09K1 09-10 ONTARIO FIELD CROP RESIDUE SURVEY OF AVAILABILITY AND PROPERTIES AS POTENTIAL FEEDSTOCK'S FOR THE BIOECONOMY

Part 2 of 4

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PLAIN LANGUAGE SUMMARY

Agricultural residues from annual crops such as wheat (*Triticum aestivum*) straw, soybean (*Glycine max*) straw and corn (*Zea mays*) are being considered as potential feedstock's for a range of uses including bioenergy, biochemicals, and bioproducts (Duguid, 2010; Kludze et al., 2010). Interest in using biomass for these purposes has dramatically increased in recent years.

A recent study has determined that wheat (*Triticum aestivum*) straw, soybean (*Glycine max*) straw and corn (*Zea mays*) residue removal from existing corn-soybean and corn-soybean-wheat rotations in Ontario could sustainably provide 1,919,802 tons of dry matter per year (Kludze et al., 2010), without negatively impacting soil organic matter levels. This is a much smaller volume than previously estimated or actually available across Ontario under present acreages and yields.

Two issues need to be considered with respect to nutrient removal in crop residues. The first issue relates to the economic implications of nutrient removal (i.e. nutrient removed per unit area) . High nutrient removal rates increases input costs, as synthetic fertilizers must be purchased to replace nutrients removed in the plant material. Nutrient costs are increasing over time. Fertilizer costs increased 23 percent between May of 2010 and 2011 (McEwan, 2011b), and increased another 4 percent between June 8 and October 5, 2011 (McEwan, 2011a). Thus, nutrient removal rate should be kept as low as possible. The second issue relates to biomass quality. Nutrient concentration (i.e. nutrient content per unit of biomass), depending on the end-use of the biomass, may negatively or positively impact feedstock quality considerations. For example, high potassium content is undesirable if the biomass is to be used for combustion, since potassium can contribute to corrosion and slagging during burning.

Nutrient removal and concentration in crop residue may be influenced by management, weather and soil type. The nature and causes of crop residue nutrient removal and concentration have not been documented for Ontario. Understanding and quantifying this variability and its causes, as well as understanding the proposed methods of altering residue nutrient removal and concentrations is required to better meet the demands of an emerging biomass industry. Such data would assist the emerging industry in minimizing both economic costs of removal for producers and also potential costs to end-users.

OBJECTIVES

The primary objective of this study was to characterize the variability and causal factors of nutrient concentrations and removal levels in winter wheat, soybean and corn residues within the province of Ontario, Canada. The study evaluated within and across site variation of nutrient concentrations as well as the relationship between residue nutrient concentrations and soil test

values. It also aimed to quantify total nutrient removal rates as affected by cutting height and the plant component harvested.

The following hypothesis related to corn, soybean and winter wheat residue were tested in the study.

1. Across site variation of N, P and K concentration and removal is greater than within site variation
2. N, P and K concentrations and removal differ across years
3. N, P and K concentrations decrease and removal rates increase as crop yield increases
4. Lowering cutting height of corn and wheat decreases concentration and increases removal of N, P and K in the crop residue
5. N, P and K concentration and removal varies with corn component harvested
6. Soil P and K concentrations are positively correlated with P and K concentrations and removal, and N, P and K concentration and removal are correlated with soil texture, OM and pH.
7. Leaching reduces concentration and removal of N, P and K; Leaching effects on N, P and K reductions in concentration and removal are not equal across plant component; Leaching reduces variability in concentration and removal of N, P and K.

MATERIALS AND METHODS

Crop residue samples were taken from commercial winter wheat, soybean and corn sites from twenty counties across southern Ontario in 2009 and 2010. The twenty sites are typical winter wheat-, soybean- and corn-producing regions, and were selected to best represent the

geographical, environmental, topographical and climactic diversity that exists within the province. Selected sites represent a range of environments and a variety of soil types ranging from clay to silt-loam. Soybean was harvested from ground level. Wheat was either harvested from ground level or from 15cm above ground level. Corn was either harvested from ground level or from 15cm and separated into cobs, leaves and stalks. The sample was analyzed immediately for grain yield and harvest index. The resulting residue sample was split, with half analyzed immediately for N, P and K concentration, and the other half subjected to a weathering/leaching period prior to analysis for N, P, K concentration. See Kendall thesis for materials and methods details.

RESULTS

Wheat, soybean and corn residue nutrient concentrations and removal rates were characterized for a range of regions and soil types in Ontario. N and K concentrations measured at harvest and reported in the present study are somewhat lower than previously reported.

Hypothesis #1 - Across site variation of N, P and K concentration and removal is greater than within site variation

For all three crops, as well as plant component within corn, across-site nutrient concentration variability accounted for 44.50 percent of total nutrient (N, P and K) concentration variability, while within-site nutrient concentration variability only accounted for 9.41 percent. Average across-site nutrient removal variability accounted for 42.53 percent of total nutrient removal variability, whereas within-site nutrient removal variability only accounted for 17.18 percent.

Hypothesis #2 –N, P and K concentrations and removal differ across years.

Across all crops and crop components, year significantly affected nutrient concentration in 60 percent of cases, and plant nutrient concentration, and nutrient removal in 46.67 percent of cases. See above tables for year effects on soybean and wheat N, P and K concentrations and removal. Year effects on corn followed a similar pattern.

Ontario soybean and wheat residues - N, P, and K concentrations and removals

Crop		Year	Range	Mean
Soybean	Nitrogen concentration (%)	2009	0.57 - 1.29	0.85
		2010	0.66 - 2.17	1.25
	Nitrogen removal (kg ha^{-1})	2009	15.27 - 37.6	23.31
		2010	3.4 - 34.28	16.63
	Potassium concentration (%)	2009	0.28 - 1.52	0.97
		2010	0.53 - 2.12	1.28
	Potassium removal (kg ha^{-1})	2009	10 - 44.24	23.87
		2010	5.24 - 36.89	16.45
	Phosphorus concentration (%)	2009	0.03 - 0.13	0.07
		2010	0.03 - 0.2	0.12
	Phosphorus removal (kg ha^{-1})	2009	0.69 - 3.69	1.78
		2010	0.28 - 3.74	1.57
Wheat	Nitrogen concentration (%)	2009	0.49 - 0.7	0.59
		2010	0.53 - 0.97	0.66
	Nitrogen removal (kg ha^{-1})	2009	12.2 - 30.34	18.05
		2010	8.69 - 28.83	15.53
	Potassium concentration (%)	2009	0.51 - 1.56	0.87
		2010	0.33 - 1.49	0.75
	Potassium removal (kg ha^{-1})	2009	7.96 - 43.76	26.72
		2010	8.7 - 37.05	17.17
	Phosphorus concentration (%)	2009	0.04 - 0.12	0.07
		2010	0.05 - 0.15	0.08
	Phosphorus removal (kg ha^{-1})	2009	1.01 - 2.94	2.06
		2010	0.88 - 4.46	1.81

Ontario corn residues - N, P, and K concentrations and removals

Nutrient	Component	Removal (kg ha^{-1})		Concentration %
		Range	Mean	Mean
Nitrogen	Cob		2.86	0.35
	Leaf		11.06	1.01
	Stalk		14.41	0.62
	Total	12.37 - 42.68	28.33	
Potassium	Cob		5.1	0.605
	Leaf		3.46	0.33
	Stalk		26.63	1.13
	Total	8.61 - 60.75	35.19	
Phosphorus	Cob		0.38	0.05
	Leaf		0.96	0.09
	Stalk		1.11	0.04
	Total	0.85 - 7.96	2.44	

Hypothesis #3 - N, P and K concentrations decrease and removal rates increase as crop yield increases

Crop yield was not a good predictor of N, P or K concentration. Only 20 percent of crop yield correlations with N, P and K concentrations were significant with some of the correlations being positive and some negative. In contrast, crop yield was a good predictor of N, P and K removal. N, P and K removal was significantly correlated with crop yield 93.3 percent of the time with correlations consistently positive.

Hypothesis #4 - Lowering cutting height of corn and wheat decreases concentration and increases removal of N, P and K

Lowering the cutting height from 15cm to ground level will significantly affect N, P, K concentration and removal of corn and wheat. Corn stalks and wheat straw nutrient concentrations and removal rates were consistently lower in the bottom 15cm segment than the upper segment. The only exception was for wheat straw, which had greater K concentration in the bottom 15 cm.

Hypothesis #5 - N, P and K concentration and removal varies with corn component harvested

Corn stalks, cobs and leaves had significantly different N, P and K concentrations and removal rates (see table above). This indicates that harvest method (eg. cob vs stover, or direct bale vs cutting/raking/baling) could significantly impact removal and concentration values.

Hypothesis #6 - Soil P and K concentrations are positively correlated with P and K concentrations and removal, and N, P and K concentration and removal are correlated with soil texture, OM and pH.

No consistent trends were observed to suggest that soil parameters are a good indicator of either nutrient concentration or nutrient removal in above ground crop residue. Further analysis of the data set, perhaps using a multivariate analysis approach, may be required to improve conclusions

Hypothesis #7 - Leaching reduces concentration and removal of N, P and K; Leaching effects on N, P and K reductions in concentration and removal are not equal across plant component; Leaching reduces variability in concentration and removal of N, P and K.

Leaching treatments (delayed fall collection for wheat crop residue, spring crop residue collection for soybean and corn) consistently reduced K concentration and removal for all crops and crop components. The effect of leaching treatment on N and P were less consistent. The leaching treatment also resulted in a loss of biomass. Wheat straw yield decreased by12 percent in 2009, and 29 percent in 2010. In 2009 wheat, soybean, corn leaf and corn stalk lost 11, 5 and

3 percent of their mass. In 2010 corn stalk, soybean, corn leaf and corn cob samples lost 20, 18, 6 and 5 percent of their mass. The leaching treatment did not reduce N, P, K concentration and removal variation in wheat, corn cob or corn leaf residues, but did decrease variation of soybean K concentration and removal, corn stalk N, P and K concentration and removal