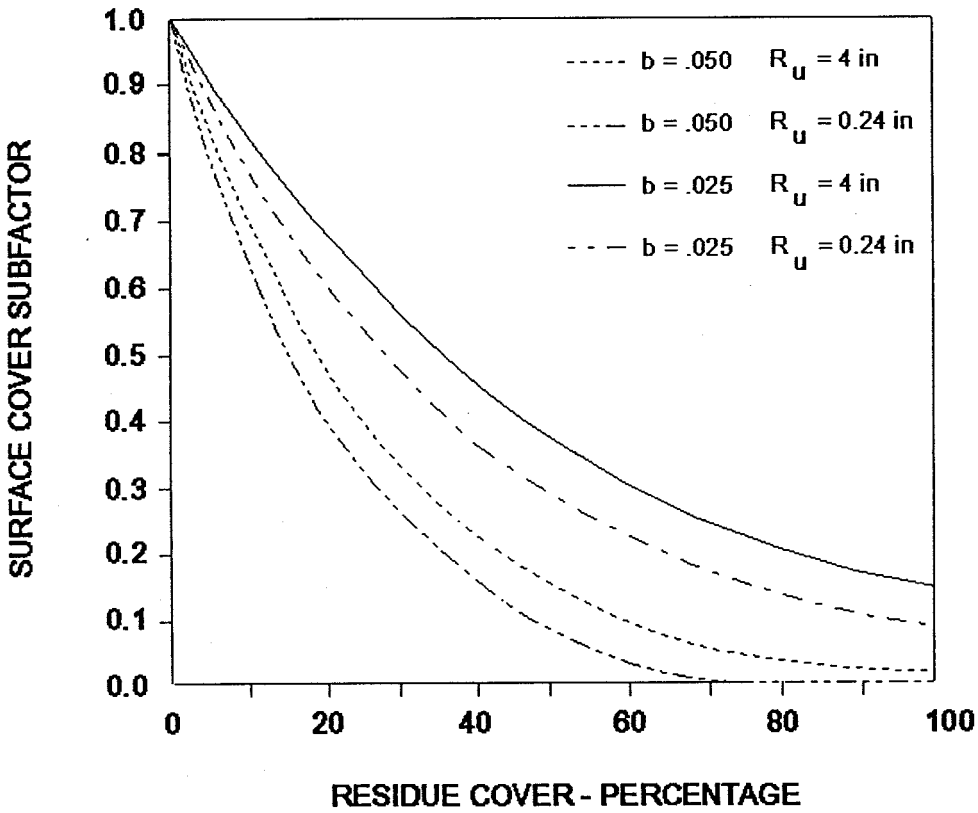


Figure 5-3.
Effect of residue cover, b values, and surface roughness on the surface-cover subfactor. An $R_u$ value of 0.24 in is typical of a field in seedbed condition. An $R_u$ value of 4 in indicates more roughness than from most primary tillage operations.

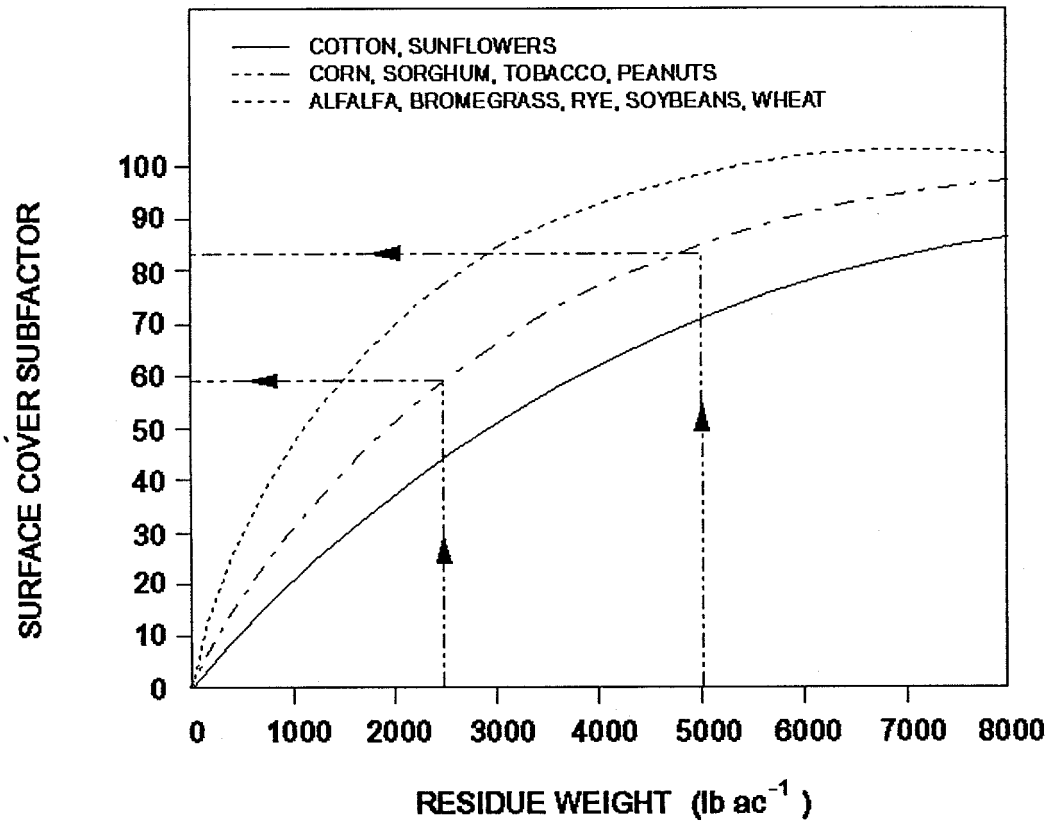


Figure 5-4.
Relationship of residue weight to percent residue cover for various crops.

Example: Dashed lines with arrows illustrate the procedure to convert weight to percent residue cover. Corn residue weighing 5,000 lb · acre$^{-1}$ at harvest leaves 82% residue cover, and 2,500 lb · acre$^{-1}$ leaves 57% cover. Note that, in this example, a 50% reduction in residue weight results in a 25% reduction in residue cover.

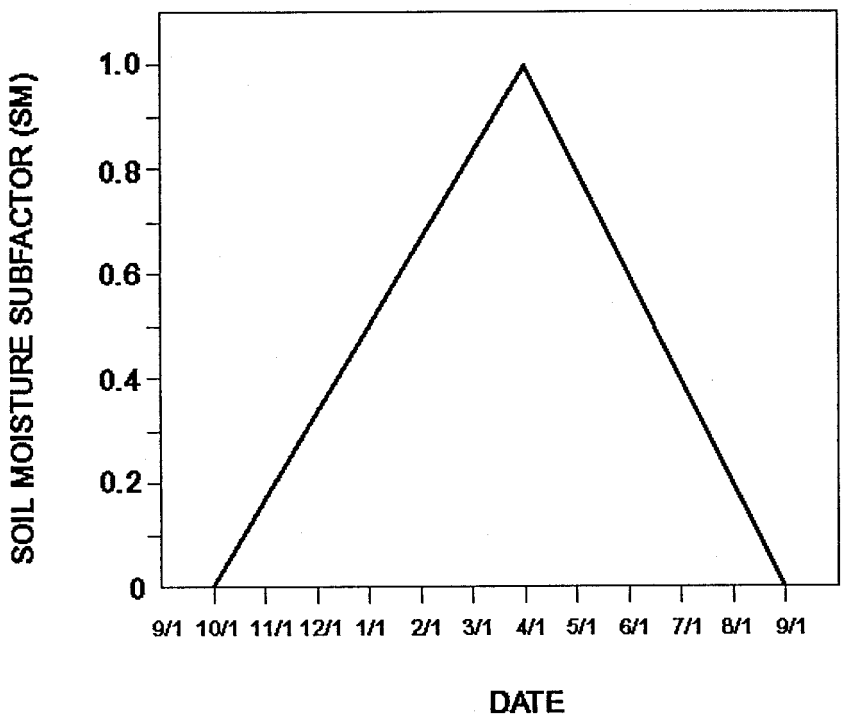


Figure 5-5.
Maximum range in soil-moisture subfactor as affected by profile replenishment and depletion for the Northwestern Wheat and Range Region

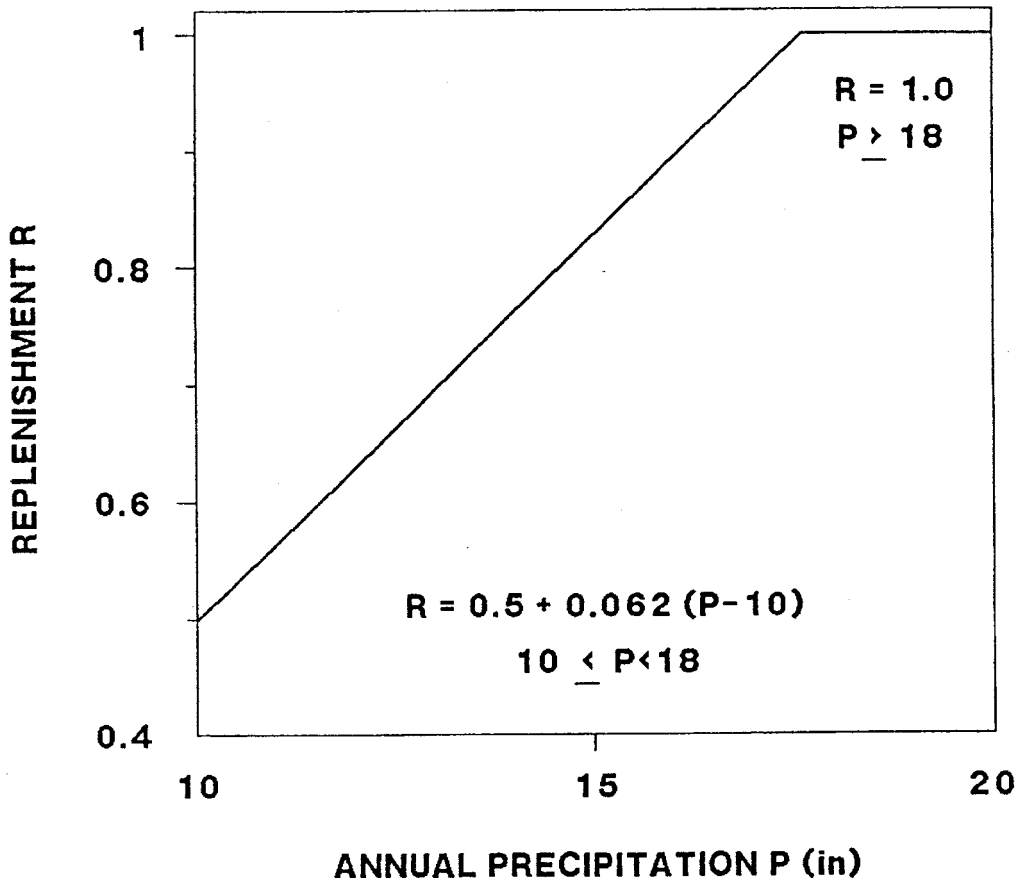


Figure 5-6.
Fraction of soil moisture replenished over winter versus annual precipitation for calculation of a soil-moisture subfactor for the Northwestern Wheat and Range Region