# Chapter 9. RESIDUE DECOMPOSITION AND MANAGEMENT

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## 9.1 Introduction

This chapter describes the approaches used in the WEPP model to simulate plant residue decomposition and management options for cropland and rangeland conditions. The decomposition and management of residues for cropland and rangeland ecosystems are simulated in separate submodels.

Plant and residue management options available to the user such as tillage, shredding, burning, or removing residue are discussed in this chapter. Separate plant residue decomposition and management sections for cropland and rangeland have been developed because of differences in user input variables.

This chapter has been organized into seven sections. Sections 9.2 through 9.5 discuss the residue decomposition and management options for cropland. Sections 9.6 and 9.7 discuss the rangeland options.

## 9.2 Cropland Residue and Root Decomposition

The model simulates the decomposition of standing and flat plant residues, as well as the roots and buried residues in the surface 0.15 m of the soil profile.

At harvest, the remaining above-ground biomass ($M_{rt}$), primarily stems and leaves, is partitioned into standing ($M_s$) and flat ($M_f$) components prior to any other management operations:

$$M_{s(t)} = M_{s(t-1)} + (M_{rt}\ F_{pc}) \tag{9.2.1}$$

$$M_{f(t)} = M_{f(t-1)} + M_{rt}(1 - F_{pc}) \tag{9.2.2}$$

where $F_{pc}$ is the fraction of the initial residue biomass partitioned into standing residue. $F_{pc}$ is calculated with

$$F_{pc} = \frac{H_{cut}}{H_{cm}} \tag{9.2.3}$$

where $H_{cm}$ is the maximum canopy height ($m$), obtained from the plant growth model (Chapter 8) and $H_{cut}$ is the cutting height ($m$) at harvest, obtained from the management file (Table 9.2.1).

### 9.2.1 Decomposition

To simulate the decomposition process, the "decomposition day" concept as presented by Stroo et al. (1989) for winter wheat residue decomposition was used as a basis for the residue biomass loss calculation. The model (Stroo et al., 1989) simulates residue decay under constant environmental conditions using C and N dynamics based on Knapp et al. (1983) and Bristow (1983). WEPP uses the single equation used in the RESMAN model (Stott and Barrett, 1995) that replaces the equations for the C and N dynamics:

$$M_{t,j} = M_{t-1,j}\ e^{ENVIND_j \cdot ORATE_j \cdot PSZIND_j \cdot FERIND_j} \tag{9.2.4}$$

where $M_{t,j}$ is the residue biomass per unit area remaining and $M_{t-1,j}$ is the biomass per unit area remaining the previous day, for the current residue type, $j$. WEPP keeps track of 3 residue types, each of which may have different decomposition parameters: 1. - residue from the last crop harvested; 2. - residue from the previous crop harvested; 3. - residue from all prior crops. The model also determines masses in 4 different biomass categories - standing, flat, buried and dead roots. Thus the model arrays tabulate the masses for up to 10 different pools of biomass: 1. - standing residue from the last crop harvested; 2,3,4 - flat surface residue from the last, previous, and prior crops; 5,6,7 - submerged (buried by tillage) residue from the last, previous and prior crops; 8,9,10 - dead root mass from the last, previous and prior crops.

Table 9.2.1. Parameter values used in the cropland residue decomposition submodel.

| Symbol | | $cf$ | $H_{cut}$ | $F_{ct}$ | | |
|---|---|---|---|---|---|---|
| Variable | | CF | CUTHGT | FACT | $ORATE_A$ | $ORATE_R$ |
| Crop | Fragility Group | $(m^2 \cdot kg^{-1})$ | $(m)$ | $(fraction\ left)$ | $(kg \cdot m^{-2} \cdot d^{-1})$ | $(kg \cdot m^{-2} \cdot d^{-1})$ |
| Alfalfa | Non-Fragile | 5.0 | 0.152 | 0.99 | 0.0150 | 0.0150 |
| Bromegrass | Non-Fragile | 5.0 | 0.152 | 0.99 | 0.0090 | 0.0090 |
| Canola | Fragile | 5.0 | 0.152 | 0.99 | 0.0130 | 0.0130 |
| Corn | Non-Fragile | 2.1 | 0.304 | 0.99 | 0.0065 | 0.0065 |
| Cotton | Non-Fragile | 1.9 | 0.900 | 0.99 | 0.0100 | 0.0065 |
| Oats | Non-Fragile | 5.1 | 0.152 | 0.99 | 0.0090 | 0.0090 |
| Peanut | Fragile | 2.1 | 0.100 | 0.99 | 0.0150 | 0.0060 |
| Ryegrass | Non-Fragile | 4.0 | 0.152 | 0.99 | 0.0090 | 0.0090 |
| Sorghum | Non-Fragile | 2.9 | 0.609 | 0.99 | 0.0074 | 0.0074 |
| Soybeans | Fragile | 5.2 | 0.152 | 0.99 | 0.0130 | 0.0130 |
| Tobacco | Non-Fragile | 2.5 | 0.000 | 0.99 | 0.0065 | 0.0074 |
| Wheat; Spring | Non-Fragile | 6.4 | 0.152 | 0.99 | 0.0085 | 0.0085 |
| Wheat; Winter | Non-Fragile | 6.4 | 0.152 | 0.99 | 0.0085 | 0.0085 |

$M_t$ is calculated for each residue biomass pool, standing ($M_{s(t)}$), flat ($M_{f(t)}$), and buried ($M_{b(t)}$) residues as well as dead roots ($M_{r(t)}$). *ENVIND* is the environmental factor determining the fraction of a decomposition day that has occurred during day $t$, *ORATE* is a decomposition constant for a given residue type, *FERIND* is a soil fertility index, and *PSZIND* is an index for residue size influence. *FERIND* is currently set to 1.0 until a nutrient cycle or fertility index is added to the plant growth model. *PSZIND* will take into account the change in decomposition rate when residues are shredded, but for now it is set to 1.0.

*ORATE* represents the decomposition rate of a residue type under the temperature and moisture conditions that maximize microbial activity. In temperate soils, maximum microbial activity generally occurs around 23 $^oC$ and 60% water-filled pore space. $ORATE_A$ is the optimum rate for above-ground residues, primarily leaves and stems. $ORATE_R$ is the optimum rate for roots. For the above-ground residues of a given crop, the same $ORATE_A$ is used whether the residues remain standing, are flat on the soil surface, or are buried by management operations. Using published data, $ORATE_A$ values were set for winter wheat (Stott et al., 1990), corn (Stott and Barrett, 1995), soybean (Stott and Barrett, 1995), cotton (Diack, 1994), sorghum (Diack, 1994) and peanut (Diack, 1994). $ORATE_R$ values were set for cotton, sorghum and peanut (Diack, 1994). *ORATE* values for the other crops were estimated based on knowledge of the residue characteristics (Table 9.2.1). The initial estimates for decay rates can be adjusted when new data and information become available.

In the field, residue decomposition rates are controlled by environmental factors (Martin and Haider, 1986). Especially important are the water content and temperature (Parr and Papendick, 1978). The effects of water content and temperature on the rate of residue decomposition were assumed to be independent of one another (Stroo et al., 1989; Stott et al., 1986). To model the influence of these factors on residue decomposition in the field, the optimum rate of decomposition during a 24 hour period for a given residue type is modified by *ENVIND* (Eq. 9.2.4), resulting in a fraction of the optimum decomposition rate, referred to as a 'decomposition day.' *ENVIND* is calculated from:

$$ENVIND = Minimum\ (WFC,\ TFC) \qquad [9.2.5]$$

where *WFC* and *TFC* are the daily water and temperature factors, respectively, with normalized values between 0 and 1.0. Hypothetically, the moisture and temperature conditions might yield an *ENVIND* value of 0.7 (Eq. 9.2.5). Thus within a 24 hr period, the amount of decomposition that would take place would be equal to 16.8 hrs at the optimum rate. *ENVIND* is calculated separately for the standing, flat and buried residues. *ENVIND* for the roots is the same as for the buried stems and leaves.

**9.2.2 Water and Temperature Factors**

To account for differences in decomposition rates due to residue placement above, on, or within the soil profile, different values for *WFC* and *TFC* are used for each residue pool (standing, flat, buried and roots). The water factor for standing residues ($WFC_{s(t)}$) is based on the rainfall depth in meters for a given day (*PRCP*), with 0.004 m of rainfall saturating the standing residues:

$$WFC_{s(t)} = \frac{PRCP}{0.004} \qquad [9.2.6]$$

The underlying assumption is that the standing residues will dry quickly, minimizing the decomposition that might occur. If the daily rainfall is greater than 0.004 m then the factor is set equal to 1.0. If the average daily temperature is less than 0, $WFC_{s(t)}$ is set equal to 0.

The water factor for flat residues ($WFC_{f(t)}$) should ideally be determined on the basis of the residue water content, however the water balance model (Chapter 5) does not include this variable. Therefore as an estimate, $WFC_{f(t)}$, for limiting conditions, is calculated from:

$$WFC_{f(t)} = \frac{\theta_{till}}{\theta_{opt}} \qquad \theta_{opt} > \theta_{till} \qquad [9.2.7]$$

where $\theta_{till}$ is the water content of the surface tilled zone of the soil and $\theta_{opt}$ is the water content of the surface soil that would be considered optimum for microbial activity. If $\theta_{till}$ is greater than $\theta_{opt}$, oxygen may become limiting, inhibiting the microbial population and slowing the rate of residue decay, therefore the water factor is calculated from:

$$WFC_{f(t)} = \frac{\theta_{opt}}{\theta_{till}} \qquad \theta_{opt} \le \theta_{till} \qquad [9.2.8]$$

The water factor for buried residues as well as roots, $WFC_{b(t)}$, is calculated using the same equations as for the surface residue (Equations 9.2.7 and 9.2.8), which take into account the moisture status of the surface tilled soil layers (0.2 m thickness). The optimum water content for soil microbial activity is about 60% of the water-filled pore space (Linn and Doran, 1984). The pore space within a soil changes with time and with tillage practices, thus the optimum water content is calculated from:

$$\theta_{opt} = \phi_{till} * 0.60 \qquad [9.2.9]$$

where $\phi_{till}$ is the volume fraction in the surface tilled soil layers that is pore space (Chapter 7). For all the water factors, the lower limit is set to 0.01.

The temperature function ($TFC$) is formally identical to the one describing photosynthesis activity as a function of temperature (Taylor and Sexton, 1972). The function is as follows:

$$TFC = \frac{2(T_{avg} + A)^2 (T_m + A)^2 - (T_{avg} + A)^4}{(T_m + A)^4} \qquad [9.2.10]$$

where $T_{avg}$ is the average daily air temperature ($^oC$), $T_m$ is the maximum temperature for the function ($^oC$), and $A$ is the minimum (Fig. 9.2.1). $T_{avg}$ is calculated as the mean of the daily minimum and maximum temperatures. $T_m$ should not be equated to the optimum temperature for microbial activity. For temperate zone soils, microbial activity is greatest at around 23° C providing there is sufficient water present. Activity would cease at about -2°C when the soil water freezes (Stott et al., 1986). Rather, $T_m$ and $A$ are experimentally derived constants that set the slope and intercepts of the quadratic function. Thus, TFC would rarely exceed 0.8 in temperate areas. This function has not yet been tested with data outside the temperate region. Based on data from Stott et al. (1986), $T_m$ was set equal to 33 $^oC$ and $A$ equal to 6.1 $^oC$. Since Eq. 9.2.10 is a quadratic formula, $TFC$ was set to 0.0 for $T_{avg} < -6.1\,^oC$ or $T_{avg} > 49.2\,^oC$.

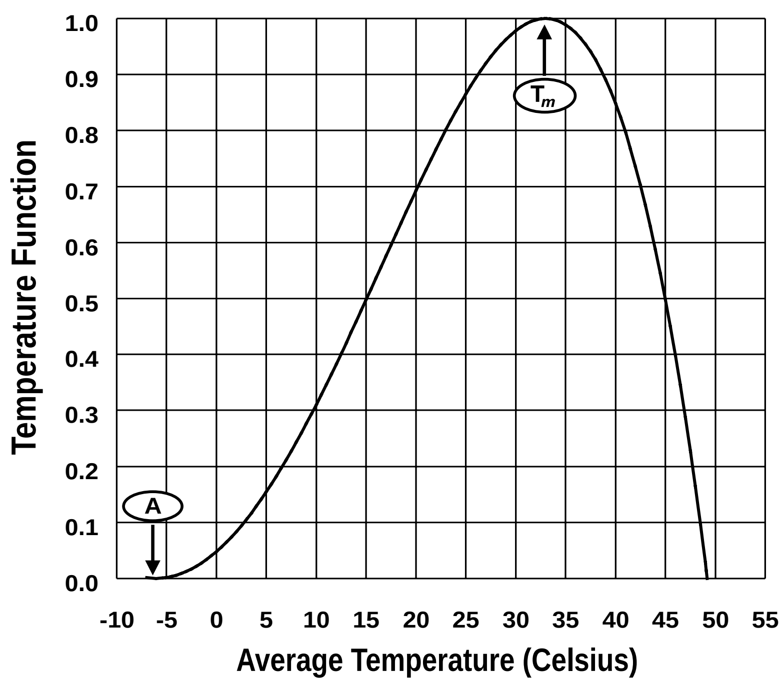


Figure 9.2.1. Temperature function used to calculate the decomposition rate of residues in the field.

### 9.2.3 Standing to Flat Residue Conversion

The standing residue biomass ($M_{s(t)}$) decreases over time not only because of microbial decomposition but also due to the stems being flattened by wind and snow. The equation to calculate the loss of standing residues is:

$$M_{s(t)} = F_{ct}\ M_{s(t-1)} \qquad [9.2.11]$$

where $F_{ct}$ is the adjustment factor to account for the effects of wind and snow on the amount of standing residue. The default value for $F_{ct}$ is 0.99, but it can be adjusted by the user to account for local climatic conditions.

The equation to increase flat residue biomass from the standing to flat residue conversion is:

$$M_{f(t)} = M_{f(t-1)} + (M_{s(t-1)} - M_{s(t)}) \qquad [9.2.12]$$

where $M_{f(t)}$ is the flat residue biomass at time $t$.

### 9.2.4 Stubble Population

The stubble population is decreased over time due to flattening by wind and snow. The equation to compute stubble population at harvest is:

$$P_{(t)} = \frac{M_{s(t)}}{M_{s(0)}}\ P_m\ F_{ct} \qquad [9.2.13]$$

where $P_{(t)}$ is the stubble population at time $t$, $M_{s(t)}$ is the standing residue biomass at time $t$, $M_{s(0)}$ is the standing residue biomass at harvest, and $P_m$ is the stubble population at harvest. After the initial calculation of $P_{(t)}$ at harvest, $P_m$ is set equal to $P_{(t)}$.

## 9.3 Cropland Residue Cover

The model simulates the amount of the soil surface covered by standing and flat plant residues.

### 9.3.1 Residue Cover

Gregory's (1982) equation is used to predict residue cover from flat residue biomass:

$$C_{rf} = 1 - e^{-cf*M_f} \qquad [9.3.1]$$

where $C_{rf}$ is the fraction of the soil surface covered by the flat residue, $M_f$ is the flat residue biomass in $kg\ m^{-2}$ and $cf$ is a crop specific constant (Table 9.2.1) to calculate flat residue cover. Surface cover for fields with more than one type of residue is calculated as follows:

$$C_{rf} = 1 - e^{(-\sum_{j=1}^{n}(cf_n M_{f(n)}))} \qquad [9.3.2]$$

Soil cover due to standing residue biomass is predicted from:

$$C_{rs} = \frac{M_{s(t)}}{M_{s(0)}}\ A_{bm} \qquad [9.3.3]$$

where $C_{rs}$ is the fraction of the surface protected by standing residue (0-1), $M_{s(t)}$ is the standing residue biomass at time $t$, $M_{s(0)}$ is the standing residue biomass at harvest, and $A_{bm}$ is the plant stem basal area at maturity per square meter of soil area for the crop of interest.

Total fraction of surface covered by residue ($C_{rt}$) is:

$$C_{rt} = C_{rf} + C_{rs} \tag{9.3.4}$$

**9.3.2 Interrill and Rill Residue Cover**

Rills are small channels in which overland flow concentrates on hillslopes. Rills are the major pathway for runoff and sediment movement down a slope, and soil detachment in rills is mainly a function of excess flow shear stress (see Chapter 11). Interrill areas are the regions between rills, which are mainly affected by raindrop impact and shallow broad sheet flow. Since the erosion processes are quite different on the two regions, separate prediction of the residue cover on the interrill and rill areas is required within the WEPP model. Tillage implement inputs can be parameterized to simulate burial of different amounts of residue on the interrill areas and in the rill channels (if the user has specified that rills are not to be destroyed by tillage operations).

For certain special situations, the WEPP model can be used to simulate the redistribution of residue from ridges to furrows in ridge tillage management systems. The model recognizes a ridge-furrow tillage system when any implement in a tillage sequence meets specific ridge height and ridge interval criteria. These criteria are that ridge height be equal to or greater than 0.10 m and ridge interval is between 0.6 and 1.4 m (see Chapter 7 for more information).

**9.3.3 Ridge-Furrow System Residue Partitioning**

Residue can be repositioned in a ridge-furrow system, either by wind blowing residue from the ridge into the furrow, by a planter with sweeps moving residue from the ridge into the furrow, or by a cultivator moving residue back to the ridge. In a ridge tillage simulation, the user should input permanent furrows (rills) of a reasonable width in the crop/management input file initial conditions inputs (i.e. rill widths of 30 to 50 percent of the ridge spacing); otherwise the model may calculate narrow rills based on flow discharge rates (Chapter 10) and unreasonably large amounts of residue will be predicted to move from the wide ridge (interrill) areas to the narrow furrow (rill channels).

For wind repositioning, the WEPP model reduces the residue cover on the ridges to a minimum of 30 percent (if the initial residue cover after harvest was greater than 30 percent). Residue cover on the ridges is calculated from:

$$C_{rr(t)} = C_{rr(0)} - \left[\frac{C_{rr(0)} - C_{sp}}{60}\right] D_h \tag{9.3.5}$$

where $C_{rr(t)}$ is the residue cover on the ridges (interrill areas) at time $t$, $C_{rr(0)}$ is the interrill residue cover immediately after harvest, $C_{sp}$ is the residue cover on the ridges at the end of the repositioning period (30 percent in WEPP), and $D_h$ is the days after harvest. All adjustments for wind moving residue from the ridge into the furrow are made within 60 days of harvest.

The daily biomass of residue moved from the ridges into furrows (rills) ($\Delta M_w$) is computed from:

$$\Delta M_w = \frac{ln(1 - (C_{rr(t-1)} - C_{rr(t)}))}{-cf} \tag{9.3.6}$$

where $cf$ is a crop specific constant (Table 9.2.1). Total residue biomass in the furrows (rills) ($M_{rl(t)}$) is:

$$M_{rl(t)} = M_{rt(t-1)} + \Delta M_w \tag{9.3.7}$$

Rill cover ($C_{rl}$), which is equal to the furrow cover, is calculated from the adjusted residue biomass:

$$C_{rl} = 1 - e^{-cf * M_{rl}} \quad [9.3.8]$$

Residue biomass on the ridges (interrill areas) ($M_{rr}$) is:

$$M_{rr} = M_{rr\,(t-1)} - \Delta M_w \quad [9.3.9]$$

Decomposition of residue on the ridges and in the furrows is accounted for separately.

The average residue cover ($C_{reo}$) over the entire soil surface is predicted from:

$$C_{res} = f_{rr}\ C_{rr} + f_{rl}\ C_{rl} \quad [9.3.10]$$

where $f_{rr}$ is the fraction of the area occupied by the ridges, and $f_{rf}$ is the fraction of the area occupied by the furrows. See Section 9.5.1 for information on how to simulate movement of residues from ridges to furrows and from furrows to ridges through tillage operations.

### 9.3.4 Ground Cover

Total ground cover from plant residues and rocks ($C_g$) is calculated from:

$$C_g = C_{cf} + C_{ri}(1 - C_{cf}) \quad [9.3.11]$$

where $C_{cf}$ is the fraction of the surface covered by coarse fragments, and $C_{ri}$ is the fraction of the interrill area covered by residues. $C_{ri}$ is equal to $C_{rr}$.

## 9.4 Cropland Residue Decomposition and Surface Cover Model Summary

Procedures followed in the decomposition model include:

1. Initialize the following variables:
   - decomposition parameter for above-ground vegetative biomass, $ORATE_a$;
   - decomposition parameter for root biomass, $ORATE_r$ ;
   - parameter for the flat residue cover equation, $cf$;
   - standing to flat residue adjustment factor for wind and snow, $F_{ct}$;
   - residue cover on ridges after wind repositioning, $C_{sp}$.
2. User initializes interrill and rill residue cover. WEPP calculates initial standing residue biomass ($M_s$), flat residue biomass ($M_f$), buried residue biomass ($M_b$), root biomass in the 0- to 0.15-m zone ($M_r$), and plant stubble population ($P$).
3. Calculates residue and root biomass from Eq. [9.2.4]:
   - standing residue biomass, $M_s$
   - flat residue biomass, $M_f$
   - buried residue biomass, $M_b$
   - dead root biomass, $M_r$
4. Converts standing residue biomass to flat residue biomass and adds that amount to the pool of flat residue biomass (Eq. [9.2.11] and [9.2.12]).
5. Computes the fraction of soil surface covered by flat and standing residue biomass (Eq. [9.3.2] and [9.3.3]), total residue cover (Eq. [9.3.4]), and, if appropriate, partitions the total cover into rill and ridge residue cover (Eq. [9.3.8] and [9.3.10]).

6. Checks date to see if it is a day on which management occurs (*MDATE*). If it is, uses equations given in section 9.5 to compute standing and flat residue biomass remaining after management. Increases the buried residue biomass by the biomass of flat residue incorporated into the soil by tillage.

7. Partitions the surface residue biomass ($M_{rt}$) at harvest into standing ($M_s$) and flat ($M_f$) components (Eq. [9.2.1] and [9.2.2]) using $F_{pc}$, (Eq. [9.2.3]) which depends upon harvesting equipment and techniques.

## 9.5 Cropland Plant Residue Management Options

The cropland plant residue decomposition and management model can accommodate fallow, mono, double, rotation, strip, and mixed cropping practices. A mixed cropping practice is one where two or more individual cropping practices (e.g. mono and double) are used in the simulation. The model is applicable to the annual and perennial crops specified in WEPP User Requirements.

### 9.5.1 Tillage

Wnen applicable, the user must specify a residue management option. Current options include shredding or cutting, burning or removal.

Effects of tillage on residue and soil properties are calculated in the model (see Chapter 7). Tillage intensity ($T_i$) is used as the classification variable to adjust standing and flat residue biomass and cover. $T_i$ values are stored by implement and crop and range from 0 to 1 (Table 9.5.1). A residue mixing factor is calculated from:

$$R_{mf} = 1 - T_i \qquad [9.5.1]$$

where $R_{mf}$ is the ratio of flat residue cover after tillage to that before tillage. The user may specify different input values of tillage intensities for an implement's effect on interrill and rill residues. Use of separate rill tillage intensity values may be desired in certain systems, in particular ridge tillage and furrow irrigation. For an input set of rill tillage intensity values to affect simulations, the user must enter a representative flow width for the furrows (rill width) and set the rill width type to permanent in the crop/management input file.

Two adjustments are made on residue biomass and cover when tillage is performed. First, standing residue is converted to flat residue using an equation from EPIC (Williams et al., 1989). Standing residue biomass remaining after tillage ($M_{s(t)}$) is calculated from:

$$M_{s(t)} = M_{s(t-1)} e^{-8.535 T_i^2} \qquad [9.5.2]$$

where $M_{s(t-1)}$ is the standing residue biomass before tillage.

Flat residue biomass is incremented by the change in standing residue:

$$M_{f(t)} = M_{f(t-1)} + (M_{s(t-1)} - M_{s(t)}) \qquad [9.5.3]$$

where $M_{f(t)}$ is the adjusted flat residue biomass, and $M_{f(t-1)}$ is the flat residue biomass before tillage.

Based on the adjusted residue masses, standing and flat residue covers are computed using the equations given in Section 9.3.1.

Table 9.5.1. Parameter values from the operations database used in the cropland residue management submodel. $T_i$ values presented are for interrill areas. The current database uses the same values for rill areas.

| | $T_i$ - Fraction Buried for Residue Type | |
|---|---|---|
| IMPLEMENT | Fragile | Non-Fragile |
| Anhydrous applicator | 0.45 | 0.20 |
| Anhydrous applicator with closing disks | 0.60 | 0.35 |
| Bedders, lister and hippers | 0.90 | 0.80 |
| Chisel plow with coulters and straight spike points | 0.65 | 0.40 |
| Chisel plow with coulters and sweeps | 0.55 | 0.30 |
| Chisel plow with coulters and twisted points or shovels | 0.75 | 0.55 |
| Chisel plow with sweeps | 0.45 | 0.25 |
| Chisel plow with straight spike points | 0.50 | 0.30 |
| Chisel plow with twisted points or shovels | 0.65 | 0.40 |
| Combination tools with disks, shanks and levelling attachments | 0.60 | 0.40 |
| Combination tools with spring teeth and rolling basket | 0.40 | 0.35 |
| Cultivator, row with finger wheel | 0.45 | 0.30 |
| Cultivator, row, multiple sweeps per row | 0.40 | 0.20 |
| Cultivator, row, ridge till | 0.75 | 0.60 |
| Cultivator, row, rolling disk | 0.55 | 0.50 |
| Cultivator, row, single sweep per row | 0.40 | 0.20 |
| Disk chisel plow with straight chisel spike points | 0.65 | 0.45 |
| Disk chisel plow with sweeps | 0.60 | 0.35 |
| Disk chisel plow with twisted points or shovels | 0.75 | 0.60 |
| Disk plow | 0.90 | 0.85 |
| Disk, offset-finishing 7-9" spacing | 0.70 | 0.55 |
| Disk, offset-heavy plowing>10" spacing | 0.85 | 0.60 |
| Disk, one-way with 12-16 blades | 0.70 | 0.55 |
| Disk, one-way with 18-30" blades | 0.80 | 0.70 |
| Disk, single gang | 0.50 | 0.40 |
| Disk, tandem-finishing 7-9" spacing | 0.70 | 0.50 |
| Disk, tandem-heavy plowing >10" spacing | 0.85 | 0.65 |
| Disk, tandem-light after harvest, before other tillage | 0.55 | 0.25 |
| Disk, tandem-primary cutting >9" spacing | 0.70 | 0.45 |
| Drill with double disk opener | 0.30 | 0.10 |
| Drill, deep furrow with 12" spacing | 0.35 | 0.30 |
| Drill, hoe opener | 0.50 | 0.35 |
| Drill, no-till in flat residues-fluted coulters | 0.50 | 0.40 |
| Drill, no-till in flat residues-ripple or bubble coulters | 0.45 | 0.35 |
| Drill, no-till in flat residues-smooth coulters | 0.40 | 0.25 |
| Drill, no-till in standing stubble-fluted coulters | 0.30 | 0.20 |
| Drill, no-till in standing stubble-ripple or bubble coulters | 0.30 | 0.20 |
| Drill, no-till in standing stubble-smooth coulters | 0.25 | 0.10 |

Table 9.5.1. Parameter values from the operations database used in the cropland residue management submodel. Values presented are for interrill areas. The current database uses the same values for rill areas. (Continued).

| | $T_i$ - Fraction Buried for Residue Type | |
|---|---|---|
| IMPLEMENT | Fragile | Non-Fragile |
| Drill, semi deep furrow or press 7-12" spacing | 0.35 | 0.20 |
| Drill, single disk opener (conventional) | 0.20 | 0.10 |
| Field cultivator, primary tillage-duckfoot points | 0.60 | 0.55 |
| Field cultivator, primary tillage-sweeps, 12-20" | 0.35 | 0.30 |
| Field cultivator, primary tillage-sweeps, 6-12" or shovels | 0.50 | 0.40 |
| Field cultivator, secondary tillage - duckfoot points | 0.60 | 0.35 |
| Field cultivator, secondary tillage - sweeps, 12-20" | 0.35 | 0.15 |
| Field cultivator, secondary tillage - sweeps, 6-12" or shovels | 0.45 | 0.25 |
| Furrow diker | 0.20 | 0.10 |
| Harrow-flex-tine tooth | 0.25 | 0.20 |
| Harrow-packer roller | 0.10 | 0.05 |
| Harrow-roller harrow (cultipacker) | 0.40 | 0.30 |
| Harrow-spike tooth | 0.30 | 0.20 |
| Harrow-springtooth (coil tine) | 0.25 | 0.15 |
| Manure, subsurface applicator | 0.70 | 0.50 |
| Mulch treader | 0.35 | 0.25 |
| Paratill/paraplow | 0.20 | 0.15 |
| Planter, double disk openers | 0.20 | 0.10 |
| Planter, no-till with fluted coulter | 0.25 | 0.15 |
| Planter, no-till with ripple coulter | 0.15 | 0.10 |
| Planter, no-till with smooth coulters | 0.10 | 0.05 |
| Planter, ridge-till | 0.70 | 0.50 |
| Planter, runner openers | 0.15 | 0.10 |
| Planter, staggered double disk openers | 0.10 | 0.05 |
| Planter, strip-till with 2 or 3 fluted coulters | 0.40 | 0.30 |
| Planter, strip-till with row cleaning devices (8-14" wide) | 0.45 | 0.30 |
| Plow, moldboard with uphill furrow (Pacific NW only) | 0.80 | 0.60 |
| Plow, moldboard, 8" deep | 0.98 | 0.95 |
| Rodweeder, plain rotary rod | 0.40 | 0.10 |
| Rodweeder, rotary rod with semi-chisels or shovels | 0.35 | 0.25 |
| Rotary hoe | 0.15 | 0.15 |
| Rotary tiller, strip tillage-12" tilled on 40" rows | 0.45 | 0.35 |
| Rotary tiller-primary operation 6" deep | 0.90 | 0.75 |
| Rotary tiller-secondary operation 3" deep | 0.70 | 0.50 |
| Subsoil-chisel, combination chisel | 0.55 | 0.40 |
| Subsoiler, combination disk | 0.85 | 0.60 |
| Subsoiler, V ripper 20" spacing | 0.30 | 0.20 |
| Undercutter, stubble-mulch sweep or blade, 20-30" wide | 0.30 | 0.15 |
| Undercutter, stubble-mulch sweep or place, >30" wide | 0.25 | 0.10 |

The second adjustment is the conversion of flat residue to buried residue. Flat residue cover remaining after tillage is predicted from the equation:

$$C_{rf\,(t)} = R_{mf}\, C_{rf\,(t-1)} \qquad [9.5.4]$$

where $C_{rf\,(t-1)}$ and $C_{rf\,(t)}$ are flat residue covers before and after tillage, respectively and $R_{mf}$ is from Eq. [9.5.1].

Flat residue biomass remaining after tillage is then calculated from:

$$M_{f\,(t)} = \frac{\ln(1 - C_{rf\,(t)})}{-cf} \qquad [9.5.5]$$

where $cf$ is a crop specific constant (Table 9.2.1).

Following each tillage operation, buried residue biomass ($M_b$) in the 0- to 0.15-m zone is increased by the biomass of flat residue incorporated into the soil. Flat residue biomass before tillage includes the biomass of residue converted from standing to flat by the tillage operation.

At present, the only way to instruct the WEPP model to alter the placement of residue cover by tillage from ridges to furrows or from furrows to ridges is through careful adjustment of the tillage intensity values. The values presented in Table 9.5.1 are all positive and result in reduction of residue on both the interrill areas and rill channels. If the user wants to instead increase the residue cover on the ridges (interrill areas) or in the furrows (rill areas), the $T_i$ values supplied to the WEPP model in the crop/management input file would have to be negative. For example, say that in a ridge tillage system the current ridge (interrill) cover is 30 percent and the current furrow (rill) cover is 70 percent. A cultivator operation is to be used which will move residue from the furrow to the ridges. To reduce the rill cover by 20 percent, the $T_i$ value for the cultivator on the rills would be 0.20. To increase the interrill cover by 10 percent (assuming that the rills take up a third of the total area, and that residue in the cultivation operation will be evenly distributed across the ridges), the $T_i$ value for the cultivator on the interrill areas would be -0.33. The final residue covers in this example would be 56% in the rill channel and 40% on the ridges.

**9.5.2 Shredding or Cutting**

The user inputs the date of shredding or cutting (JDCUT). At that time, standing residue ($M_s$) is converted into flat residue ($M_f$) depending upon the fraction of standing residue cut ($F_{cut}$), which is a user input variable:

$$M_{f\,(t)} = M_{f\,(t-1)} + (M_{s\,(t)} F_{cut}) \qquad [9.5.6]$$

Flat residue cover is calculated from the adjusted flat residue biomass using Eq. [9.3.1].

**9.5.3 Burning**

The impact of burning on standing and flat residue biomass depends upon environmental and plant conditions at the time of the burn. Therefore, the user must input the fractions of standing and flat residue that are lost by burning, as well as the date the burn occurs (*JDBURN*). The standing and flat residue biomass left after burning are calculated from:

$$M_{s\,(t)} = M_{s\,(t-1)}(1 - F_{bs}) \qquad [9.5.7]$$

$$M_{f\,(t)} = M_{f\,(t-1)}(1 - F_{bf}) \tag{9.5.8}$$

where $F_{bs}$ and $F_{bf}$ are the fractions of standing and flat residue lost by burning, respectively.

### 9.5.4 Straw Harvesting

Small grain residue is often harvested for livestock bedding. If standing residue is cut, the user must input the cutting date (*JDCUT*) and the fraction of residue cut ($F_{cut}$) under the residue management options for the just harvested small grain crop. A fallow crop period next needs to be defined to allow entry of an additional residue management for the straw harvest operation, including the removal date (*JDMOVE*), and the fraction of flat residue removed ($F_{rm}$). Standing and flat residue masses after cutting are predicted from:

$$M_{s\,(t)} = M_{s\,(t-1)}(1 - F_{cut}) \tag{9.5.9}$$

$$M_{f\,(t)} = M_{f\,(t-1)} + (M_{s\,(t-1)} - M_{s\,(t)}) \tag{9.5.10}$$

Flat residue biomass remaining after removal from the field is calculated from:

$$M_{f\,(t)} = M_{f\,(t-1)}(1 - F_{rm}) \tag{9.5.11}$$

If standing residue is not cut, and only the residue that passed through the combine is harvested, the user must input the removal date (*JDMOVE*) and the fraction of flat residue removed ($F_{rm}$). The flat residue biomass remaining after removal of the residue is then calculated from Eq. [9.5.11].

## 9.6 Rangeland Decomposition

The rangeland submodel uses an older set of decomposition algorithms based on the work of Ghidey et al. (1985). The loss of litter and organic residue on the soil surface ($R_g$) is estimated from the antecedent rainfall, average daily temperature, and the carbon-to-nitrogen ratio of the residue.

$$R_g = (R_g\ \omega_L) - B_c \tag{9.7.1}$$

$$\omega_L = 1 - (\alpha_f\ \tau)^2 \tag{9.7.2}$$

$$\tau = \frac{S_{mi}\ T_{avg}}{C_n} \tag{9.7.3}$$

where $\omega_L$ is the fraction of litter after decay and $B_c$ is a daily disappearance of litter as a function of insects and rodents. $\alpha_f$ is the litter decay coefficient and is a function of the antecedent moisture index, average daily temperature ($T_{avg}$), and the carbon nitrogen ratio of dead leaves and roots ($C_n$). The antecedent moisture index, $S_{mi}$, is the amount of rainfall recorded in the last 5 days. $S_{mi}$ values > 100 mm are set to 100 mm to reduce the decomposition rate of litter and organic residue during high rainfall periods.

For woody plant communities the trunks, stems, branches, and twigs ($W_n$) of the plants are considered to be nondecomposable but are important components in the calculation of foliar cover and ground surface cover. $W_n$ is estimated on day one of the simulation from:

$$W_n = N_d \, R_a \qquad [9.7.4]$$

where $N_d$ is the initial standing woody biomass, and $R_a$ is the standing, above-ground dead biomass. $W_n$ is held constant until management changes.

The fraction of the soil surface covered with litter is estimated with an exponential function, where $cf$ is a shaping coefficient and $R_g$ is the amount of litter and organic residue biomass on the soil surface and are discussed in detail in the Chapter 8, Section 8.5.

The decomposition of the rangeland root biomass ($B_{rt}$) is calculated in a manner similar to that used for litter and organic residue.

$$B_{rt} = B_{rt} \, \chi \qquad [9.7.5]$$

$$\chi = 1 - (\alpha_r \nu)^2 \qquad [9.7.6]$$

$$\nu = \frac{S_r \, T_{avg}}{C_n} \qquad [9.7.7]$$

where $\chi$ is the fraction of roots left after decay, $\alpha_r$ is the root decay coefficient, and $\nu$ is a function of the antecedent moisture index, average daily temperature ($T_{avg}$), and the carbon nitrogen ratio of dead leaves and roots ($C_n$). The antecedent moisture index, $S_r$, is the amount of rainfall recorded in the last 5 days.

## 9.7 Rangeland Management Options

Rangeland management options impact both the living plant communities and any dead biomass residues which exist. Thus, the rangeland management options of livestock grazing, burning, and herbicide application are all discussed in Chapter 8 Section 8.5, and are not repeated here. The WEPP model currently does not support mechanical practices on rangeland.

**9.8 References**

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## 9.9 List of Symbols

| Symbol | Definition | Units | Variable | Land Use* |
|---|---|---|---|---|
| $A$ | Absolute value of the TFC minimum temperature for residue and root decomposition | $^oC$ | ATEMP | C |
| $A_{bm}$ | Plant basal area at maturity in one square meter | $m^2$ | BASMAT | C |
| $B_c$ | Daily removal of surface organic material by insects | $kg{\cdot}m^{-2}$ | BUGS | R |
| $B_{rt}$ | Total root biomass for rangeland decomposition | $kg{\cdot}m^{-2}$ | RTMASS | R |
| $cf$ | Parameter for flat residue cover equation | $m^2{\cdot}kg^{-1}$ | CF | R,C |
| $C_{cf}$ | Fraction of the surface area covered by coarse rock fragments | $NOD$ | ROKCOV | C,R |
| $C_g$ | Total fraction of soil surface covered by residues and rocks | $NOD$ | GCOVER | R,C |
| $C_n$ | Carbon to nitrogen ratio of residues and roots | $NOD$ | CN | R |
| $C_{reo}$ | Average fraction of the soil surface covered by residues in a ridge-furrow system | $NOD$ | RESCOV | C |
| $C_{rf}$ | Total fraction of soil surface covered by flat residues | $NOD$ | FLRCOV | C |
| $C_{ri}$ | Fraction of interrill area covered by residues | $NOD$ | INRCOV | R,C |
| $C_{rl}$ | Fraction of rill area covered by residues | $NOD$ | RILCOV | R,C |
| $C_{rr}$ | Fraction of ridge area covered by residues | $NOD$ | RIGCOV | C |
| $C_{rs}$ | Total fraction of soil surface covered by standing residues | $NOD$ | STRCOV | C |
| $C_{rt}$ | Total fraction of soil surface covered by residues | $NOD$ | RESCOV | R,C |
| $C_{sp}$ | Fraction of ridge area covered by residues after wind repositioning | $NOD$ | SPRCOV | C |
| $D_h$ | Number of days after harvest | $NOD$ | DAH | C |
| $f_{rl}$ | In a ridge-furrow system, the fraction of area occupied by furrows | $NOD$ | WIDTH/RSPACE | C |
| $f_{rr}$ | In a ridge-furrow system, the fraction of area occupied by ridges | $NOD$ | 1-WIDTH/RSPACE | C |
| $F_{bf}$ | Fraction of flat residue mass lost by burning | $NOD$ | FBRNOG | C |
| $F_{bs}$ | Fraction of standing residue mass lost by burning | $NOD$ | FBRNAG | C |
| $F_{cut}$ | Fraction of standing residue mass mechanically shredded or cut | $NOD$ | FRCUT | C |
| $F_{ct}$ | Standing to flat residue adjustment factor for wind and snow | $NOD$ | FACT | C |
| $F_{pc}$ | Fraction of residue mass at harvest that is standing | $NOD$ | PARTCF | C |
| $F_{rm}$ | Fraction of live biomass or flat residue mass removed from a field | $NOD$ | FRMOVE | C |
| $H_{cm}$ | Maximum canopy height | $m$ | HMAX | R,C |
| $H_{cut}$ | Cutting height at harvest | $m$ | CUTHGT | C |
| $j$ | Current residue type | | IRESD | C |
| $M_b$ | Buried residue mass | $kg{\cdot}m^{-2}$ | SMRM | C |
| $M_f$ | Plant residue mass lying on the ground | $kg{\cdot}m^{-2}$ | RMOG | C |
| $M_r$ | Non-living root mass | $kg{\cdot}m^{-2}$ | RTM | C |
| $M_{rl}$ | Amount of residue mass on the rill areas | $kg{\cdot}m^{-2}$ | RILRM | C |
| $M_{rr}$ | Amount of residue mass on the ridge areas | $kg{\cdot}m^{-2}$ | RIGRM | C |
| $M_{rt}$ | Total above-ground residue mass at harvest (excludes roots) | $kg{\cdot}m^{-2}$ | RESAMT | C |
| $M_s$ | Plant residue mass standing above-ground | $kg{\cdot}m^{-2}$ | RMAG | C |
| $M_{so}$ | Standing residue mass at grain or biomass harvest | $kg{\cdot}m^{-2}$ | SRMHAV | C |
| $\Delta M_w$ | Residue mass moved from ridges to furrows by wind | $kg{\cdot}m^{-2}$ | DELTRM | C |
| $N_d$ | Initial standing non-decomposable woody biomass | $NOD$ | WOOD | R |
| $ORATE_A$ | Optimum decomposition rate for the above-ground part of a residue type | $kg{\cdot}m^{-2}{\cdot}d^{-1}$ | ORATEA | C |
| $ORATE_R$ | Optimum decomposition rate for the dead roots of a given residue type | $kg{\cdot}m^{-2}{\cdot}d^{-1}$ | ORATER | C |
| $P$ | Maximum potential standing live above-ground biomass | $kg{\cdot}m^{-2}$ | PLIVE | R |
| $PRCP$ | Daily precipitation | $m$ | PRCP | C |
| $P_m$ | Plant population at maturity | $plants{\cdot}m^{-2}$ | POPMAT | C |

| | | | | |
|---|---|---|---|---|
| $R_a$ | Standing above-ground dead biomass | $kg \cdot m^{-2}$ | RMAG | R |
| $R_g$ | Litter and organic residue mass | $kg \cdot m^{-2}$ | RMOG | R |
| $R_{mf}$ | Residue mixing factor | *NOD* | RMF | C |
| $S_{mi}$ | Antecedent moisture index for litter decomposition | *m* | AMC | R |
| $S_r$ | Antecedent moisture index for root decomposition | *m* | AMC2 | R |
| $T_{avg}$ | Average daily temperature | $^oC$ | TMPAVE | R |
| $T_i$ | Tillage intensity | *NOD* | MFO | C |
| $t_i$ | Current Julian date | *Julian day* | SDATE | R,C |
| $T_m$ | Maximum TFC temperature for residue/root decomposition | $^oC$ | TM | C |
| $W_n$ | Standing woody biomass - nondegradable, nonconsumable | $kg \cdot m^{-2}$ | DECOMP | R |
| $\alpha_f$ | Decomposition constant to calculate flat residue mass change | *NOD* | ACA | R |
| $\alpha_r$ | Decomposition constant to calculate root mass change | *NOD* | AR | R |
| $\phi_{till}$ | Soil volume fraction in tilled soil layers that is pore space | *NOD* | AVPOR | C |
| $\theta_{opt}$ | Fraction of water filled pore space that is optimal for decomposition | *NOD* | OPTWAT | C |
| $\theta_{till}$ | Fraction of soil pore space filled with water in tilled soil layers | *NOD* | SUMWAT | C |
| $\omega_L$ | Litter remaining after decomposition occurs | *NOD* | SMRATI | R |
| $\tau$ | Weighted-time variable for standing and flat residue decomposition | *NOD* | TAU | R |
| $\nu$ | Weighted-time variable for buried residue and root decomposition | *NOD* | TAU2 | R |
| $\chi$ | Fraction of roots remaining after decomposition | *NOD* | RPATIO | R |
| - | Environmental index used to determine residue decomposition | *NOD* | ENVIND | C |
| - | Change in decomposition rate due to soil fertility | *NOD* | FERIND | C |
| - | Julian day of burning crop residue | *Julian day* | JDBURN | C |
| - | Julian day of crop residue shredding or cutting | *Julian day* | JDCUT | C |
| - | Julian day of residue removal from a field | *Julian day* | JDMOVE | C |
| - | Change in decomposition rate due to residue particle size | *NOD* | PSZIND | C |
| - | Temperature factor used in the environmental index determination | *NOD* | TFC | C |
| - | Water factor used in the environmental index determination | *NOD* | WFC | C |

* C and R refer to cropland and rangeland, respectively.