Direct Seeding

Revised August 2008

Agdex 519-25

Estimating the Value of Crop Residues

Crop residues – straw plus chaff – are the by-products of harvesting annual grain crops. Retaining crop residues on a field improves or maintains soil quality and moisture. The economic value of retaining or removing crop residues from the field depends on the following:

- present level of soil organic matter
- field's soil erosion risk
- nutrient levels in the residues and soil
- soil's moisture content
- value of using the residues for other purposes such as bedding, coarse feed or industrial uses such as fibreboard
- effects of any problems caused by poorly spread or heavy residues (such as the need for extra field operations)

Thus, the value of straw and chaff differs greatly from area to area. Farmers sometimes struggle with the decision to sell straw to improve their short-term economic returns or to retain straw to sustain the soil's long-term productivity. This factsheet provides information to help farmers with this complex decision.

Organic Material in Crops

We often concentrate on straw's value and ignore crop organic materials produced below ground. This is partly due to the difficulty of studying or measuring roots. For example, researchers often determine root mass by washing the soil away from roots. This technique unfortunately misses the very fine root hair mass. Also, considerable root hairs, mucilage and exudates are sloughed from the root system during the growing season.

Researchers estimate that the root mass measured at harvest probably underestimates the total root organic material left in the soil by two to three times. Table 1 illustrates the distribution of the mass of a wheat plant at harvest.

Table 1. Distribution of the mass of wheat plant parts at harvest

Wheat plant part	Per cent by weight of total
Roots (not including growing season losses)	10 - 20
Leaves	5 - 10
Stems	30 - 40
Non-grain head parts	5 - 10
Grain	25 - 35

A common question is: How much straw and chaff are produced from a particular crop? Generally, as crop yields increase due to high moisture and fertility conditions, the amount of straw increases relative to the grain. Thus, there are different grain-to-straw ratios for the various soil zones, as shown in Table 2.

Table 2. Typical amounts of harvestable straw and chaff per bushel of grain

Crop	Soil zone	Pounds of straw per bushel of grain*	Pounds of chaff per bushel of grain**
HRS wheat	Brown	50	20 - 25
	Dark Brown	65	
	Black	80	
CPS wheat	Brown	40	20 - 25
	Dark Brown	50	
	Black	60	
Barley	Brown	30	5 - 10
	Dark Brown	35	
	Black	45	
Oats	Brown	30	5-10
	Dark Brown	35	
	Black	45	
Canola	Brown	40	15 - 20
	Dark Brown	50	
	Black	60	
Peas	Brown	40	20 - 25
	Dark Brown	50	
	Black	60	

* Amount of harvestable straw, assuming about 80 per cent recovery in cereals and 50 per cent in peas and canola, with 2- to 4-inch stubble left.

** Amount of harvestable chaff, assuming little or no weed chaff.

Erosion Control

Anyone considering straw removal should first evaluate the soil erosion risk. Wind and water erosion remove topsoil, resulting in long-term yield reductions that are difficult to alleviate. Bare soils are especially vulnerable to erosion. Plant cover – growing crops or residues – protects the soil.

Wind erosion typically removes fine particles and organic matter, leaving the soil less productive (see *An Introduction to Wind Erosion Control*, Agdex 572-2). Sandy soils and pulverized clay soils are most susceptible to wind erosion. Areas with higher average wind speeds are also more susceptible. Thus, the value of crop residues for wind erosion control is highest in windy areas with susceptible soils.

Crop residues reduce wind speeds at the soil surface, and standing stubble anchors the soil. Most soils are protected from wind erosion when more than 30 per cent of the soil surface is covered by growing plants or crop residues. With cereal crop residues, this amounts to about 800 to 1,000 lb/acre. Highly erodible sandy soils may need double this amount.

Water erosion can remove the top layer of soil, which is the most fertile part. Or it can cut rills and gullies, making those areas not only less productive but also in need of physical reclamation.

Water erosion occurs on sloped land during snowmelt and rainfall events (see *An Introduction to Water Erosion Control*, Agdex 572-3). Bare soils on steep slopes or long uninterrupted slopes are especially vulnerable to water erosion. Silty soils, soils low in organic matter and soils with an impermeable subsoil are also more susceptible.

Surface residues cushion the impact of raindrops, so soil particles are not as easily detached. They also slow the flow of water, allowing more infiltration and thereby reducing runoff and erosion. The minimum amount of crop residue needed to prevent water erosion depends on the soil, crop, tillage system and slope characteristics. Table 3 provides a rough guide.

Table 3. Amounts of crop residue needed for water erosion control

Field slope	Cereal residue needed to control water erosion (lb/acre)
gentle: 6 - 9%	700 - 1,000
moderate: 10 - 15%	1,000 - 1,500
steep: 16 - 30%	continuous grass
very steep: >30%	native vegetation

The amount of residue needed for water erosion control can be reduced if the stubble is anchored to the soil, as in zero tillage. Farmers with sloping land must consider the value of residue for water erosion control, but this value will vary with the level of risk.

Farmers with land at moderate to severe risk of erosion should highly value crop residues (probably several times the nutrient value) and thus should not remove straw. However, they could consider chaff removal because chaff does not provide as much erosion control and is a source of weed seeds.

Soil Organic Matter Maintenance

Organic matter is a critical component of soil and serves many purposes. Soil organic matter contributes to the soil's structural stability and resistance to erosion. It binds with nutrients and herbicides, so they are not easily leached from the soil. It has a high moisture-holding capacity and improves infiltration. It is also a storehouse of food for soil microbes and thus is involved with nutrient cycles and pesticide breakdown. It buffers against changes in acidity. And it stores carbon, thereby opposing the buildup of atmospheric carbon dioxide (a greenhouse gas) and global warming.

Plant matter (roots, root exudates, above-ground material) is the major source of organic (carbon based) material that builds soil organic matter. Soil microbes, animal bodies and their waste also contribute to soil organic matter by directly or indirectly processing plant material. The addition of plant materials or other organic substances is essential to build or maintain soil organic matter. However, the amounts needed vary according to soil texture, initial organic matter content, management system and climate (especially moisture and temperature).

If an agricultural soil is managed the same over time, the organic matter will not keep building or declining indefinitely. Eventually, annual losses of organic matter from decomposition and erosion will balance with the additions, and thereafter, the soil organic matter will remain relatively constant.

Changes in the soil environment, such as breaking up grassland, changing from conventional to zero tillage or increasing grain and straw yield due to higher inputs (fertilizer, manure, fungicides) will change the relative rates of addition and decomposition of organic matter. Thus, the soil will trend toward a new steady state with a different soil organic matter level. Within any overall trend, the soil will have slightly different dynamics every year due to changes in weather and crop residue types and amounts.

An often asked, important question is **"How much crop residue should be retained to have a sufficient level of soil organic matter?"** Unfortunately, there is no magical level of organic matter recommended for each soil type or zone. Soils with low organic matter can be productive but need more inputs and more careful management.

Probably the best target organic matter level is the average level found in productive virgin soil for that area. Virgin soil organic matter is 3 to 4 per cent for Brown soils, 4 to 5 per cent for Dark Brown, 6 to 10 per cent for Black and 4 to 5 per cent for Dark Gray. Gray Wooded soils have only 1 to 2 per cent organic matter in the virgin state, which is not adequate for good, sustained crop production. Therefore, farmers with Gray Wooded soils need a strategy to build organic matter to perhaps 4 per cent.

The addition of organic material is essential to maintain productive levels of soil organic matter. What is not clear is how much crop residues are needed or if occasional removal is sustainable. Annual addition of straw is not always a critical factor for maintaining sufficient soil organic matter levels.

Straw removal experiments have found inconsistent effects on soil organic matter levels (see *Straw Harvesting: Impact and Assessment, Final Report*, Alberta Agriculture). For example, regular harvesting of straw every crop year in a fallow-wheat-wheat rotation over 30 years on a Black soil at Indian Head, Saskatchewan, did not influence grain yields or soil carbon, but did reduce the stability of soil aggregates. In contrast, 11 years of straw removal on a Black soil in north central Alberta did decrease the soil organic matter. Two straw removal experiments on Gray Wooded soils have found small benefits due to straw retention, whereas N fertilization substantially increased the soil organic matter.

In many cases, adequate fertilizer or the use of zero tillage is as important as straw retention for building soil organic matter levels. Researchers are speculating that chaff, stubble, roots and exudates left from crops must play a significant role in maintaining soil organic matter. The removal of straw involves only the stem above the cutter bar height. This is only about half of the total plant non-grain organic matter.

Also, true differences in soil organic matter contents may be difficult to detect. For example, calculating organic matter on a volume basis can lead to erroneous conclusions when soil bulk density has changed between sampling times. Finally, there are differences in the quality of soil organic matter, which further confounds studies.

The above discussion indicates that the economic value of straw for soil organic matter is difficult to determine. Farmers with lower organic matter soils should place a higher value on straw additions than those with thick Black soils. Management also influences the value of straw for soil organic matter health. Zero tillage systems probably require less straw than conventional systems. Well fertilized fields produce more straw with higher nutrient contents than poorly fertilized fields.

A PFRA study concluded that significant amounts of cereal residues may be available from Black soils for industrial and other uses, provided that adequate fertilization, crop rotation and reduced tillage are practiced. This study considered only the erosion value of straw, not the value for soil organic matter purposes.

A wise strategy may be to allow straw removal once in a three- or four-year rotation on Black soils with a low risk of erosion, preferably after a crop that produces high amounts of residue such as HRS wheat. On other soils, the value of straw for organic matter maintenance or building would be significant (probably at least the value of nutrients), and thus, straw removal would not be as economical or recommended. For highly erodible rental land, landlords should specify retention of a crop residue cover in their lease agreements with tenants.

Nutrient Value

Most discussions about the economic value of crop residues focus on the equivalent fertilizer cost of the nutrients within. Although crop residues contain both macro- and micronutrients, only values for the macronutrients – nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) – are economically significant.

Nutrients in most crop residues are not immediately available for crop use, and their release (called *mineralization*) occurs over a period of years. The biological processes involved in soil nutrient cycles are complex. As a rough guide, about 10 to 15 per cent of the nutrients are released from cereal straw by the next year and about 35 per cent from pea residues.

The speed of mineralization depends on the N and lignin (fibre) content, soil moisture, temperature and degree of mixing with the soil. N is released fairly quickly from residues when the content is higher than 1.5 per cent N (such as in pea residues). In contrast, below 1.2 per cent N (such as cereal residue), soil available N is tied up (called *immobilization*) by the microbes as they decompose the residue.

Thus, pea residue would have short- and long-term benefits to soil fertility, whereas cereal straw would reduce next year's soil supply of available nutrients. Over time, the nutrients tied up in soil microbes and humus are released and available to crops.

Nutrients from residues are not fully recovered by crops. Just like fertilizer nutrients, nutrients released from crop residues into the soil are susceptible to losses such as leaching (N and S), denitrification (N), immobilization (N, P, K and S) and fixation (P and K).

The efficiency of nutrient uptake by crops from fertilizers or residue release is generally thought to be similar (for example, about 50 per cent recovery of N in the above-ground plant in the first year). There is some residual benefit of fertilizers – a small amount of the nutrients are taken up by crops two and three years later. Fertilizer placement can significantly affect the efficiency of crop uptake. The impact of residue placement (buried by tillage or left on the surface in zero tillage) on nutrient cycling and efficiency is under study.

Thus, the practice of calculating the fertilizer equivalent value of the nutrients in crop residue is a reasonable guide to estimating the partial value of crop residues. Tables 4 and 5 provide average nutrient values for the major crop residues.

Remember, there is a wide range in actual nutrient contents, and thus, samples should be analyzed for more accuracy. For example, well fertilized crops have much higher nutrient contents in the straw than poorly fertilized crops.

Table 4. Average nutrient contents in straw*

Crop straw	lb N/ton	lb P_2O_5/ton	lb K_2O/ton	lb S/ton	Total $/ton**
Wheat	12	3.7	30	2.8	29.22
Barley	15	4.1	41	2.8	37.25
Oats	14	4.1	43	3.4	37.25
Peas	24	4.6	30	5	42.62

* straw with 10 per cent moisture

** based on fertilizer prices of $0.99/lb N; $1.10/lb P_2O_5; $0.42/lb K_2O; and $0.24/lb S.

Table 5. Average nutrient contents in chaff*

Crop chaff	lb N/ton	lb P_2O_5/ton	lb K_2O/ton	lb S/ton	Total $/ton**
Wheat	18	4.6	24	3.6	33.82
Barley	20	6	36	3.6	42.38
Oats	20	4.6	36	4	40.94
Peas	34	10.6	24	5	56.60

* chaff with 10 per cent moisture and not excessive weed seed

** based on fertilizer prices of $0.99/lb N; $1.10/lb P_2O_5; $0.42/lb K_2O; and $0.24/lb S.

Soil Moisture Conservation

A crop residue cover plays a key role in moisture conservation for better crop yields especially in drier areas (see *Soil Quality and Moisture Conservation Benefits of Direct Seeding*, Agdex 570-6).

Surface residues trap snow and reduce evaporation. The residues also increase infiltration by slowing the flow of water over the soil surface and increase the soil's moisture-holding capacity by increasing the amount of soil organic matter. Farmers in drought-prone areas should always retain crop residues.

Detrimental Effects

In some situations, crop residues can have some undesirable effects. Estimating the net economic impact of these various effects is very difficult.

Heavy residues: One of the most common complaints about crop residues is that they physically interfere with seeding operations by plugging and hairpinning. However, openers on newer seeding units are better designed to seed through a fair amount of surface residue.

During wet years in the Black soil zone, excessive residues are produced that may interfere with even the best openers. The key to avoiding plugging and hairpinning problems is proper spreading at harvest (see *Equipment Issues in Crop Residue Management*, Agdex 519-4).

With conventional seeding systems, excessive residue can force extra tillage operations to allow seeding the next spring. This is an identifiable cost that could be subtracted from straw value in these cases.

Poorly spread residues: When residues are not adequately spread, several problems can occur:

- Heavy clumps of surface residue cause soil to remain colder later in the spring, causing differences in crop emergence.
- The chaff row often ties up nutrients, which causes yellowing, poor crop growth and lower yields. This occurs even with residue burial.
- The chaff row often contains volunteer grain and weed seeds, which can cause problems next year with weed control (dense weed stands have poorer herbicide efficiency) and disease carryover (through *green bridging*, where growing weeds act as temporary hosts for a disease organism, allowing it to be transmitted from one crop to the next).
- Certain types of crop residues can release chemicals that inhibit the germination and growth of crop seedlings (called *allelopathy*).
- Certain insects are favoured with the wetter soil surface found under residues (for example, the cabbage root maggot).

Carbon Sequestration

Because of a possible link between increased levels of atmospheric carbon dioxide (CO_2) and global warming, there is interest in finding ways to remove atmospheric CO_2 along with controlling emissions. When CO_2 is transferred from the atmosphere into another carbon-based substance, we call that *sequestration*.

Soil organic matter contains carbon, and thus increasing this soil component would counter, to some degree, the increase in atmospheric CO_2. Also, since crop residues decompose to mostly CO_2, reducing the amount or rate of decomposition would be beneficial.

Research has shown that soil organic matter and, thus, carbon can be increased by improving plant nutrition with fertilizers or legume rotations, reducing fallow and reducing tillage.

As discussed previously, straw retention is important but not the only strategy for increasing soil organic matter and thus carbon sequestration. In many cases, adequate fertilizer or zero tillage is as important as straw retention. Probably any management practice that leads to consistently higher yields will increase soil organic matter levels.

Soils that are relatively infertile have the greatest potential for increased organic matter and thus sequestration, but unfortunately, they need a high level of management. Alternatively, removing straw for an industrial use such as fibreboard would sequester carbon very well because the carbon would be protected from decomposition for many years.

Summary

Maintaining crop residues offers many benefits including reduced erosion risk, increased soil organic matter, plant nutrient recycling and improved soil moisture conservation. However, selling straw may be an option for some areas in some years.

Estimating the value of straw is complex. The past approach based primarily on nutrient content is too simplistic. In different areas and situations, crop residues can have vastly different values. For example, in erosion-prone areas, the value of straw for erosion protection is several times the fertilizer value of the straw's nutrients. Also, many topics, such as the allelopathic nature of residues, are not well understood. Thus, the net value of residues remains elusive.

Some of the key considerations in deciding whether to retain straw on a field are as follows:

- If the risk of wind or water erosion is moderate to severe, do not remove straw.
- On thick Black soils with a low risk of erosion, straw removal once in a three- or four-year rotation is an option, preferably after a crop that produces high amounts of residue. On other soils, straw removal would be less economical or not recommended.
- Chaff removal is an option in many areas because chaff does not have much erosion control benefit and is a source of weed seeds.
- For low organic matter soils, retaining crop residues is very important to maintain sufficient soil organic matter. For soils with high levels of organic matter, the annual addition of straw may not always be critical.
- Adequate fertilizer or use of zero tillage is often as important as straw retention for building soil organic matter levels.
- Crop residues are very important for soil moisture conservation. Do not remove straw in drought-prone areas.
- Crop residues contain economically significant amounts of macronutrients. However, the actual nutrient contents vary greatly. Test samples for an accurate assessment.
- When retaining a crop residue cover, spreading the residues uniformly across the field is **essential** to avoid or reduce such problems as equipment plugging, poor seed germination, nutrient tie-up and infestations of diseases, weeds or insects.

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