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Crop Residue Management Challenges: A Special Issue Overview

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ABSTRACT

The amount of crop residues that can be sustainability removed is highly variable and is a function of many factors including the soil, climatic, and plant characteristics. For example, leaving an insufficient amount of crop residue on the soil surface can be detrimental for soil quality, result in loss of soil organic matter (SOM), and increase soil erosion, whereas leaving excessive amounts can impair soil-seed contact, immobilize N, and/or keep soils cool and wet. This special issue evolved as an outcome of, "Crop Residues for Advanced Biofuels: Effects on Soil Carbon" workshop held in Sacramento, CA, in 2017. The goal of the special issue is to provide a forum for identifying knowledge gaps associated with crop residue management and to expand the discussion from a regional Midwestern U.S. to a global perspective. Several crop residue experiments as well as simulation modeling studies are included to examine effects of tillage, crop rotation, livestock grazing, and cover crops on greenhouse gas (GHG) emissions, crop yield, and soil or plant health. The special issue is divided into 4 sections that include (i) Estimating Crop Residue Removal and Modeling; (ii) Cultural Practice Impact on Soil Health; (iii) Residue Removal Impact on Soil and Plant Health; and (iv) Cultural Practice Impact on Carbon Storage and Greenhouse Gas Emissions.

Core Ideas

- Farmers struggle to maintain and balance economic and environmental sustainability.
- Identification of knowledge gaps related to crop residue management.
- Discussion of crop residue manage expanded from the U.S. Midwest to a global perspective.
- Use of carbon flux tower data to validate simulation models.
- Crop residue harvesting impacts soil health, productivity, and greenhouse gas emissions.

Worldwide, crop residue management is a challenge as farmers strive to maintain economic viability, provide food, feed and fiber for their families, and meet long-term production requirements in a changing environment. One strategy for increasing revenue and production per unit of land is to harvest and use crop residues for animal feed or as feedstock for biofuel production (Maw et al., 2019). However, crop residues are also needed to reduce wind and water erosion, and to recycle essential plant nutrients for future crops and provide inputs to sustain soil organic matter. The positive and negative impacts of harvesting crop residues were discussed at an ASA–CSSA–SSSA sponsored workshop on "Crop Residues for Advanced Biofuels". Workshop participants included scientists, corn producers, ethanol producers, and ethanol industry regulators. A summary of the workshop by Karlen et al. (2019) identifies several consensus points including that:

(i) Multiple strategies are needed to produce the required goods and services from our agricultural lands,
(ii) Soil erosion is a critical natural resource problem,
(iii) Tillage and crop residue management are closely coupled, and
(iv) Simulation models are important tools for guiding crop residue management, but to improve model predictions, coordinated effort and multi-location, long-term data sets are needed.

The remainder of this special issue expands those initial workshop discussions, which intentionally focused on the U.S. Corn Belt, to encompass crop residue experiments from around the world. Therefore, paper contributions have been grouped into four general categories focusing on (i) estimating current amount of residue removed, (ii) assessing residue removal impacts on soil and plant health, (iii) identifying cultural practices to improve soil health, and (iv) quantifying cultural practice impacts on GHG emissions.

This introduction provides a short over view of the significant findings associated with each paper contribution. This special issue also builds on Qin et al. (2018), where the CENTURY model was used to assess the impact of harvesting corn (*Zea mays*) leaves and stalk (stover) on greenhouse gas emissions. The

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Abbreviations: GHG, greenhouse gas; SOC, soil organic carbon; SOM, soil organic matter.

special issue also addresses one of the recommendations given by Qin et al. (2018): the need for long-term data sets to validate soil organic carbon (SOC) simulation models. Selected highlights for each section are below.

ESTIMATING CROP RESIDUE REMOVAL AND MODELING

There are many reasons for harvesting crop residues, but little information is available on the percentage of fields from which crop residues are harvested. In the United States, Obrycki and Karlen (2018) used data from the 2010 Agricultural Resource Management Survey of U.S. Corn Growers to estimate stover harvesting rates. This assessment indicates that in the U.S., most of the crop residues were not harvested in 2010. Since 2010, several factors including provision of biofuel and bio-product feedstock as well as that collected for livestock feed and bedding have increased the amount of harvested crop residue. Higher crop yields, especially for corn, have also encouraged residue harvest in lieu of increased tillage intensity to incorporate and hasten decomposition of the plant material.

To estimate the potential ramification of residue harvesting, we need to understand the impacts on the soil system. This is essential because crop yield and residue production are highly variable and site specific. Simulation models can predict crop yield and residue production, but they must be validated using locally derived data. One potential source of validation information is carbon flux tower data. Zhan et al. (2019) used such data to validate their model and concluded for Nebraska (i) residue removal can result in increased CO_2 emissions, (ii) models can be used to develop carbon budgets, and (iii) the harvesting of crop residues can reduce SOC.

RESIDUE REMOVAL IMPACT ON SOIL AND PLANT HEALTH

Removing crop residues affects water and nutrient cycling, which if not accounted for, can have unexpected consequences on other crop production factors. For example, Johnson (2019) discussed how solutions to one problem can result in a cascade of unexpected impacts. One of the primary effects of excessive crop residue harvest is increased erosion, but it can also result in soil surface crusting, reduced water infiltration and increased water stress. Collectively, these impacts can also reduce nutrient efficiency and increase pest problems (Hansen et al., 2013).

Impacts of residue harvest can also impact crop growth, yield, and quality. In China, Gao et al. (2018) investigated the impact of different residue management systems on plant roots. They showed that when crop residues were pulverized and returned to the field, corn root dry weights and summer yields were 18.5 and 15.1% higher, respectively than when the residues were removed. They recommended that a moderate amount of crop residue returned to the field optimized corn growth. In a Brazilian study, Satiro et al. (2019) evaluated and developed a model that predicts the impact of straw removal on sugarcane yield. They reported that over the short term, straw removal reduced soil C in the surface 5 cm but did not reduce yield. Similarly, Ulmer et al. (2019) reported that residue removal did not affect subsequent corn, soybean (*Glycine max*), or dry bean (*Phaseolus vulgaris* L.) yields. Research conducted in China, suggests that food quality may also be impacted by residue management. Li et al. (2019) reported that returning crop residue (i) increased wheat (*Triticum aestivum*) production per plant and total starch and decreased amylose content; (ii) accelerated endosperm cell development; (iii) changed the size of the starch granules; and (iv) increased the ratio of amorphous to ordered carbohydrates. Shuo (2018) reported that residue removal reduced corn and wheat yields in China. In a microcosm study, Wang et al. (2018) determined that the release of luteolin, from peanut (*Arachis huypogaea* L.) residue reduced peanut nodulation, soil dehydrogenase activity, and microbial biomass.

To provide a holistic assessment of surface residue management on long-term sustainability, techniques for combining information from different tests are needed. Karlen and Obrycki (2019) provided on-farm soil health reference values. These values can be used as references values for similar studies. One approach to improve soil health might include increasing rotational diversity. On many farms, this may involve rotating perennial plants with annual crops and then marketing the biomass in an appropriate market. Roozeboom et al. (2019) conducted an experiment in Kansas that compared biomass production and ethanol yield from annual and perennial plants. Their findings indicated that annual corn and sorghum (*Sorghum bicolor*) crops, as well as perennial grasses such as miscanthus (*Miscanthus × giganteus*) and switchgrass (*Panicum virgatum*), could be potential bioenergy feedstocks in diversified production systems. Molas et al. (2019) report on investigations on whether an alternative crop, Virginia fanpetals (*Sida hermaphrodita* L. Rusby) can be used to produce biofuels. Green manure or cover crops might provide a replacement source of biomass when the crop residues are harvested. Marshall and Lynch (2018) investigated the impact of different green manure termination strategies on SOC. They reported that overall, SOC was higher under no-till green manure than with spring or fall tillage. In South Dakota, Chalise et al. (2019) investigated the impact of cover crops [winter rye,(*Secale cereale* L.) and hairy vetch (*Vicia villosa* L.)] and crop residue removal on SOC, bulk density, water retention and infiltration, and soybean yield. They showed that returning the crop residue reduced the soil bulk density and increased SOC. They concluded that cover crops, when combined with returning the crop residues, improved soil properties, conserved soil moisture, and increased crop yield.

When animal and crop production enterprises are still integrated, producers may have a choice between grazing or baling crop residues. In research conducted on six farms, Rakkar et al. (2019) showed that residue baling reduced surface soil cover by 57%, whereas grazing reduced it by only 17%. Baling also reduced soil water, presumably due to greater evaporation, and increased the risk of erosion because of less surface cover.

CULTURAL PRACTICE IMPACT ON CARBON STORAGE AND GREENHOUSE GAS EMISSIONS

Crop residue harvest and changes in crop diversity also have the potential to impact GHG emissions (Johnson and Barbour, 2018), but to accurately quantify the impact appropriate sampling protocols for measuring GHG emissions must be used. For example, McGowan et al. (2019a) reported that peak N_2O emissions in Kansas occurred following large, short duration rainfall events and that between 30 and 50% of the total annual

N_2O emissions were emitted in September. In a related study, McGowan et al. (2019b) compared the impact of perennial and annual crops on changes in soil organic carbon (SOC). This work showed that changes in SOC were limited to the surface soil and that increases in SOC were correlated to root biomass, abundance of arbuscular mycorrhizae and saprophytic fungi, and soil aggregate diameter. Cates and Jackson (2019) reported no effect of cover crops on the net ecosystem carbon balance. Additionally, they concluded that while cover crops may provide multiple benefits to farmers and society, their capacity to directly increase SOC is low when corn is grown for grain or silage.

SUMMARY AND CONCLUSIONS

In summary, our overall goals for the special issue were to provide a forum to identify gaps in crop residue management knowledge and expand the discussion of crop residue management strategies from the Midwestern U.S. to other locations around the world. The presented papers address critical issues ranging from model validation to how crop residue management affects food, crop, and soil health. Future issues of the *Agronomy Journal* will continue to include contributions that expand on these critical discussions.

Overall, based on this collection of research results, we conclude that the consequences of harvesting crop residues for any use must be clearly defined and practices implemented using site-specific technologies so that productivity and agronomic resources are not impaired for future generations.

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