Soil Tillage Intensity Rating STIR

The STIR rating is a replacement for the Soil Disturbance Rating component in the Soil Conditioning Index and functions as a stand-alone rating to evaluate tillage and/or planting systems on parameters other than the traditional ground cover and surface disturbance parameters. It replaces the subjective ratings contained in the Soil Disturbance Rating component of the SCI with more scientifically supported parameters. It utilizes the various operations database parameters in RUSLE2 to calculate a tillage intensity rating for the system used in growing a crop or a rotation. STIR ratings are calculated for cropping systems in WEPP, WEPS and the Integrated Erosion Tool. STIR ratings tend to show the differences between systems across the spectrum from true no-till all the way to conventional plow systems. It does so, better than surface cover or surface disturbance criteria since the kind, severity and number of ground disturbing passes are evaluated rather than only result or a snapshot of soil conditions after planting.

The parameters used in the STIR rating are derived from the RUSLE2 operations database that are now incorporated into CRLMOD used for WEPP and WEPS. Those values are based on a set of ARS core operations which the RUSLE2 model developers obtained from various research studies. In creating operation record several things need to be known when used under typical soil, residue and crop conditions including: range of operating speeds, range of operating depths, tillage type, amount of surface disturbance, residue burial and resurfacing fractions for five residue classes ranging from fragile residues to stones, standing residue flattening fractions, random roughness and ridge roughness and tillage intensity parameters. The ARS core operations were used as a starting point and the values for a new operation are adjusted based on observations, pictures, and on-site measurements, as provided by manufacturers, researchers and technical specialists.

The STIR rating for an individual operation is calculated by multiplying the individual parameter values and by applying "weighting" factors for each. They are speed times 0.5; tillage type times 3.25; average depth times 1; and surface soil disturbance times 1. This was done in order to calibrate the STIR component of the SCI back to the original systems and the base location and calibration sites so the resulting SCI answer would be the same as the original SCI before the Soil Disturbance Rating (SDR) parameter was replaced by the STIR rating.

The STIR rating applies to the entire tillage system used in producing a crop. All operations involved in tilling, fertilizing, planting, controlling pests, harvesting the crop and managing residues are evaluated in the STIR rating for a tillage system for a given crop. STIR ratings can be calculated for single crop intervals or for crop rotations. Higher STIR ratings are shown for systems with greater disturbance and more frequent operations. Comparison of STIR ratings for different tillage and planting systems provide insight into soil carbon loss, moisture depletion, and fugitive dust issues related to soil tillage.

The components of the STIR rating are the following parameters from the land management operations database.

1. Recommended Operating Speed:
This process represents the recommended speed for this operation. RUSLE2 can compute how speed of an implement affects residue burial. Speed between the range of a minimum and maximum can be entered in the management screen. The recommended speed is the generally is the recommend speed that the manufacturer suggests for the implement. This speed is the default speed for this operation, and indicates the assumed condition under which the flattening, burial, and re-surfacing values are defined.

2. Tillage Type:
Tillage type describes how the operation mixes the soil and associated residue. This variable refers to the type of mechanical disturbance on the soil, and how that affects the distribution of residue within the soil. The distribution of material, like plant residue, incorporated into the soil depends on the type of mechanical disturbance, referred to as tillage type. Also, tillage type affects the distribution of material within the soil as subsequent mechanical disturbances, i.e. tillage operations, occur.

The following values are assigned to individual tillage types in the STIR rating:
1.0 Inversion some mixing
0.8 Mixing + some inversion
0.4 Lifting and fracturing
0.7 Mixing only
0.15 Compression

Inversion with some mixing places most of the surface material in the lower half of the depth of soil disturbance (tillage depth). In effect, the soil in disturbance depth is “flipped over” with some mixing in the soil. Several subsequent operations result in the material being somewhat uniformly distributed in the soil. A moldboard plow is an example of an implement that inverts the soil with some mixing.

Mixing with some inversion places most of the surface material in the upper half of the depth of soil disturbance (tillage depth). The next operation leaves a somewhat uniform distribution of the material in the soil. The material becomes increasingly concentrated with subsequent operations and moves down in the soil in a “lump” as illustrated in the figure. Tandem disk, chisel plows, and field cultivators are examples of implements that are a tillage type of mixing with some inversion.

Mixing only places most of the surface material in the upper three tenths of the depth of soil disturbance (tillage depth). The next operation or two leaves a somewhat uniform distribution of the material in the soil. The material becomes increasingly concentrated with subsequent operations and moves down in the soil in a “lump” as illustrated in the figure. Rotary tillers are examples of implements of mixing only.

Lifting, fracturing places most of the surface material in the upper three tenths of the depth of soil disturbance (tillage depth). The next operation or two leaves a somewhat uniform distribution of the material in the soil. The material becomes increasingly concentrated with subsequent operations and moves down in the soil in a “lump” as illustrated in the figure. Subsoilers, fertilizer and manure injectors, and scarifiers are examples of implements of lifting, fracturing.

Compression “pushes” surface material into the soil without the soil being disturbed. The initial distribution of material in the soil is the same as the mixing only tillage type. Examples of implements that are a compression type include sheep foot’s rollers used on construction sites and cattle trampling.

When an operations fits into multiple tillage type categories the highest rated tillage type is used for calculating STIR values. In addition, many tillage, planting and fertilizer operations have multiple devices or processes that need to be accounted when determining STIR value. For example, a “Seedbed Conditioner” has three devices/processes that must be accounted for including a coulter caddy, field cultivator, and a spike toothed harrow which must be accounted for.

3. Recommended Tillage Depth:

Many site operations disturb the soil, causing changes in soil physical properties and incorporation and mixing of residue. One of the key parameters is the depth to which the residue is incorporated, and soil is disturbed. Note that database values are average and may or may not be the same as the actual depth of tillage. Typical implements work best at a tillage depth recommended by the manufacturer.

4. Surface area disturbed:
This value is used to determine the impact of an operation on long-term soil consolidation. A plow assumed to completely invert the surface layer would receive a value of 100%, while a no-till planter which cuts a 3-inch slot every 30 inches could be assumed to disturb 10% of the surface.

Disturbing the soil causes erosion to increase and reduces soil aggregation. Soil that has not been disturbed for an extended period, (the time to soil consolidation—typically assumed to be seven years), is assumed in RUSLE2 to only be about 45% as erodible as soil that has been recently disturbed. Operations like planters, strip tillage tools, and drills typically disturb the soil in strips. The fraction (percent) of the total soil surface that is disturbed is the value entered.

Selection of a value for the fraction of the surface disturbed sometimes requires special consideration. In general, the area disturbed plus the area receiving soil “thrown” (displaced termed splash) by the soil disturbance is used for the input. However, if the displaced soil is very thin, the area of disturbance may be limited to the fraction of the soil surface (source area) that produces (generates) the displaced soil. This consideration is especially important in certain no-till cropping systems where the displaced soils doesn’t interfere with long-term no-till which can facilitate the buildup of organic matter and improve surface soil physical properties.

The fraction of surface disturbed is an important variable for disturbed forestland and similar lands that are disturbed in a “patchy” pattern. This input is used to represent the portion of the surface disturbed and it should not be used to represent percent ground cover. Percent ground cover should be based on the entire area, not just on the area disturbed.

All the operations involved in tilling, fertilizing, planting, controlling pests, harvesting the crop and managing residues are evaluated in the STIR rating for a tillage system for a given crop. STIR ratings can be calculated for single crops or for crop rotations. Higher STIR ratings are shown for systems with greater disturbance and more frequent operations. Comparison of STIR ratings for different tillage and planting systems provides insight into the carbon loss, moisture depletion, and fugitive dust issues related to tillage of the soil. However, STIR ratings are only qualitative and are not a substitute for more quantitative models.

As an example of how STIR ratings work the “Stalk chopper, rolling” operation represents a machine consisting of typically 5 heavy blades that rotate around a heavy shaft. The shaft is mounted to a heavy frame which is typically attached to the tractor’s rear 3-point hitch system. This machine is full width meaning that the blades are continuous across the width and thus tills in a continuous swath. The machine is typically used to cut, size, and partially incorporate corn residue to improve decomposition and reduce planter plugging. However, stand uniformity and germination may be adversely impacted by mixing the residue near the surface.

A variation of this operation is produced by the same manufacturers consisting of short rotor gangs of the same blade type but are 18 to 24 inches wide with adjustable spacing between gangs. The individual gangs can be angled to create more aggressive action. When only one gang is used there is an area between the gangs that is not tilled. However, it receives considerable “displaced” or thrown soil particles. If this thrown soil is deeper than 0.5 inch then that area is included in the surface disturbed because it impacts the erosion rates, residue decomposition, and water movement processes. When two ranks of these short gangs are mounted in a staggered pattern the disturbance is 100%. Both operations are available in single and double rotor designs and can be equipped with various leveling board, spiked, coiled tine and linked tine harrows.

Manufacturers pictures and specifications information from Bessler, Buffalo and McFarlane manufacturers were referenced. Typical conditions were assumed to be in the spring on soils with acceptable moisture content to allow traffic and tillage without significant compaction and residues that were reasonably dry and easily cut. Pictures of the soil and corn residue appeared to be disturbed in a fashion like that of a light disking. At least one manufacturer's literature described the machine as eliminating a disking operation.

In creating the "Stalk chopper, rotary operation" record, the ARS core operation that was used as a starting point was the light tandem disk. Values selected were speed 8 MPH; depth 3 inches; a tillage type of mixing with some inversion; and surface disturbance of 100% based on manufacture's literature and pictures of the machine under typical operating conditions. Depth, amount of disturbance and residue burial is like that of a light tandem disk as shown by the manufacturer's pictures except that the speed of operation is faster, and soil and residue is thrown more than by a light tandem disk. The only significant difference in the values between the light tandem disk and the "Stalk chopper, rotary operation" when operated on un-ridged soil is the speed. The light tandem disk has a STIR of 19.1 while the stalk chopper has a STIR of 31.2. Although one manufacturer recommends speeds of 12 to 15 mph, a faster speed would significantly increase the STIR calculation based on the STIR formula.

Operation Name	**Rec. speed**	**Rec. speed**	**Surf. area disturbed**	**Rec. till. depth**	**Tillage type**	**Component STIR**
Disk, tandem light finishing	5	**5**	100	3	0.8	**19.5**
Stalk chopper, rotary	8	**8**	100	3	0.8	**31.2**

<u>STIR Calculation</u>

All operation STIR values are consistently calculated using the following formula based on the RUSLE2 operations parameters described previously: (speed times 0.5; tillage type times 3.25; average depth times 1; and surface soil disturbance times 1)

(8mph x.5) x (tillage type 0.8x 3.25) x (3-inch depth x 1) x (surface disturbance 100%/100 x1) = 31.2 STIR Value

These operations were assumed to be operated on un-ridged soils. Other conditions such as operation on beds or ridge tilled corn, fall operation on green or fresh residues, wet or muddy conditions or frozen soils were not considered in creating these operations records. At the time of CSP signup no requests were pending to create additional stalk chopper operations to represent operation on ridges or on frozen soil or on fresh residue. However, such conditions are to be evaluated this fall, winter and spring and additional operations records developed to represent such different conditions. As with all requests for additional operations, these will be developed and added to the database as the information becomes available. There is no plan to change the values for the existing stalk chopper operations unless the data indicates it is necessary.

The STIR used for certain program eligibility or contained in conservation practice standards is typically the composite STIR for the entire cropping system. For example, a ridge-till system involving the use of a rolling stalk chopper, planter with row clearing devices or trash whippers and one or two cultivations to re-form the ridges, has a significantly higher STIR rating than No-till or Strip till. For example, a typical ridge-till system on continuous corn with two ridge-till cultivations will have a STIR rating in the high 30's to low 40's while the same system with the additional stalk chopper operation in the spring will score in the low to mid 60's.

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