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Harvesting Crop Residues

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This NebGuide addresses issues of crop residue harvest including nutrient removal and effects on erosion, soil quality, water loss, and yield.

Harvesting crop residue has increased in recent years and demand is likely to grow. Letting cattle graze corn stalks is a long-standing practice in many areas, but increased use of distillers grain in the beef cattle diet is contributing to reduced feeding of alfalfa hay and corn silage and increased harvesting and feeding of crop residue. In addition, harvesting of crop residues for cellulosic ethanol production is anticipated in the near future. While corn stalk grazing usually results in little nutrient or organic material removal, mechanical harvest removes nutrients and organic material critical to maintaining soil productivity.

Decisions about how much crop residue can be sustainably harvested need to be based on the effects on:

- soil nutrient availability;
- soil organic matter;
- water erosion and runoff;
- wind erosion;
- soil water availability;
- yield; and
- economics.

Estimated Amount of Crop Residue Produced

The amount of crop residue produced is related to grain production. Approximately 1 ton of crop residue (at 10 percent moisture) is produced with 40 bushels of corn or grain sorghum (56 lb/bu at 15.5 percent), 30 bushels of soybean, and 20 bushels of wheat.

Value of Removed Nutrients

The most easily estimated cost associated with crop residue harvest is the value of the nutrients removed. The concentration of nutrients in crop residues varies with season, management practice, time of harvest, and location. In addition, crop residue components differ in nutrient concentration, with most elements concentrated more in leaves and husks than stalks. The typical nutrient contents are about 17 lb N, 4 lb P_2O_5, 34 lb K_2O, and 3 lb S per ton of dry harvested corn or sorghum residue. The value of the nutrients removed can then be calculated as in *Table I* by entering current fertilizer nutrient prices in column "d." Similar calculations can be made for soybean using 17 lb N, 3 lb P_2O_5 , 13 lb K_2O, and 2 lb S per ton of harvested soybean residue. For wheat, suggested values are 11 lb N, 3 lb P_2O_5 , 15 lb K_2O, and 2 lb S. Harvesting crop residues also removes cations (positively charged ions) such as calcium, magnesium, and potassium, which help neutralize soil acidity. This suggests that more lime will be needed eventually. Harvesting 1 ton of corn residue removes the equivalent cations contained in 35 lb of lime. If lime is worth $40/ton, this adds $0.70/ton to the value of crop residue on a low pH soil.

Table I. The fertilizer value of nutrients in one ton of corn residue. Substitute current fertilizer nutrient values as appropriate in column d and calculate the $ values in column e.

Element	*Concentration In residue %*	*Pounds Per ton lb/ton*	*Fertilizer* Nutrient Price $/lb*	*Value of Nutrient In residue $/ton*
a	*b*	*c = b/100 x 2000*	*d*	*e = c x d*
N	0.85	17	$0.60	$10.20
P_2O_5	0.2	4	$0.90	$3.60
K_2O	1.7	34	$0.40	$13.60
S	0.15	3	$0.50	$1.50
Total value				$28.90

*Prices May 2012

Soil Organic Matter

Maintenance of soil organic matter is important to nutrient supply and to soil physical properties that are critical to soil tilth, water infiltration, and water-holding capacity. Soil organic matter is maintained by decomposition of plant biomass returned to the soil. Both aboveground and belowground plant parts (for example, shoots, roots, and root exudates) contribute to soil organic matter, but the relative importance of each component is unknown. The information basis for estimating the amount of crop residue needed to maintain soil organic matter is incomplete. To maintain soil organic matter the best current estimate is that 2 to 3 ton/acre of crop residue should be left in the field annually through conservation tillage or no-till systems. Greater residue amounts are necessary with more aggressive tillage practices because tillage accelerates the rates of decomposition of both new residues and existing soil organic matter.

Water Erosion and Runoff

The value of maintaining ground cover to reduce water erosion and slow runoff is well known. Crop residue or a cover crop can provide the needed soil protection. With medium and high erodibility soils and rain-fed production, little if any crop residue should be harvested. On soils of low erodibility, leaving

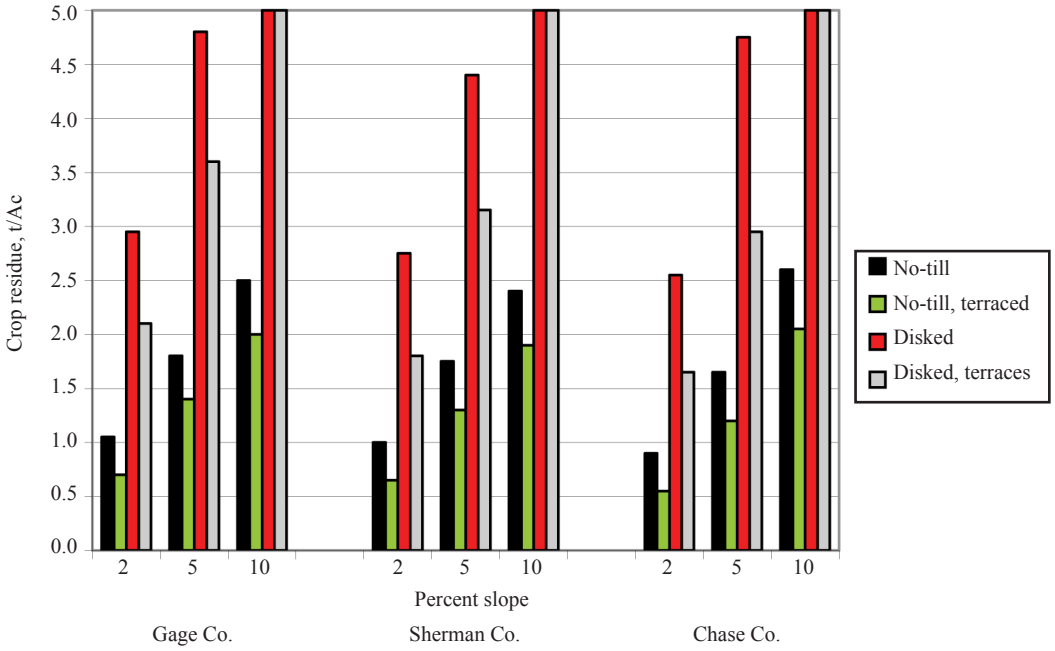

Figure 1. Crop residue needed to keep water erosion to below 5 ton/acre/year for silt loam and silty clay loam soil on three slopes in three counties of Nebraska. Bars reaching the upper limit of the chart indicate that more than 5 ton/acre of crop residue needs to remain as ground cover in the field.

2 to 3 ton/acre (2 tons of corn or grain sorghum crop residue usually gives about 50 percent cover) for maintenance of soil organic matter should be sufficient to prevent erosion from exceeding 5 ton soil/acre. More crop residue can be harvested under no-till compared with tilled conditions, and with terraces compared with no terraces.

The USDA-NRCS water erosion estimator RUSLE2 was used to determine the average amount of crop residue needed to provide sufficient ground cover to limit soil loss to no more than 5 ton/acre/year (*Figure 1*). The minimum mean corn yield required with a continuous corn system (assuming no cover crop) to produce this amount of crop residue was also estimated (*Figure 2*). The calculations were for silt loam or silty clay loam soils with different management practices in counties located in eastern (Gage County), central (Sherman County), and western (Chase County) Nebraska. The soil series used were Wymore at 2 and 5 percent slope and Deroin at 10 percent slope in Gage County, Holdrege at 2 and 5 percent slope and Uly at 10 percent slope in Sherman County, and Keith at 2 and 5 percent slope and Colby at 10 percent slope in Chase County.

The results shown in *Figures 1* and *2* indicate that with these soils and slopes, no residue can be removed if the land is tilled by disking unless the field is terraced. With disking terraced land, some residue can be harvested from high yield corn land with 2 percent slope but not from land with a slope of 5 percent or greater and not from land where mean yield is less than 150 bu/acre. With no-till, especially if more steeply sloping land is terraced, much more crop residue could be harvested while keeping erosion to less than 5 ton/acre/year.

Wind Erosion

Wind erosion often exceeds water erosion, especially in western Nebraska, and is worse during periods of extended drought. In addition, blowing soil particles can damage young plants and reduce air quality, affect human and animal health, and cause traffic accidents due to reduced visibility. Wind erosion is best controlled with ground cover of crop residue or a cover crop. Maintaining standing crop residue is important for reducing wind velocity at the soil surface and trapping soil particles, as well as for trapping snow. Crop residue removal could eventually result in reduced size and stability of soil aggregates, making the soil more erodible. Ground covers of 30 and 60 percent are estimated to be sufficient to reduce wind erosion by 70 and 90 percent, respectively, compared to bare soil. For more information, see NebGuide 1537, *Wind Erosion and Its Control* (*http://www.ianrpubs.unl.edu/sendIt/g1537.pdf*).

County soil survey reports rate the sensitivity of soils to wind erosion on a scale of 1 to 7 with smaller numbers indicating greater erodibility. The NRCS Wind Erosion Prediction System

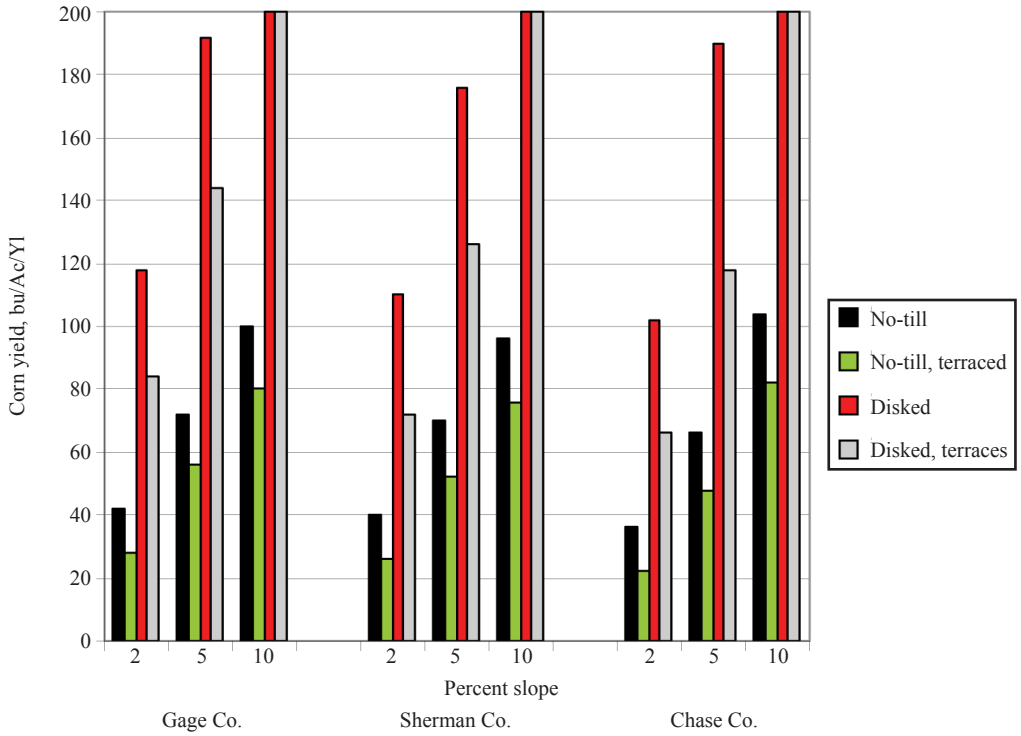

Figure 2. Continuous corn yield needed to produce enough crop residue to keep soil erosion to less than 5 ton/acre/year with a silt loam or silty clay loam soil for three slopes in three counties in Nebraska. Bars reaching the upper limit of the chart indicate that more than 200 bu/acre of corn yield is needed to maintain adequate ground cover.

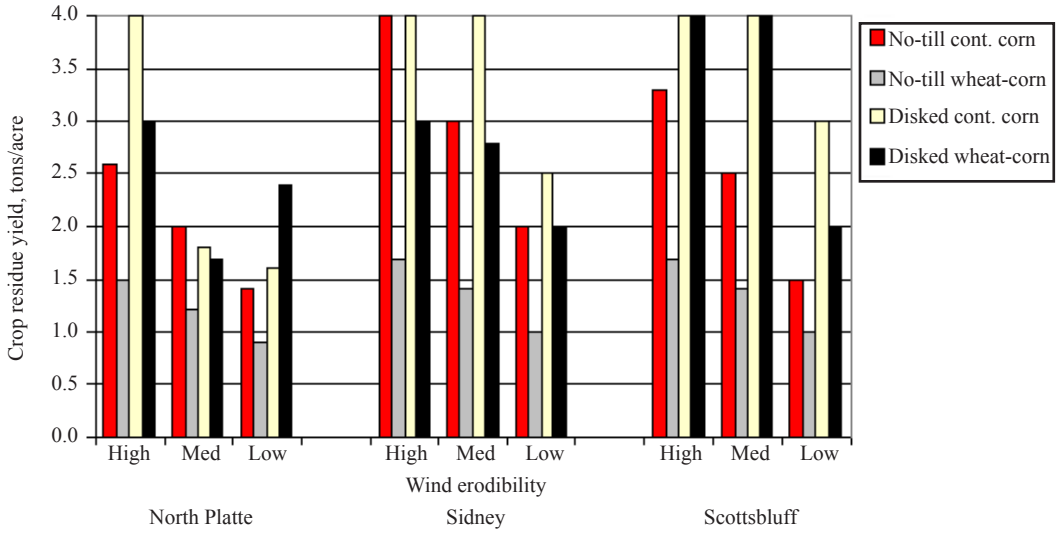

Figure 3. The amount of crop residues needed to keep wind erosion to less than 5 ton/acre/year for soils of high, medium and low susceptibility to wind erosion at three locations in western Nebraska. Bars reaching the upper limit of the chart indicate that more than 4 ton/acre of crop residue needs to remain in the field.

(WEPS; www.weru.ksu.edu/new_weru/nrcs/) was used to calculate crop residue needed to prevent soil loss from wind erosion of more than 5 ton/acre/year. Under rain-fed, tilled conditions in western Nebraska, often no crop residues can be removed (*Figure 3*). With no-till, 1 to 2 ton/acre of crop residue cover is adequate to keep erosion to less than 5 tons/ac/year for the low erodibility soils while 1.5 to 2.5 ton/acre of crop residue is needed for moderately erodible soil. The algorithm predicts that less crop residue is needed to control wind erosion for a wheat-corn rotation compared to continuous corn under rain-fed conditions because the smaller, more closely spaced wheat straws (if they remain upright) are more effective than the larger, more widely spaced corn stalks in reducing wind velocity near the soil surface. WEPS estimates that about 20 percent less crop residue is needed to control wind erosion with irrigated than with rain-fed continuous corn.

Soil Water

Crop residue affects soil water by reducing evaporation, catching snow, reducing runoff, and enhancing infiltration. Soil water loss associated with increased crop residue removal may be the greatest short-term cost of crop residue harvest, especially under rain-fed conditions in drought-prone areas. Under water-limiting conditions, a corn crop is expected to produce approximately 12 bushels of corn per inch of available water after the 7 to 10 inches needed before any grain is produced. Soil water losses to evaporation may be increased by 1 to 5 inches depending on the amount of residue removed from the field. This is illustrated by research results from Garden City, Kan., where water loss to evapotranspiration for an irrigated corn crop was 4.3 inches less with corn or wheat residue remaining on the soil surface than when all residue was removed (*Figure 4*). In addition, the snow trapping effect of erect crop residues may equal 1 inch or more of water available to the crop. Good ground cover often will result in reduced runoff and increased infiltration for further improvement in soil water availability.

In water deficit situations, the reduction in available soil water due to crop residue harvest could often result in yield decreases of more than 30 bu/acre the following year. In one study conducted in eastern Nebraska, corn yield declined by 2 bu/acre for each ton of crop residue removed. In irrigated situations, water applications and pumping costs will be increased to replace the water lost to evaporation when crop residues are removed. In one study in west central Nebraska removing the soybean residue from 68 and 61 bushel crops resulted in yield reductions of 25 and 17 bu/ac when the corn was irrigated according to soil moisture levels in the plots. However, if moisture is not limiting, high levels of residue may delay emergence and slow early growth. In other studies in eastern Nebraska and elsewhere in the Corn Belt, removing up to 50 percent of corn residue has resulted in increased or no effect on yield for the following crop. Because of the varied effects on crop yields, the crop producer is advised to conduct replicated strip trials comparing yield of full residue with yield from harvesting 2-3 tons/acre of residue.

Manure Application

Some of the negative effects of crop residue harvest can be overcome with regular manure application. Manure, especially feedlot manure, will return some nutrients to the soil and often has a liming effect. An application of 10 ton/acre of feedlot manure, dry weight, may replace the carbon removed in the harvest of 5 ton/acre of crop residue. However, carbon content in manure is highly variable and laboratory analysis is necessary to estimate the carbon application rate. Manure application is valuable for improving soil physical, chemical, and biological properties that will result in improved water infiltration, reduced runoff, and reduced erosion. Unfortunately, it can't reduce evaporation and trap snow like crop residue does.

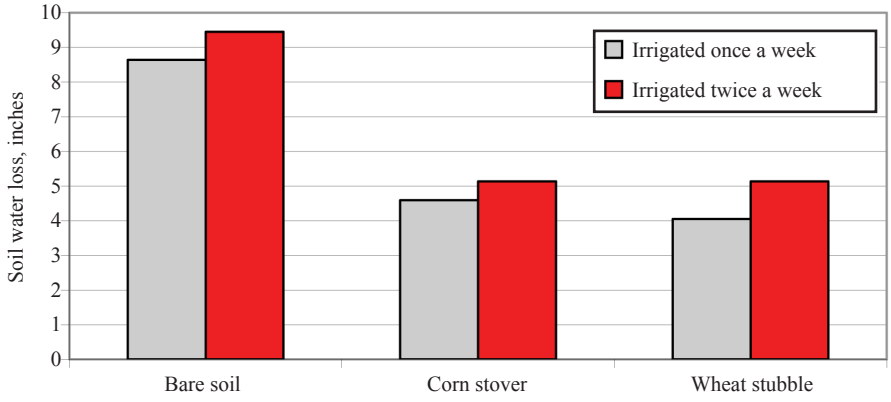

Figure 4. Water loss to transpiration for irrigated corn at Garden City, Kan., with all crop residue remaining compared with bare soil.

Cover Crops

A cover crop will mitigate some of the effects of crop residual removal, such as erosion control and carbon production, but will not replace removed nutrients. Under rain-fed conditions, water loss from evapotranspiration by the cover crop may reduce yield of the following crop. Also, there will be added costs in establishing and terminating the cover crop.

Table II. Worksheet to estimate the cost of crop residue harvest ($/ton). Example of corn residue harvest are for western Nebraska.

Costs	*Example of costs ($/ton)*	*Actual Field*	*Comments*
Nutrients removed/ton	28.90[1]		
Lime equivalent value	0.70		
Yield loss	3 bu @ 5.00 = 15.00[2]		
Soil loss from wind and water erosion	5.00		
Increased irrigation[3]	8.00		
Raking, baling, transporting	36.00		
Total	$93.60/ton		

[1]In this example, the full fertilizer value of removed nutrients is considered. However, if the soil has adequate capacity to supply some nutrients, the value of the removed nutrients may be less, perhaps 0 to 50% of fertilizer value. This is commonly the case for potassium in Nebraska.
[2]In this example, we use a yield loss which is common under water-limiting conditions. However, removing up to 50% of the crop residue often has resulted in no effect or increased yield in eastern Nebraska and elsewhere in the Corn Belt.
[3]Increased irrigation to compensate for increased water deficit due to more evaporation and less trapping of snow.

Harvest Equipment Limitations

A row-crop header, normally used in soybean or sorghum harvest, cuts stalks with a rotating knife immediately below the gathering belts. All plant material above the cut will pass through the combine.

Harvest efficiency depends on many factors:

- time of residue harvest relative to grain harvest;
- amount of traffic on residue during grain harvest;
- surface soil water content and precipitation amount and type during and after grain harvest; and
- equipment used for grain and residue harvest.

In a study conducted in Iowa, approximately half of the corn residue was collected when the combine row-crop header was positioned about midway between the base of the ear and the soil. Crop residues passed directly from the combine into a prototype chopper and were blown into a collection wagon. If the crop residue falls into a windrow and is collected later, a smaller percentage (about 40 percent) is recovered. The time of harvest can affect the nutrient content of N and K. Cutting with a windrower immediately after harvest allows you to collect a larger proportion of the corn residue. Related field operations will add to cost and risk of wheel traffic compaction.

Estimating the Amount of Crop Residue to Harvest

With most Nebraska soils, crop residue should not be harvested every year. The crop residue harvest rate might be estimated as the average crop residue produced annually over the crop rotation minus the mean amount needed to accommodate the maximum soil and water constraint, adjusted for frequency of crop residue harvest. The maximum constraint may be the organic material needed to maintain soil organic matter and productivity, to control wind or water erosion, or to prevent substantial yield loss or increased irrigation costs due to increased evaporation. In all cases, the value of nutrients removed needs to be considered.

For example, if the mean yield for continuous corn yield is 200 bu/acre, approximately 5 ton/acre of crop residue is produced (1 ton / 40 bu x 200 bu). If more crop residue is needed to control erosion from water, for example 2.5 ton/acre/year, compared with wind erosion control or other constraints, than this 2.5 ton is subtracted from the 5 ton produced. If the harvest is once every two years, multiply the difference by two. Therefore, the difference (5 – 2.5 = 2.5) multiplied by two, or 5 ton/acre can be harvested once every two years. This method is discouraged if the land is subject to wind and water soil erosion.

The potential for wind erosion can be reduced by harvesting alternate strips, of maybe 24 rows, every second year with the crop sown at right angles to the prevailing wind. Similar rotations could be used if residue is harvested every three to four years.

Summary

Before harvesting crop residue for off-site uses, consider these issues:

- Impact on wind and water erosion, water runoff, and the residue cover needed to comply with conservation programs
- Value of nutrients removed in crop residue and impact on fertilizer and lime requirement
- Need of crop residues to maintain soil organic matter
- Effect of reduced ground cover on soil water availability
- Effect on yield
- Impact of residue harvest on soil compaction from additional field operations
- Availability of manure to replace carbon and nutrients removed with crop residue
- Need to use cover crops to provide ground cover and control erosion and runoff plus provide additional carbon to the soil system
- Availability of equipment to effectively harvest residue

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This publication has been peer reviewed.

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