Determining How Much Crop Residue to Remove on Your Farm
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The following four-step approach will help determine a rate of residue removal that is sustainable for your farm. These calculations are based on common corn-soy and corn-soy-wheat rotations. Other crops might sustain residue removal, but will require further research by the farmer.

The four steps outlined by Kludze et al. 2010 include:

1) Estimating the minimum amount of residue required to be left in the field to maintain current soil organic matter levels;
2) Estimating aboveground residue produced from grain yield under a rotation system (i.e., aboveground post-harvest residue less the grains);
3) Estimating belowground root residue (including rhizodeposits), produced under a rotation system;
4) Estimating total crop residue (belowground root and aboveground residue in a rotation system;

Kludze et al. 2010 suggests that once these steps are completed farmers can subtract total crop residue (calculated in step 4) from the SOM maintenance requirement (calculated from step 1).

Total crop residue:	Biomass from above and below ground, excluding grain.
SOM maintenance requirement:	Total amount of organic matter (residue) needed to maintain SOM at current level

Total crop residue – SOM maintenance requirement = sustainable residue removal (SRR) rate

Note: Although these steps provide a good starting point, farmers practicing sustainable residue removal (SRR) must continually re-evaluate soil and crop characteristics to ensure soil health is not degrading.

Step 1: Minimum amount of residue to be left in the field to maintain soil organic matter
Soil organic matter is primarily composed of soil organic carbon (SOC). Since decomposition processes reduce SOC content there is a need for continuous carbon inputs to maintain soil organic matter (SOM) formation. In most cropping systems this equilibrium is achieved when crop residues are left in the field. How much to leave depends on SOM formation and decomposition rates. A high formation rate and low decomposition rate would require less carbon input than a low formation rate and high decomposition rate. On average microbes decompose SOM at a rate of 2-2.5% a year and SOM formation rates range from 10-20% (Kludze et al. 2010).

Based on Kludze et al. 2010, a typical healthy Ontario soil with 3% SOM in the plough layer (0-15 cm depth) contains 67,200kg of SOM/ha, then this means that 1344-1680 kg of SOM/ha is lost annually through decomposition processes. To replace this at a 15% SOM formation rate means that 8,960-11,200 kg/ha of new organic input must be supplied annually.

Kludze et al. 2010 suggest using the calculations below for your personal farm:
(% SOM) x (*hectare furrow slice weight) = weight of SOM per hectare (SOM kg/ha)

(SOM kg/ha) x (**SOM decomposition rate) = SOM loss per year (SOM loss/yr)
(SOM loss/yr) / (***SOM formation rate) = Minimum amount of residue to be left in the field to maintain soil organic matter content

* A hectare furrow slice is the weight of soil in one hectare to a depth of 0-15cm. It is generally around 2,250,000 kg/ha (2,000,000 lbs/acre).
** SOM decomposition rates are site-specific, but generally range between 2-2.5%.
*** SOM formation rates are site-specific, but average 15% in Ontario.

Step 2: Estimating above ground residue produced from grain yield
Corn, soy and wheat all have harvest indices of 0.5, meaning there's a 1:1 ratio between grain weight and above ground residue weight (Kludze et al. 2010). Therefore, the weight of grain harvested per acre is a good estimate of the weight of above ground residue.

Step 3: Estimating below ground residue produced
Below ground residues also contribute to carbon inputs and they are calculated from above ground residue weights based on root-to-shoot ratios. For example, a 1:1 ratio means that there's an equal proportion of above and below ground residue, conversely a 6:5 ratio means there's 20% more residue below ground.

Step 4: Estimating total crop residue produced
Add above and below ground residue weights to get total crop residues produced. The table below illustrates the calculations involved for this, starting from step 2.

Table 2: Calculating residue weights based on grain yields (2004-2008 average yields) (Kludze et al 2010)

	Corn (kg/ha/yr)	Soy (kg/ha/yr)	Wheat (kg/ha/yr)
Grain yield	8573.77	2572.03	4584.30
Harvest Index	1:1	1:1	1:1
Above ground biomass	8573.77	2572.03	4584.30
Root-to-shoot ratio	1:1	6:5	8:5
Below ground biomass	8573.77	3086.44	7334.88
Total crop residue	17147.55	5658.47	11919.20

Table 3: Sustainable residue removal for corn, soy, and wheat (2004-2008 average yields) (Kludze et al. 2010)

	Corn (kg/ha/yr)	Soy (kg/ha/yr)	Wheat (kg/ha/yr)
Total crop residue	17148	5658	11919
SOM maintenance requirement	8960-11200	8960-11200	8960-11200
SRR harvest	5948-8188	(-)3302 – (-)5542	719-2959

Table 3 shows that residue can only be removed in corn and wheat years of a rotation. However, if soy is part of rotation there will be a "residue debt" carried forward. To determine average annualized yields, a farmer must multiply the number of years each crop has in the rotation and then add all crop totals together and divide by the number of years in a rotation. For example, to

calculate SRR for a four year rotation of corn-corn-soy-wheat:

Table 4: Kludze et al. 2010 demonstrates calculating annualized average SRR yields based on a corn-corn-soy-wheat rotation

	Annual SRR (kg/ha/yr)	# years in rotation	Total SRR of crop (kg/ha/rotation)
Corn	5948-8188	2	11896-16376
Soy	(-)3302 – (-)5542	1	(-)3302 – (-)5542
Wheat	719-2959	1	719-2959

Total SRR (kg/ha/rotation)	7073-16033
Annualized average SRR (kg/ha/yr)	1768 - 4008

These annualized average SRR rates are intended only as a guideline, but are likely similar to conditions on many farms. Site-specific analysis is required to ensure accurate SRR rates are established. Furthermore, it should be noted that the annualized average SRR yields are merely meant as a planning tool. Farmers should strive to remove only what is sustainable for that crop year. Based on the above information SRR will be much higher in corn years and will likely not happen at all during soy years.

Data and information from: Kludze, H., Deen, B., Weersink, A., van Acker, R., Janovicek, K., & De Laporte, A. (2010). *Assessment of the availability of agricultural biomass for heat and energy production in ontario*. Crop Science, University of Guelph: Ontario Ministry of Agriculture, Food and Rural Affairs.