Kansas State University
Department of Agronomy MF-2604 Crop Residue

The Value of Crop Residue

Nearly every year, somewhere in the state, a field of crop stubble is lost to an accidental fire. When this happens, what is the effect on production in that field? How much damage has been done? Plant residue plays an important role in making crop production successful. To determine the value of crop residue, a breakdown of some individual benefits attributed to crop residue is necessary.

Soil Erosion

The most important function of plant residue is controlling soil erosion. Researchers around the world have shown that keeping the soil surface covered with residue or growing plants greatly reduces the severity of water erosion. Unprotected soils have had measured annual soil losses of more than 30 tons per acre. No-till soil systems and conservation reserve program (CRP) establishment often reduce annual soil losses to less than one ton per acre. Water erosion starts with the impact of the first raindrop. If raindrops can be intercepted by plant leaves or residues such as wheat straw or sorghum stalks, the kinetic energy of the rain is expelled there. This prevents that energy from reaching the soil surface and starting erosion.

Wind erosion, capable of moving many tons of unprotected soil great distances, can be just as severe as water erosion. In the case of wind erosion, flowing air rather than flowing water transports the soil. Researchers have shown that wind speeds of 13 mph are necessary to lift a particle of fine sand into the air. When this particle falls back to the surface, it collides with other exposed soil particles and kicks them up into the air. More particles are picked up by the wind, and this process repeats itself across the landscape. How do we prevent this kind of erosion? Separate particle detachment from collision and you stop wind erosion. Growing crops and attached residue can reduce wind speed near the soil surface. This reduces the energy level of the wind near the exposed sand grains. Residue places a barrier between those fine soil particles and the soil surface, which intercepts the collision process and stops wind erosion before it starts.

Less Soil Crusting

Another benefit of keeping the soil surface rich in residue is to prevent crusting. Damage occurs at the soil surface from the repeated impact of raindrops and by the disruption caused as air escapes from aggregates as they saturate. Researchers have shown that the rate and intensity of seal formation increases with increased kinetic energy of the raindrop. The seal becomes a crust as the surface dries out following the storm.

Crusts lower infiltration rates allowing runoff to occur sooner. Soil crusts can prevent seedling emergence, which reduces crop stands and could lead to replanting or lower yield potentials. In reduced tillage systems, organic matter content of the surface inch typically increases over a period of just a few years. This is especially true of soils that have previously been conventionally tilled. Soils higher in organic matter are physically and chemically more resistant to crusting.

In soils with low electrolyte levels, clays can disperse, dissolving aggregates and releasing very fine particles. These particles then move downward with infiltrating water and are quickly filtered out by the soil matrix, plugging soil pores. Drastic reductions in water infiltration rates have been measured under these conditions.

If clays disperse, adsorbed chemicals such as phosphorus can be released into runoff water. In soils with higher levels of organic matter as found with no-till cropping systems, electrolyte levels are typically maintained above that needed for clay dispersion to occur. Alternatively, amendments such as fertilizer or gypsum have been shown to keep electrolyte concentrations high enough as to prevent clay dispersion.

Water Infiltration

To understand water infiltration, think of soils as a complex of weathered rock, loosely glued together by decomposing plant residue (organic matter). A critical part of the soil is the space between all these physical parts. That is the pore space: the place where water and air reside. A soil's capacity to take in water is a function of this pore space and its connectivity. The hydraulic connection of soil pores to some depth controls the rate of water infiltration. Water is received at the surface, and to conduct it deeper into the soil requires that the surface pores remain open. Residue plays an important role in protecting these pores, as well as creating a surface roughness that slows horizontal movement. This allows time for water to move vertically into the soil.

A clay soil can have greater than 50 percent pore space, but pores in these soils are very small in diameter. These fine pores conduct water at low rates, usually much lower than the precipitation rate.

By its nature, a sandy soil will have a greater proportion of large pores. But if the surface becomes sealed because of a lack of physical protection, then even sandy soils can have low infiltration rates resulting in significant runoff. Higher infiltration rates are maintained in soils that have a greater amount of macropores (big pores) that remain connected to the soil surface. Macropores are created by earthworms and crop roots, like the brace roots of corn or sorghum, or tap roots of cotton and soybean. Soils that shrink and swell become cracked when dry, creating macropores that conduct large volumes of water during a storm. The majority of these pores are lost over time due to traffic, tillage, and planter and fertilizer operations. Residue plays a vital role in preserving some of these fragile conduits for water by providing physical protection at the soil surface. Maintaining just a few large pores can mean the difference between keeping precipitation on the field or allowing it to become runoff.

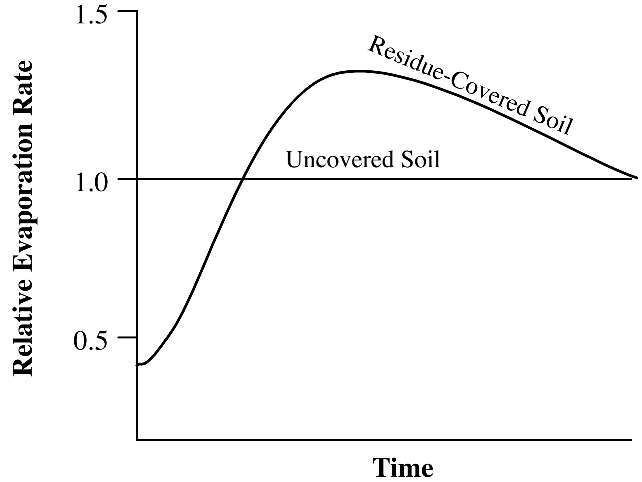
Less Evaporative Losses

Residue can be effective in reducing evaporation. Figure 1 shows the relative loss of water from a soil surface comparing a residue covered soil to an uncovered soil surface. In the early stages of evaporation, residue reduces evaporative loss by reducing albedo, reflecting energy back to the atmosphere. Consequently, soil temperature under the mulch is lower. This reduces the vapor pressure gradient between the surface and the atmosphere. Residues also provide resistance to vapor flow. After more drying, a dry layer forms in the uncovered soil. At this point, evaporation from residue-covered soils can exceed that of a bare soil. Eventually, a dry layer forms in the residue-covered soil, at which point evaporation rates of the two soils will not differ.

Precipitation in the Great Plains follows a summer rainfall pattern. Typically, 75 percent of the annual precipitation occurs during the spring and summer months, and only 25 percent during the fall and winter. Evaporation demand is much greater during the summer when precipitation is likely. Conditions rarely reach the middle of Figure 1, but return to the left-hand side with each subsequent rainfall. Under these environmental conditions, a system with high levels of residue is likely to have greater soil water savings than any tilled or residue-free management system.

Evaporation reduction varies with residue type. A given mass of wheat straw has been shown to be twice as effective as sorghum stubble in evaporation reduction, and four times as effective as cotton stalks. These differences are due to the specific densities of different residues, and subsequently the mulch thickness and total surface coverage that develops.

Figure 1. *Theoretical relationship of relative evaporation rates from the soil surface as affected by residue cover. Adapted from Jalota and Prihar, 1998.*



Residue that lays flat, providing continuous coverage across the soil surface, reduces evaporation much more than upright residue of the same mass. Residue lying in strips, like that found in strip-till or following planting operations with aggressive residue managers, is less effective in reducing evaporation compared to conditions of complete residue coverage.

Crop Residue Contains Nutrients

Residues contain significant amounts of nutrients. As residue decomposes, nutrients are released and recycled by the next crop. Table 1 provides some nutrient values for consideration. Fire can volatilize a significant amount of the nutrients found in this residue. Depending on the completeness of the burn and the temperature generated at the soil surface, most of the aboveground carbon and nitrogen will be lost. If the fire is hot enough to develop a white ash, then even 25 percent of the phosphorus in that residue may be lost. The remaining ash is subject to movement by wind and water until it is either incorporated by tillage or stabilized by a new crop. Research indicates that plant growth immediately following fire is enhanced due to the better availability of nutrients that

Table 1. *Percentage of Nutrients Derived from Crop Residue*

	P	K	S	Ca	Mg	N
Sorghum	0.13	1.20		0.52	0.28	0.83
Corn	0.10	1.45	0.17	0.57	0.40	1.06
Soybean	0.06	0.56	0.26	1.59	0.92	0.83
Wheat	0.05	1.42	0.19	0.32	0.12	0.63

United States-Canadian Tables of Feed Composition 3rd Revision, 1982

Table 2. *Relationship Between Grain Yield and Percentage of Cover Produced Following Harvest*

% cover	Winter Wheat	Oats	Soybean	Corn	Grain Sorghum	Sunflower
	bu/acre					lbs/acre
5	1	1	1	2	3	98
10	2	3	2	5	5	200
15	3	4	4	8	8	307
20	4	6	5	10	11	423
25	5	8	7	13	14	545
30	6	9	8	17	18	675
35	7	11	10	20	21	816
40	8	14	12	24	25	968
45	10	16	14	28	30	1,132
50	12	18	16	33	34	1,314
55	13	21	18	38	40	1,511
60	15	24	21	43	45	1,736
65	17	28	24	49	52	1,989
70	20	32	27	57	60	2,280
75	23	37	31	65	69	2,625
80	27	43	36	76	80	3,048
85	32	50	43	89	94	3,593
90	38	61	52	108	114	4, 361

Adapted from: USDA Field Office Technical Guide Notice KS-251, 2000

remain at the surface. But in the total balance of nutrients, fire always results in a net loss.

How Much Residue Do I Have?

Residue amounts are reported in different ways. Percentage of surface coverage is a common approach, and probably the most meaningful. Rainfall interception can be accomplished by one leaf, or one stem that covers a region of soil, so more protection isn't gained with multiple depths of stems over the same area. On the other hand, if evaporation reduction is the goal, then greater depths of mulch are preferred.

Percentage. This measurement estimates the amount of ground cover that exists. For example, imagine an aerial view of your field. Zoom into an area and divide that area into a 10 by 10 grid of cells. Evaluate each cell as to whether you are looking at soil or at plant material (either living or dead). The number of cells that are plant material divided by the total number of cells (100 in this example) would be an estimate of percent ground cover. In this case, it doesn't matter if the plant material is 6 inches deep, or one leaf thick. As long as the material is large enough to intercept a raindrop, then it qualifies as ground cover. A good field technique to estimate residue coverage is to stretch a 100-foot measuring tape across an area of the field. It's best to go at a slight angle to any planted rows. Evaluate soil conditions on one side of the tape at 1 foot intervals ignoring those areas between the 1 foot marks. For example, if looking at each 1 foot interval you came up with 38 marks that had plant material rather than soil, then you would estimate ground cover at 38 percent. Repeating this measurement in several locations in the field and averaging your results provides a good field estimate.

Yield. There is typically a good correlation between grain yield and the amount of residue produced by crops. This varies according to crop and weather extremes. Use Table 2 to estimate the percent cover for yields of various Kansas crops. For most row crops, the harvest index is 1, which means that for every pound of grain produced, a pound of residue, or stover, is produced. For example, 100 bushels of corn weighs approximately 5,600 pounds, so a grain yield of 100 bushels produces 5,600 pounds of residue. Wheat is a large residue producer with roughly 102 pounds of stover produced for every bushel (60 lbs) of grain. Regardless of crop, a management goal should be to leave a minimum of 1 ton/acre of crop residue following harvest.

Residue Half-life

Crop residues are fragile by their nature. By harvest time, a 40 bushel wheat crop will have produced more than 2 tons of stover. By sorghum planting time the following year, residue levels that began at 100 percent following harvest, are now lucky to be 70 or 80 percent. If any tillage has occurred, then residue levels can easily drop below 50 percent. This amounts to a decomposition of 1½ tons of the original residue mass over the course of only 9 months.

One tillage pass of a disk will typically reduce residue levels by 50 percent. A moldboard plow will bury nearly 90 percent of crop residue. Depending on residue type, the planter or drill can reduce coverage by 10 to 15 percent. Judicial use of tillage is necessary if you are trying to maintain higher levels of residue.

Legume residues, like soybean, breakdown much quicker than those of the grass crops. There are differences in residue strength among the grasses, as sorghum stalks are much more resilient than corn. Residues that remain standing will last longer than those that are flat on the soil surface because they are physically separated from the microbes that help break them down.

Federal conservation plans require that residue levels be maintained above a certain level following planting. Because a further reduction in percent coverage occurs at planting, a minimum level of 50 percent residue coverage should be a goal.

Managing Residue in a Cropping System

When do you have too much residue? In irrigated systems, continuous corn production could create residue levels too great to plant through without some kind of residue managers or tillage operation. In dryland cropping systems, it is difficult to build residue to unmanageable levels. One of the problems of high residue levels is the associated cold and wet soils of early spring. This is especially a problem when rotating to corn, with its early planting date. High residue levels can be reduced by tillage. But residue levels also can be controlled through good crop management decisions. The benefits of greater levels of residue far outweigh any benefits that can be credited to tillage.

Rotating crops is a good way to manage residue. A one- or two-year rotation of high residue producing crops can be followed by a low residue crop to help keep residue levels manageable. In eastern Kansas where cold, wet, soils occur nearly every spring, scheduling corn to follow soybean (a low residue crop) is a good way to improve the odds of being able to get in the field on time. If the previous crop was sorghum or wheat, and a high level of residue is in place, rotating to a crop that doesn't need as early of a planting date, such as soybean or sorghum is a good alternative. Being flexible in your planting decisions is important because long-term weather predictions are not very accurate. That way, if soil conditions are good early in April or late March, corn can be planted as long as good weather persists. On the other hand, if the spring has been wet and the soils stay too cold, switching to sorghum or soybean may be a better choice.

If residue levels are low, and you want to build residue, then planting wheat back-to-back (stacking the rotation) can be a good approach. The biggest risk to this management is increased disease pressure. If disease pressure hasn't been high in the first year, choosing a variety that has greater disease resistance for the stacked crop may provide adequate protection. The goal should be to build residue levels high enough so when you rotate back to a summer crop, a good bed of residue will be in place.

Summary

It's difficult to put a dollar amount on the value of residue. On one hand, protecting the soil is worth the value of your entire farming operation. Without it, you have nothing left to farm. On the other hand, if residue is lost to an accidental fire, soil protection can be regained by quickly planting a cover crop. In this case, the liability would be no more than the cost of seed and labor to plant, and arguably the cost of chemicals to terminate growth after adequate cover has been established. The most important thing to remember is that keeping the soil covered keeps the soil protected, and keeping the soil covered is the key to a sustainable system of farming.

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