Download Spreadsheet

To 2003 Excel (xls)

To 2007/2010 Excel (xlsx)

Nebraska University of Nebraska–Lincoln EXTENSION

Know how. Know now.

EC711

Baling Corn Residue

A Decision Support Tool to Evaluate the Economics

Simon J. van Donk, Extension Water Resources/Irrigation Specialist
Robert N. Klein, Extension Western Nebraska Crops Specialist
Bo Liu, Extension Cropping Systems Disease Management Specialist
Tim M. Shaver, Extension Nutrient Management Specialist
Aaron Stalker, Extension Beef Range Systems Specialist
Matt C. Stockton, Extension Agricultural Economist
Steve L. Young, Extension Weed Ecologist

Removing corn residue by baling is widely practiced in Nebraska. Propelled by high feed costs, ethanol co-products, and the potential for the bio-energy industry's use of corn residue, residue removal is expected to increase. The availability of ethanol co-products such as distillers grains has already increased demand for corn residue to serve as roughage in finishing diets for beef cattle.

Removing residue affects many processes and can lead to greater evaporation and runoff of water, and reduced soil aggregation (*Figure 1*). Removing residue also may increase erosion and weed pressure, and will remove nutrients from the field, resulting in increased fertilization cost. Conversely, removing residue may decrease disease pressure and, if abundant amounts of residue are present, make planting the next crop easier.

Considering all the relevant factors can make decisions about harvesting corn residue challenging. That's why a decision support tool (Microsoft Excel® spreadsheet) was developed to help producers estimate the costs and returns associated with removing corn residue. This user-friendly tool requires data that producers can easily obtain and provides information to help producers decide whether to bale corn residue. This publication includes a step-by-step guide to completing each worksheet to arrive at the costs and benefits of baling corn residue on your farm.

Sheet 1 — Inputs

This sheet specifies input factors used in more than one of the other sheets. These common input factors only need to be specified in this "Inputs" sheet. They will be used automatically in other relevant sheets. The common input factors are corn price in \$/bu, field size in acres, and residue removed by baling in tons/acre.

To estimate the amount of residue removed it may help to know how much residue has been produced. Residue production is related to grain yield. Approximately 1 ton of residue (at 10 percent moisture) is produced per 40 bu of corn (56 lb/bu at 15.5 percent). If corn grain yield is 200 bu/ac, then 5 tons/ac of residue is produced. If corn grain yield is 120 bu/ac, only 3 tons/ac of residue is produced.

Use blue-shaded cells to input information that pertains to your situation. Placing the cursor over a cell will show additional information. (This feature is not available for all cells.)

IANR

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

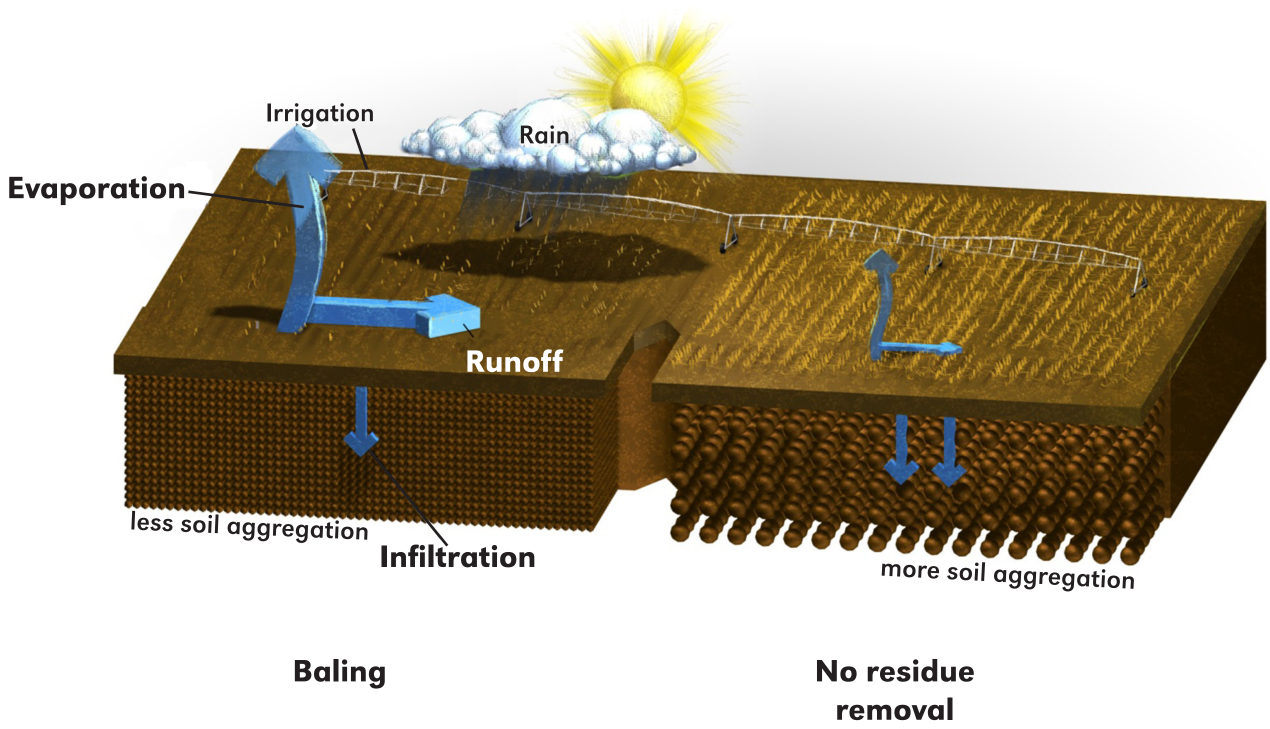

Figure 1. Depiction of two situations: harvesting (baling) of corn residue (left) and no residue removal (right). Some expected effects of residue removal are indicated in the figure, including greater evaporation and runoff of water and reduced soil aggregation.

Sheet 2 — Revenue from Harvesting (Baling) Corn Residue

When corn residue is harvested and sold, revenue will be generated. Suppose we remove 2 tons/ac of corn residue. If we can sell it at $70/ton, this represents a gross income of $140/ac or $18,200 for a 130-acre field. Enter the price, in $/ton, you expect to receive for selling the residue.

Sheet 3 — Cost of Harvesting (Baling) Corn Residue

Harvesting corn residue is not free. For example, if it costs $12 per big round bale for custom baling and we have six bales per acre, the cost is $72/ac and $9,360 per 130-acre field. Enter your own cost per bale and the number of bales per acre.

Sheet 4 — Nutrients

Crop residue is an important reservoir of essential macronutrient and micronutrient pools and recycles soil organic matter. Removing residue can reduce soil fertility levels. The rate of residue removal, rate of residue decomposition, residue quality, amount of fertilizer applied, soil characteristics, and climate all affect the amount of nutrients depleted from the soil when residue is removed. The estimated cost of replacing these essential nutrients is discussed in the NebGuide *Harvesting Crop Residues* (G1846). This NebGuide is also the source for the nutrient concentrations in corn residue used in the spreadsheet. These values can be edited. To account for this loss, enter current fertilizer prices for the source you would use, for example, anhydrous ammonia, urea, etc.

It is difficult to quantify the effects of corn residue removal on soil fertility as they can be highly variable and will depend on the interaction of many factors, including climate, soil type, and farm management practices. Additionally, the effects of residue removal can take several years to materialize and will most likely be site specific. The information presented in the spreadsheet contains the best, current, research-based estimates. However, it is difficult to quantify the economic impact on soil fertility from removing residue. Therefore, the best way to determine how residue removal is affecting soil fertility and crop nutrient needs is through a comprehensive soil testing program (*soiltest.unl.edu*). This is the case for all farm management programs including those with crop residue removal as a component.

Sheet 5 — Lime

Baling also removes cations such as calcium, magnesium, and potassium. These elements help neutralize soil acidity. This may or may not be an issue, depending on your location in Nebraska. Western Nebraska fields with calcareous soils most likely will not be affected by the amount of cations removed in the residue. Fields in eastern Nebraska may see an effect. A comprehensive soil testing program is the best way to determine if soil acidity is an issue and if lime is required. Typically, the cost for lime is expected to be much less than the cost to replace nutrients taken off the field with the residue. If liming is required, current application costs should be included in considerations.

Water Conservation

When corn residue is baled and removed from the field, less residue remains on the soil surface. This is expected to increase evaporation of soil water, potentially increase runoff, and decrease snow trapping in the winter. A four-year study under no-till conditions at North Platte showed that 2.5-5.0 inches per year more soil water was available when residue was left in place compared to when it was bare soil (residue cover of less than 5 percent). This means that for irrigated crops effective irrigation could be reduced by 2.5-5.0 inches. Alternatively, in a rainfed situation, not removing the residue would result in the same crop yield as a 2.5-5.0 inch increase in effective precipitation. The word "effective" refers to irrigation water or precipitation that would be stored in the crop root zone and be available to the crop. Not all irrigation and precipitation is effective. Some of it may run off or be lost to deep percolation. Therefore, more than 2.5-5.0 inches of actual irrigation or precipitation may be needed to compensate for residue removal. Other studies have shown similar amounts of water conservation.

Usually, baling corn residue leaves more than 5 percent residue cover, so water conservation may be less than the 2.5-5.0 inches per year measured in the North Platte study. Conversely, the North Platte study did not include the positive effects of reduced runoff, increased off-season evaporation, and increased snow trapping that can be expected when more residue is left on the soil surface. No runoff was observed on any of the flat field plots during the study and there were no differences in off-season evaporation and snow trapping between the residue and the bare-soil treatments because in each year of the study, residue was not removed from the bare-soil plots until April. Thus, in your field, water conservation could be even more than 2.5-5 inches per year.

The amount of water conservation resulting from residue depends on climate. The picture may be quite different for western versus eastern Nebraska due to the large differences in precipitation. There are several considerations:

- Water conservation will be more important in western Nebraska than in eastern Nebraska where precipitation is more abundant.
- With more residue on the soil surface, more water is expected to be stored in the soil profile due to reduced evaporation and increased infiltration of water into the soil. This extra water may be partially lost to deep percolation if the field capacity is exceeded, which will happen more often in wetter climates. This loss would reduce the water conservation benefits.
- Water conservation due to residue increases when there are more wetting events, either from precipitation or irrigation. Thus, the greater frequency of precipitation events in eastern Nebraska would result in more water conservation due to residue. This would apply to dryland agriculture, but for irrigated agriculture, there are typically more irrigation events in western Nebraska. Thus, the total number of wetting events (precipitation plus irrigation) may be very similar between east and west.

Overall, more water conservation due to residue can be expected in western Nebraska, especially in irrigated agriculture. For more information, see the NebGuide *Tillage and Crop Residue Affect Irrigation Requirements* (G2000). Corn yield responses to irrigation are illustrated conceptually in *Figure 2* for two fields — one where corn residue is baled and removed and one where it is not removed.

Sheet 6 — Irrigation Water Pumping

More irrigation water needs to be pumped when water is lost due to residue removal. This translates into an increased pumping cost. For example, using *Figure 2*, a corn field where the residue was baled may be fully irrigated with 16 inches of water while one with residue would need only 13 inches. The extra cost of pumping 3 inches of water on a 130-acre field would be $4,899 for a dynamic pumping lift of 200 feet and a diesel price of $3.50 per gallon (*Table 1*). In the spreadsheet, you can choose from five energy sources: diesel, electricity, gasoline, natural gas, and propane. Use the spreadsheet to enter your own numbers and calculate the extra pumping cost you may be incurring. Enter "0" in a rainfed (dryland) situation.

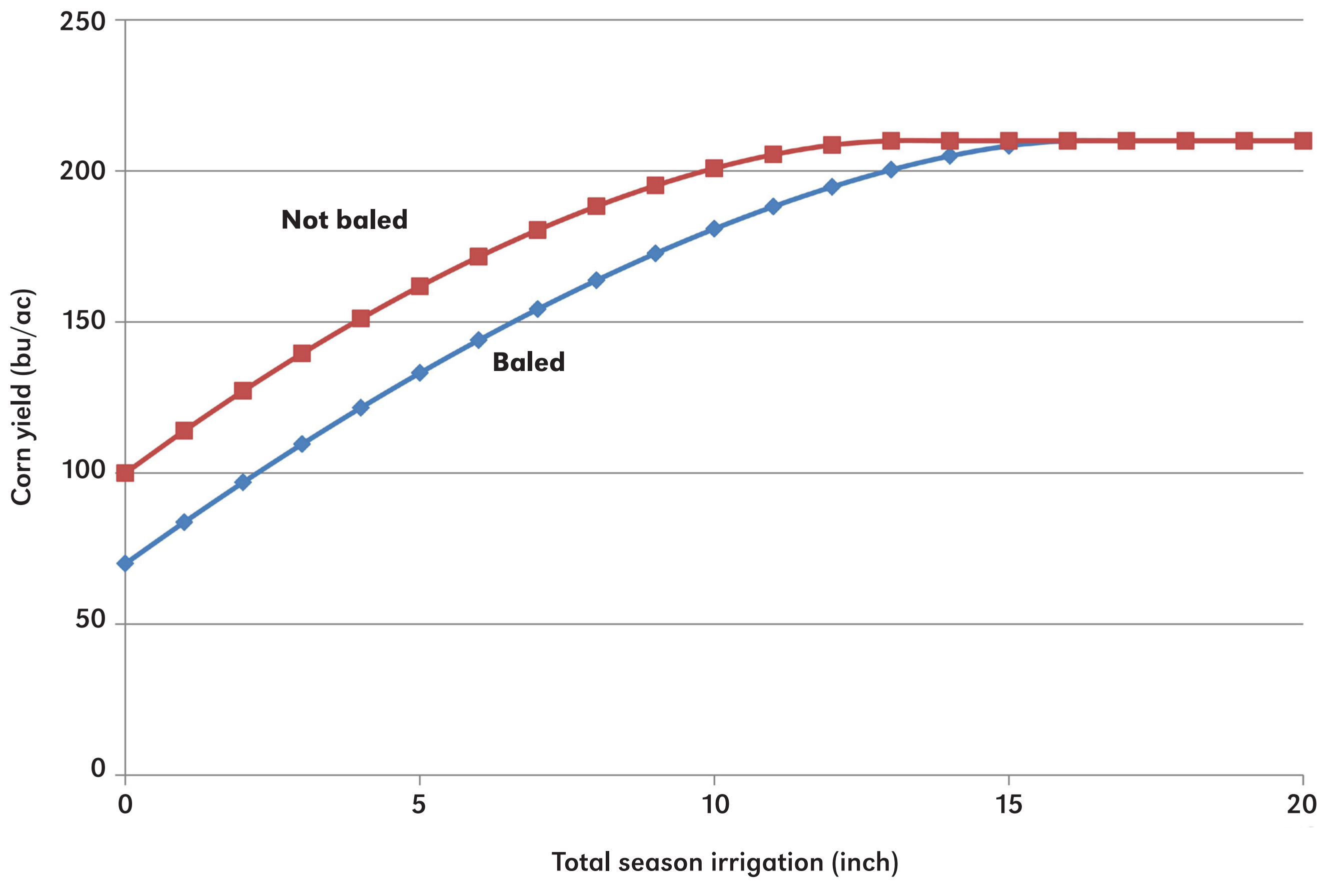

Figure 2. Conceptual illustration of corn grain yield response to total season irrigation for a field where corn residue is baled and removed and for a field where residue is not removed. Yield and irrigation values are for illustration purposes only.

Table 1. Cost to pump 3 inches of water on a 130-acre field for a dynamic pumping lift ranging between 0 and 400 feet and a diesel fuel cost ranging from $2.50 to $5.00 a gallon. The circled values are used in the example discussed in the text.

Lift (ft)	*$2.50*	*$3.00*	*$3.50*	*$4.00*	*$4.50*	*$5.00*
0	$1281	1538	1794	2050	2306	2563
50	1836	2203	2570	2937	3304	3672
100	2390	2868	3346	3824	4302	4781
150	2945	3534	4123	4712	5301	5890
200	3499	4199	4899	5599	6299	6999
250	4054	4865	5675	6486	7297	8108
300	4608	5530	6452	7373	8295	9217
350	5163	6195	7228	8260	9293	10326
400	5717	6861	8004	9148	10291	11435

Assumes a pumping plant with an average performance rating and a pump discharge pressure of 50 psi.

Sheet 7 — Deficit Irrigation

In a deficit-irrigation or rainfed situation, the cost associated with water losses due to residue harvest comes in the form of lower yields. This is because a crop on a field with less surface residue would experience more water stress when applying the same limited amount of water. The closer the amount of applied water is to full irrigation, the smaller the yield difference will be (*Figure 2*). Using the previous example, if we irrigate a season total of 7 inches of water, we would get 26 bu/ac less yield if we bale compared to if we leave the residue. For corn at $6/bu, this would be a value of $156/acre or $20,280 for a 130-acre field. In this example, if we irrigate 10 inches, yield on the baled field would be 20 bu/ac less than in the field with residue. This would account for $120/acre or $15,600 for a 130-acre field. If we irrigate 13 inches, we would get only 10 bu/ac less yield or $60/acre and $7,800 for a 130-acre field. As these examples indicate, the yield advantage due to maintaining residue cover diminishes as the level of deficit-irrigation approaches the level of full irrigation.

Sheet 8 — Weed Pressure

Weeds are important pests in agricultural production and can cause considerable crop losses. Yield losses due to weeds are well documented and emphasize the importance of understanding the impact of weed competition on crops and developing ecological and economical weed management practices. Corn is not a particularly high value crop, so there is economic incentive to combine grain production with baling of residue or cattle grazing, but it's also important to recognize that residue removal will affect weeds that emerge and compete with the crop.

A major goal of any weed control strategy is to manipulate the environment or agroecosystem to shift the competitive advantage to the crop. Retaining crop residue on the soil surface rather than removing it can have significant impacts on the emergence, growth, and type of weeds. In combination with herbicides and crop rotations, crop residue can help effectively control weeds in cropping systems. Alternatively, removing crop residue will allow more weeds to germinate, grow, and compete with the crop. Residue removal reduces cover and shading that prevents newly emerging weed seedlings from developing. In addition, cultivation operations will reduce soil moisture levels due to increased evaporation.

Weeds emerge in corn and many other crops when environmental conditions and seed dormancy cycles are met for germination. Soil temperature and moisture are two factors that influence germination of most weed seeds. Depending on soil moisture conditions, seed of some species will respond quickly to infrequent rainfall events and wide temperature fluctuations, while others require a combination of consistent moisture and temperature.

When residue is removed, there may be a greater need to control weeds with tillage or an herbicide application. If the cost of a pre-plant tillage operation is $14/ac, the cost for a 130-acre field would be $1,820 for one tillage operation and $3,640 for two operations. If the cost of herbicide is $39.30/ac and the cost associated with spraying is $5.50/ac, the cost for a 130-acre field would be $5,824. (These values were taken from the 2012 Nebraska Crop Budgets, UNL Extension EC 872.)

If a grower is using a limited herbicide program (for example, a single application or a single product), there may be a cost in the form of reduced crop yield caused by increased weed pressure from reduced residue. In addition, using tillage prior to planting will provide limited weed control and contribute to reduced stored soil moisture. If significantly higher rates of a single herbicide are used more frequently in the absence of residue, the potential for developing herbicide-resistant weeds will increase.

Finally, monitoring the growth and development of weeds is necessary for timely chemical weed control applications. Two important components govern how post-emergence herbicide application timing may affect control of an annual weed:

1) the average weed size and
2) the proportion of the weed population that is at the correct stage of development when the herbicide is applied.

Without following weed morphology and failing to rotate herbicides and cultural practices and crops, the risk for developing herbicide-resistant weeds increases dramatically.

Sheet 9 — Disease Pressure

Corn residue insulates soil from solar radiation and delays soil warming and drying in the spring, which creates a favorable environment for seed rot and seedling blight. Moreover, soilborne pathogens can survive better with more crop residue. If residue is not removed, there may be an increased need for seed treatments to ensure a healthy stand.

Foliar, stalk, and ear pathogens can survive over winter in corn residue. Foliar diseases include gray leaf spot, northern leaf blight, and anthracnose leaf blight. Common stalk rots include anthracnose stalk rot, Fusarium stalk rot, Gibberella stalk rot, Diplodia stalk rot, and charcoal rot. Common ear rots include Fusarium ear rot, Gibberella ear rot, and Diplodia ear rot. Goss's bacterial wilt and blight also survive in corn residue. Research has shown that the more corn residue present on the soil surface, the higher the risk of foliar diseases if a susceptible hybrid is planted.

On the other hand, corn residue increases soil organic carbon, fertility, and soil microbial diversity, and consequently increases the soil's ability to suppress soilborne pathogens, since beneficial microorganisms compete with soilborne pathogens for food. They also feed on pathogens and some can secrete a substance with antibiotic-like properties that harm pathogens. In most situations, however, residue removal is advantageous for preventing diseases.

When the weather is favorable for disease development, fungicides may be used. There may be less need for spraying fungicide if residue is removed. This could result in a cost savings due to not applying fungicide associated with harvesting residue. If the fungicide cost is $30/ac, the cost for a 130-acre field would be $3,900. Other application costs such as labor and fuel also would need to be considered.

There also may be an economic benefit of harvesting crop residue if the reduced disease pressure results in a crop yield increase. However, if you believe that in your particular situation disease pressure won't be affected by harvesting residue and if you are (not) applying fungicide either way, the bottom line of this "Diseases" worksheet should be $0.

Sheet 10 — Summary

The benefits and costs associated with retaining residue on the field need to be weighed against the benefits and costs associated with harvesting (baling) the residue. This "Summary" sheet summarizes all the other worksheets. It presents the bottom line in dollars per year for the given corn price, field size, etc. If the bottom line is positive, baling makes economic sense. If it is negative, baling does not make economic sense.

The summary sheet also contains a number of input cells concerning erosion, soil temperature, compaction, and other factors. Here, you have an opportunity to assign a dollar value for each of these factors for the given corn price, field size, and amount of residue removed.

Erosion

Erosion washes or blows the most fertile top soil off the field. In the long term, this will be a cost to the producer. Wind erosion also can damage young plants through "sand blasting." Additionally, there is an environmental cost of erosion: eroded soil (sediment) and agricultural chemicals can contaminate the environment, and wind erosion reduces air quality and visibility, affecting human health and causing traffic accidents.

Erosion is affected by factors such as soil type, slope, tillage practices, and crop rotation. It is well established that surface residue helps control erosion from wind or water. Residue cover breaks the impact of water droplets from rain or irrigation. Standing corn stalks reduce air velocity near the soil surface, reducing wind erosion. More residue can be removed from no-till fields than from tilled fields (since no-till keeps more residue on the soil surface) and more can be removed from irrigated fields than from dryland fields. For dryland agriculture in western Nebraska on tilled, highly erodible fields, residue should never be removed. For more information on erosion, see "Wind Erosion and its Control" (NebGuide G1537) and "Harvesting Crop Residues" (NebGuide G1846).

It is difficult to assign a dollar value to the adverse effects that removing residue can have on erosion. On your particular field erosion may not be an issue even when removing some residue. Use your experience as a guide. The local Natural Resources Conservation Service office (NRCS) may also be able to help. NRCS conservation plans require that a minimum amount of crop residue be present to control soil erosion on highly erodible land (HEL). Producers with such land should contact their local NRCS office to review their conservation plan and discuss the potential impact of harvesting crop residue on erosion before they remove any residue from the field.

If you are confident the level of residue removal you are considering will not affect erosion, you may enter $0 in the spreadsheet. However, if you think erosion will be affected by residue removal, you should assign a negative dollar value in the spreadsheet. Use your judgment. Never assign a positive dollar value for erosion when removing residue.

Soil Temperature and Wetness, Planting Challenges, Compaction

Retaining more residue on the soil surface may be an issue in the spring, especially in northeast Nebraska, because of colder soil temperatures and wetter soils.

Colder soil temperatures may delay crop emergence. Wetter soils can make it more challenging to carry out spring field operations. Abundant surface residue also may make planting more challenging and potentially result in poor plant stands and yield reductions.

Retaining residue can be a benefit, however, in the middle of a hot summer because it helps provide more moderate soil temperatures. Also, equipment used for harvesting corn residue may compact the soil, potentially reducing yields. All these considerations may interact with tillage practices, specific equipment, and other factors which may be unique to each operation. Use your judgment when placing a dollar value on these factors.

"What If?" and Best/Worst Case Analysis

Once we have considered the dollar value of all the factors potentially affected by harvesting residue, we can analyze some "What if?" scenarios.

- *What if the price of corn is $9/bu instead of $6/bu?* Make this change in the "Inputs" sheet and check the Summary to see how the results changed. Affected sheets are "Deficit Irrigation," "Weeds," and "Diseases."

- *What if we remove 3 tons/ac instead of 2 tons/ac?* When we make this change in the "Inputs" sheet, the "Revenue," "Nutrients," and "Lime" sheets are directly affected. Other sheets are affected indirectly. These sheets are "Cost," "Irrigation Water Pumping," "Deficit Irrigation," and "Diseases." They won't change with a change in tons/ac in the "Inputs" sheet, but rather, in these sheets the amount of residue harvested needs to be represented in a different way. For example, in the "Cost" sheet, the amount removed from the field is not entered in tons/ac but in bales per acre. If we remove more tons/ac then, of course, we will remove more bales/ac. Another example is the "Irrigation Water Pumping" sheet. Here, we enter inches of extra irrigation water needed when we remove a certain amount of residue. This number should be greater when we remove more residue.

We also can look at best and worst case scenarios to obtain more insight for a particular situation. Look at one scenario that favors harvesting residue and another one that does not. If the bottom line in the "Summary" sheet is positive for either scenario, you can be confident that baling makes economic sense. If it is negative for either scenario, you can be sure that harvesting residue does not make economic sense. If the outcome of one scenario is negative and the other is positive, your options may be less obvious. But if, for example, one is -$4,000 and the other +$19,000, it probably makes economic sense to harvest residue. It may be helpful to "fine-tune" your inputs and enter several scenarios to reduce the difference in outcome among scenarios. Of course, non-economic factors also should be considered before making the final decision as to whether to harvest corn residue.

Related Publications

- *Tillage and Crop Residue Affect Irrigation Requirements*, NebGuide G2000
- *Harvesting Crop Residues*, NebGuide G1846
- *Wind Erosion and its Control,* NebGuide G1537
- *2012 Nebraska Crop Budgets*, EC872
- *Harvesting Crop Residues, What's it Worth?* USDA NRCS Nebraska Fact Sheet 2008.

This publication has been peer reviewed.

UNL Extension publications are available online at *http://extension.unl.edu/publications*.