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Environmental Implications Of Biomass Removal

Development of initiatives to replace a portion of the energy resources with bio-based materials has increased excitement in terms of the potential for creation of new uses for agricultural crops. It is estimated that nearly one billion dry tons of cellulosic biomass would be available from agricultural lands. This biomass would be obtained from corn residues and energy crops. The current estimate for removable biomass from corn is approximately 75 million tons and accounts for nearly 60 percent of the potential biomass production required. The current trend in corn biomass production from corn has shown a steady increase since 1949 because of the continual increase in corn grain yield with only a slight change in the harvest index (yield relative to total biomass production, Figure 1). The environmental implications of biomass removal need to be considered before using crop residue for energy because of the long-term consequences on the soil resource and environmental quality.

> ***Removal of corn residue would lead to decreases in vitally needed soil organic matter and increases in soil erosion.***

The linear increase in biomass production also removes large amounts of nutrients per acre. It is estimated that in 2006 there were 136 lbs/A of nitrogen (N) removed in the grain and 115 lbs/A of N removed in the corn stover. The removal of nutrients in biomass for different nutrients shows there are larger potential amounts removed from the soil and left in the corn stover and wheat straw (Table 1). Removal of these nutrients from the field will have a potential impact on the soil resource because to replenish these nutrient levels will require applications of nutrients and, since many of these are relatively immobile, incorporation of the nutrients into the soil will be necessary. Soil disturbance for nutrient incorporation will require tillage during times in which the soil has a minimal soil residue cover and the potential for soil erosion may exist during times of intense rainfall. This aspect begins to demonstrate the potential environmental consequences of biomass removal.

Removal effects

On crop production. Studies have shown that removal of one pound of biomass has reduced subsequent grain production by 0.13 lb and stover production by 0.29 lb. One aspect of biomass removal could be to reverse the increasing trend shown in Figure 1 of annual increases because of the cumulative impact of bio mass removal on soil-plant interactions. Such reduction could be caused by changes in SOM, nutrient availability, soil water, and general soil condition. It has been shown that SOM is one of the primary factors affected by management of crop residues. Differences are dependent upon the initial organic matter content in the soil profile. Another parameter affected by residue removal is the impact on soil compaction. Change in management and harvesting methods could potentially increase the number of harvest trips across a field and could cause compaction. Research has shown that wheel-induced compaction could impact water runoff and soil erosion and concluded that more harvest trips, with the potential for more wheel-tracked areas, would increase potential for runoff.

On soil organic matter. Changes in SOM levels will be one of the first noticeable changes to occur within the soil. Soil organic matter provides a valuable asset to the soil in terms of soil structure, water-holding capacity, and energy source for microbial activity.

SUMMARY

There are potential soil and environmental problems associated with the removal of crop residue from croplands for the production of ethanol, as being urged upon agriculture by portions of the public and political world. Removal of corn residue leads to decreases in soil organic matter (SOM). Decreases in SOM reduce water-holding capacity and the ability of a plant to extract water during short-term water deficits. Placement of residue on the soil surface protects the surface from water and wind erosion and also moderates the extremes in soil temperature and moisture required for optimal microbial activity. Decline in SOM and extreme microclimate can lead to crusting, which limits water infiltration and gas exchange. Both have an impact on crop production and environmental quality.

Table 1. Amount of nutrients removed in the 2006 corn stover and wheat straw production season across the U.S.

Nutrient	Corn (lbs/A)	Wheat (lbs/A)
N	115.00	27.20
P_2O_5	40.00	6.80
K_2O	167.00	47.60
Ca	30.00	8.16
Mg	23.00	4.08
S	16.00	6.80
Cu	0.06	0.01
Mn	1.72	0.22
Zn	0.34	0.20

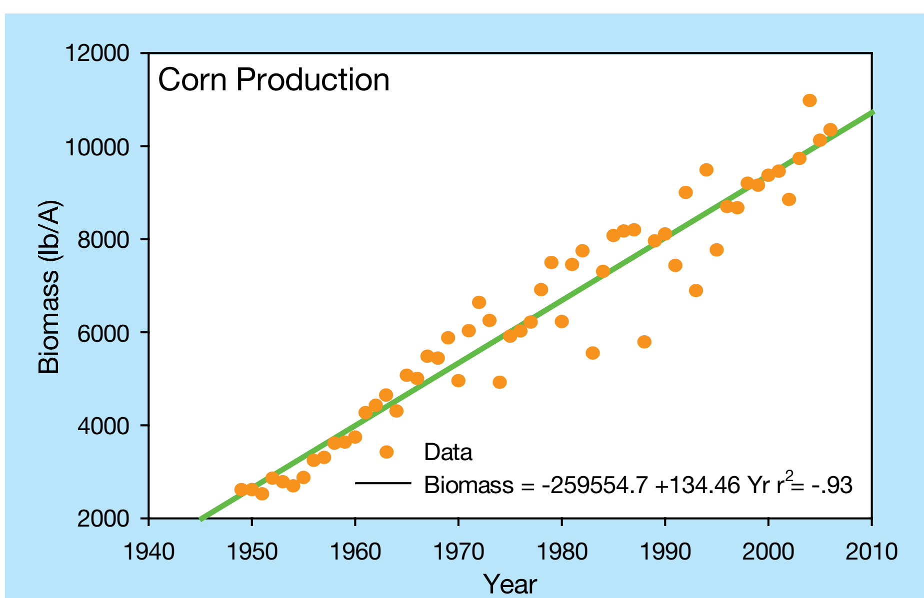

Figure 1. Annual increase in corn stover biomass production for U.S. corn production, 1949 through 2006.

Research has shown that tillage and rotation were more important than residue removal for changing carbon sequestration in the soil profile. Further studies have shown that SOM is derived from the root system more than the above-ground biomass. A consequence of reducing the SOM levels is to decrease the water-holding capacity of the soil. Water availability in different soils is directly affected by organic matter content and field capacity value of the soil increases rapidly as organic matter increases. The impact of modifying soil water availability cannot be dismissed in the current climate regime where rainfall events have and will become more variable. A number of studies have found that the amount of residue required to maintain SOM levels ranged from 900 to 15,000 lbs/A/yr.

These summaries reveal that there are complex interactions among residue production, residue removal, and the impact on subsequent crop production and SOM content. These changes have potentially large environmental impacts and the effects of residue removal need to be thoroughly understood before implementing residue removal programs.

On soil water and microclimate effects. Crop residue has a major impact on the surface energy balance. Energy balance of the soil surface determines the rate at which water is evaporated from the soil as well as the temperature extremes of the upper soil profile. The presence of crop residue acts as a barrier to the soil surface and solar radiation is absorbed at the upper boundary of the residue layer. Because the crop residue is typically a fairly porous material with a large amount of air space, the rate at which heat or water vapor is transferred through the residue layer is quite slow. Evidence of this is seen in how long it takes the soil surface to dry when there is a layer of residue on the soil. Crop residue provides a layer on the soil surface and reduces the soil water evaporation rate. Studies have shown that corn residue reduces daily water evaporation by 0.016 in/day compared to a bare soil surface. They also found that the properties of the residue change during the over-wintering period so that the residue acts more as a water-absorbing material in the spring because the waxy cuticle is no longer present. This changes the dynamics of the residue layer on the soil microclimate.

The presence of fresh crop residue has had more of an impact on soil temperatures in the fall than in the spring for several reasons. In the fall the residue has a different reflectance and absorbs less energy, while in the spring the residue has decayed and often has become denser because of the degradation process and also settling over the winter due to the presence of snow on the residue. Soil temperatures are affected in the upper four inches of the soil profile. The effect is to decrease the maximum temperature extremes in the layer by as much as 10 to 15° F and the minimum temperatures by 5 to 10° F. Moderation of the soil temperature extremes and the increased soil water content in this layer promotes a more active soil microbial and megafauna system (earthworms, etc.). This increase in biological activity helps to incorporate the residue material into the soil layer and maintain the SOM content. There is a linkage between the decline of microbial activity, SOM, and the decrease in crop productivity.

One of the aspects of crop production is water use by the crop and the concept of water-use efficiency (WUE) that relates yield or total biomass production

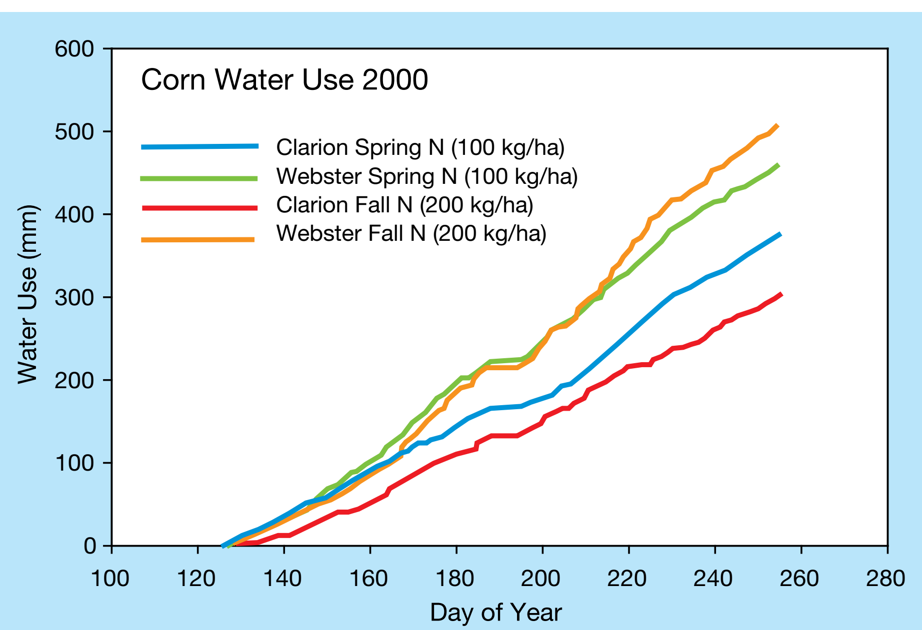

Figure 2. Seasonal water patterns for corn grown on a Clarion and Webster soil in central Iowa during 2000 using fall and spring-applied N management practices.

to the amount of water used by the plant, offering a concept to characterize field variation in yield. Studies have described how soil management practices have affected WUE. Large variations have appeared in seasonal water use rates across production fields, varying almost 200 mm (8 inches) between a Webster soil having 4 to 5 percent organic matter and a Clarion soil having 1 to 2 percent SOM (Figure 2).

The differences in Figure 2 are typical of what we have seen in fields and there is a relationship between water availability and crop water use rates. The seasonal differences in crop water use are related to the carbon dioxide (CO_2) uptake rates across fields. In a comparison of water use (evapotranspiration) and CO_2 uptake there was a large difference among the six fields of corn and five fields of soybean that were studied throughout the growing season. These differences in water use and CO_2 uptake translate into crop production and yield differences. We typically observed yield variations between the Clarion and Webster soils of 50 to 75 bu/A. The differences in total biomass production are less because the major differences in water use occur during the grain-filling period rather than during vegetative growth (Figure 2). Continual removal of biomass from the field and reduction in SOM will exaggerate these differences within and among fields.

Implications

Removal of biomass for energy production should be planned and managed to protect and enhance the soil resource. Management for efficient production of both grain and biomass from our grain and grass crops needs to be carefully considered relative to the soil resource and climatic conditions. Integrating all of these components will produce a system that avoids potentially negative consequences and increases our production capacity for grains and biomass into the future.

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