Integrating Cover Crops Into Annual Cropping Systems To Increase Total Biofuel Production And Environmental Sustainability

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Abstract

Integrating cover crops into existing annual crop systems is a plausible way to increase available cellulosic bioethanol feedstocks; improve the environmental performance of annual cropping systems; and address food versus fuel concerns. An Austrian pea plus winter cereal rye cover crop mix was integrated into continuous corn and corn plus soybean cropping systems at Arlington, Wisconsin and Hickory Corners, Michigan in 2013 and 2014. The experimental design was a randomized complete block with five replications at each location. The objective of the study was to evaluate the yield and quality of biomass feedstock produced from the cover crop plus annual rotational crop systems. Biomass quality analysis included total sugars, lignin and estimated ethanol yield. Long term analysis will include a determination of the global warming potential, energy balance, and economic performance of each respective system.

Field Design and Picture

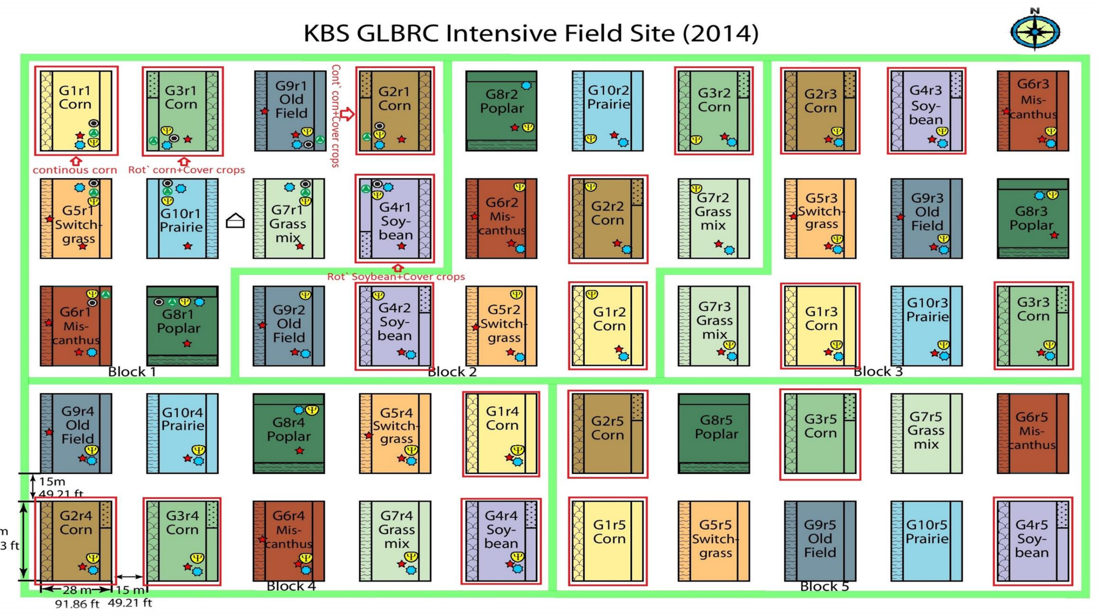

Figure 1. RCBD with 10 treatments and 5 Blocks at KBS, this study focused on G1-G4 annual cropping systems

Figure 2. Winter cereal rye plus Austrian pea cover crop.

G1: Continuous Corn (full season)
G2: Continuous Corn (short season) + Cover crops
G3: Soybean & Corn + Cover crops (2013 soybean)
G4: Corn & Soybean + Cover crops [2013 corn (short season)]

Timeline of Field Activities and Climatological Summary of two locations

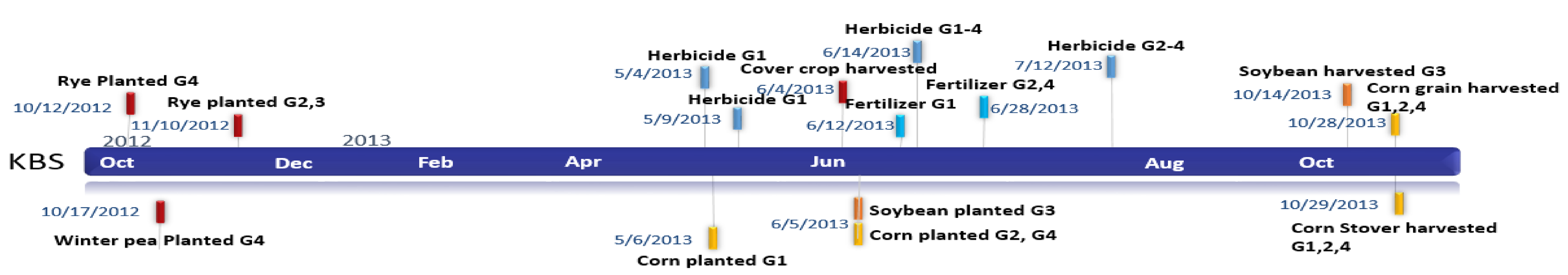

Figure 3. Timeline of KBS G1-G4 Annual Cropping Systems

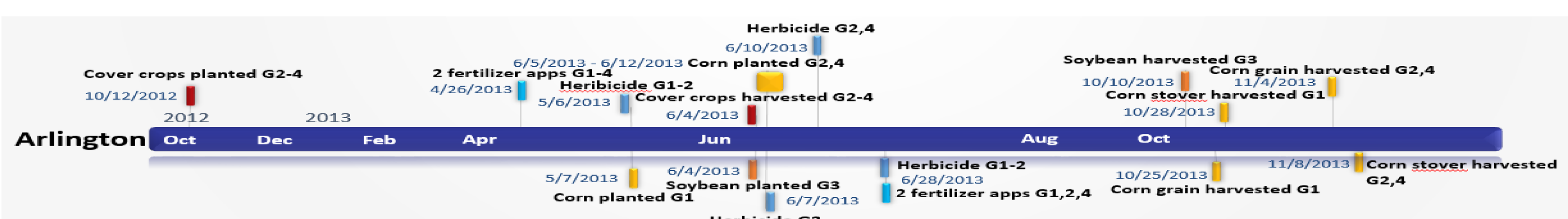

Figure 4. Time of Arlington G1-G4 Annual Cropping System

KBS		Mean Temperature(C°)			Total Precipitation (mm)		
Crop	Month	2012/2013	2013/2014	30 years	2012/2013	2013/2014	30 years
Cover Crops	November	3.87	2.82	-2.94	13.72	113.03	84.87
	December	1.31	-3.78	0.24	52.07	64.26	68.66
	January	-3.47	-9.00	2.12	50.55	75.44	59.14
	Febrary	-4.01	-8.03	8.84	188.47	60.45	51.70
	March	-0.56	-2.94	14.83	28.70	52.07	60.43
	Spring	6.98	8.40	19.79	159.51	67.31	90.73
Soybean/corn	May	16.44	14.93	21.31	127.76	80.52	93.21
	June	19.70	20.51	20.15	107.95	146.81	95.24
	July	21.75	19.06	15.83	75.95	103.63	97.62
	August	20.38	20.71	10.16	126.49	73.66	102.16
	September	16.90	15.95	3.86	19.30	66.04	107.16
	October	11.41	10.83	-1.75	55.12	136.40	93.53

Table 1. Monthly mean precipitation and temperature with 30-yr means at KBS

Arlington		Mean Temperature(C°)			Total Precipitation (mm)		
Crop	Month	2012/2013	2013/2014	30 years	2012/2013	2013/2014	30 years
Cover Crops	November	1.98	0.35	1.52	24.88	56.89	37.85
	December	-2.83	-9.40	-5.14	27.18	10.67	20.13
	January	-7.31	-13.01	-7.65	49.02	4.32	16.55
	Febrary	-7.01	-12.51	-5.66	33.79	15.24	16.52
	March	-4.07	-3.53	0.50	51.04	22.61	43.62
	Spring	5.25	5.87	1.83	154.18	171.70	50.33
Soybean/corn	May	14.34	14.18	13.67	158.25	59.18	81.82
	June	18.80	19.99	18.51	188.70	237.75	111.22
	July	19.53	18.69	16.63	69.07	35.31	81.64
	August	19.79	19.87	21.42	42.42	67.57	79.52
	September	15.95	14.17	14.78	73.40	38.61	68.12
	October	8.80	8.68	8.39	49.51	60.45	52.16

Table 2. Monthly mean precipitation and temperature with 30-yr means at Arlington

Yield Results:

Total crop yields, energy yields and cover crop yields are analyzed from 4 different cropping systems. *Means with the same lowercase letter(s) within the same year or same uppercase letter(s) within the same cropping systems are not statistically different (α= 0.05).

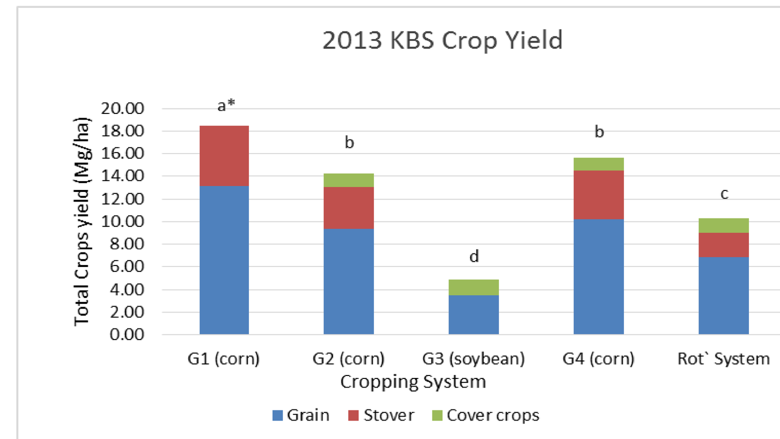

Figure 5. Crops Yield of KBS 2013

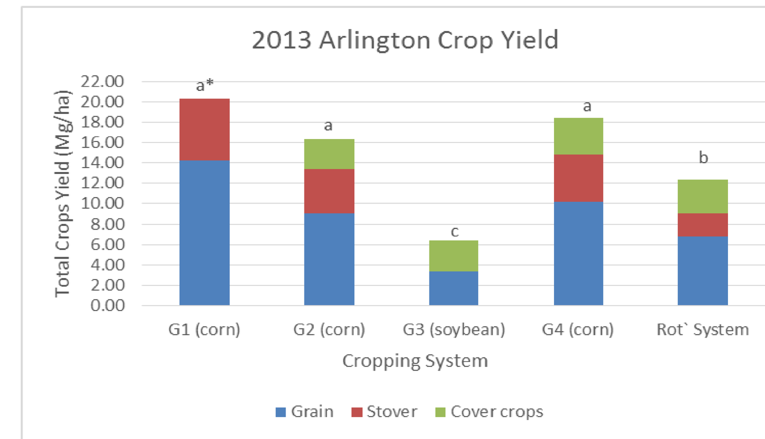

Figure 6. Crops Yield of Arlington 2013

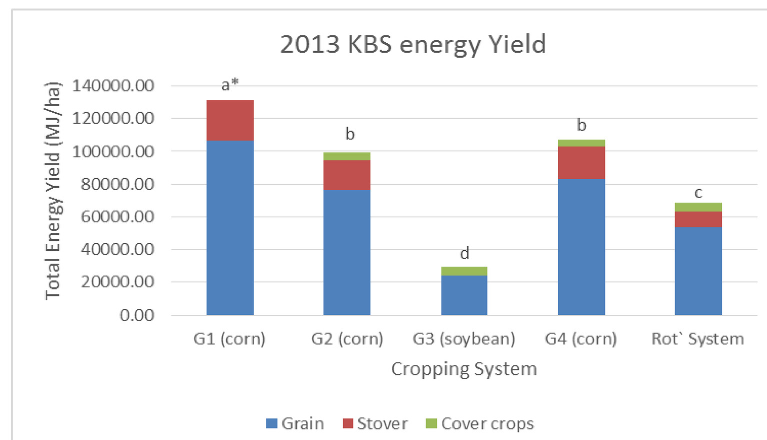

Figure 7. Estimated Energy Yield of KBS 2013

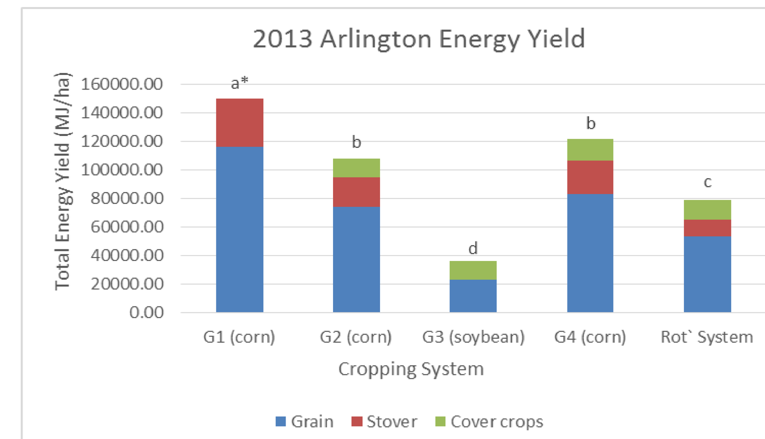

Figure 8. Estimated Energy Yield of Arlington 2013

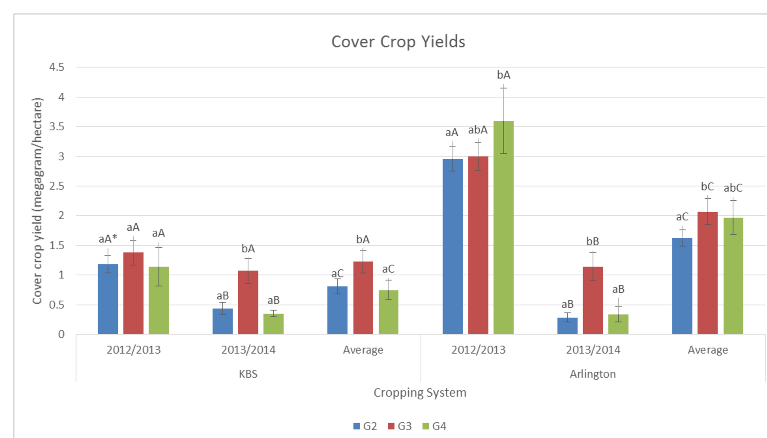

Figure 9. 2012/2013, 2013/2014 Cover Crop Yield

Conclusions:

The continuous corn (full season variety) cropping system had a significantly higher total yield at KBS and significantly higher energy yields at both locations. The cold weather and delayed spring warm up during the 2013/2014 winter annual growing season, reduced cover crop yields relative to the 2012/2013 winter annual growing season. During the 2013/2014 winter annual growing season, cover crops from the soybean system had a significantly higher yield than from the corn systems, due to a slightly earlier fall planting date facilitated by an earlier soybean harvest date relative to corn.

Analytical Results:

Cell wall crystalline cellulose (glucose), xylose, and lignin compositions were obtained. Weak-acid enzymatic digestibility of untreated biomass was performed to obtain glucose and xylose hydrolysis yields. *Means with the same letter(s) within the same composition are not statistically different (α= 0.05).

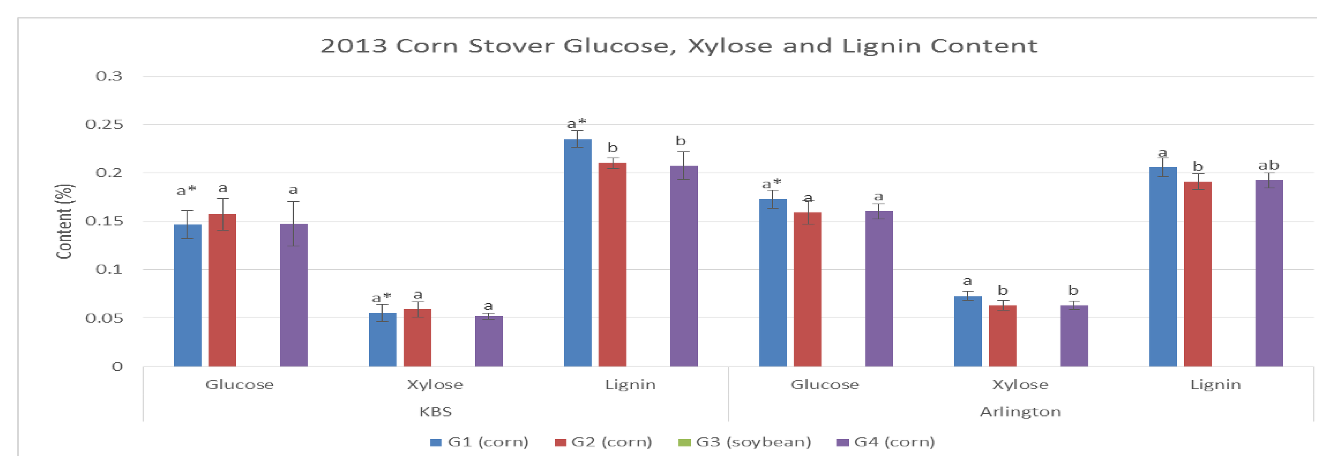

Figure 10. Glucose, Xylose and Lignin Content of Corn Stover

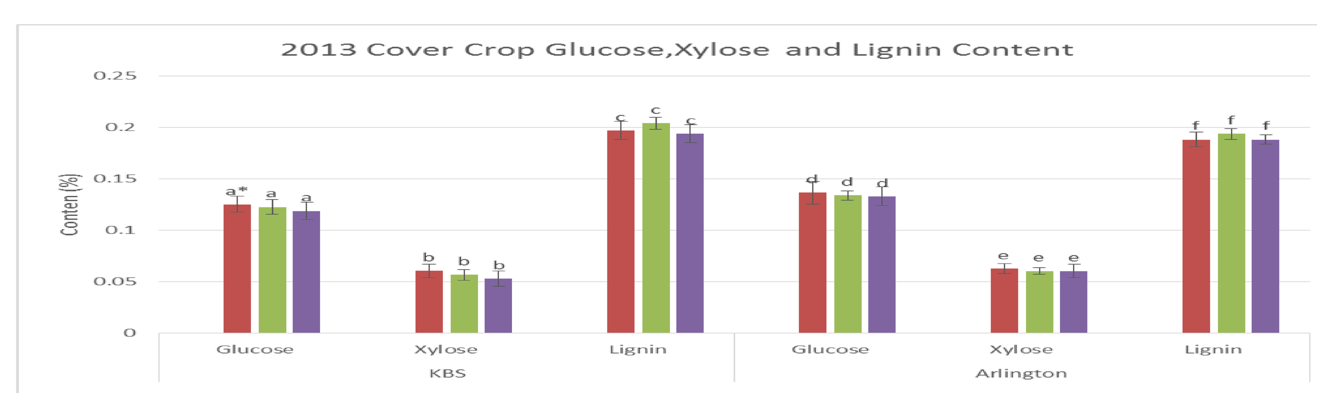

Figure 11. Glucose, Xylose and Lignin Content of Cover crops

Conclusions: The cover crop glucose, xylose and lignin content from the different cropping systems were not significantly different. The lignin content in stover from the full season continuous corn grown w/o cover crops was significantly higher than that from stover from the shorter season corn grown with cover crops. At Arlington (WI), stover xylose content was significantly higher from the full season continuous corn grown w/o cover crops relative to the other corn systems. Glucose content was not significantly different in the stover or cover crops at both locations.

Life Cycle Assessment:

Life Cycle Assessment (LCA) was performed using GaBi 6 Professional + Extension 2012 database (PE international). This study complies with ISO14000 and ISO 14040. TRACI 2.1 Impact Assessment Method is adopted to evaluate environmental burden of Global Warming Potential, Acidification Potential, Eutrophication Potential and non-renewable energy use.

Goal and Scope :

- **Temporal Scope -** 2012/2013 growing season
- **Geological Scope -** two locations
  Hickory corner, MI (KBS)
  Arlington, Wisconsin
- **System boundary -** cradle to farm gate
- **Functional Unit -**one hectare of arable land per year
- **Reference Flow –** average MJ of energy produced from the system on one hectare of arable land per year

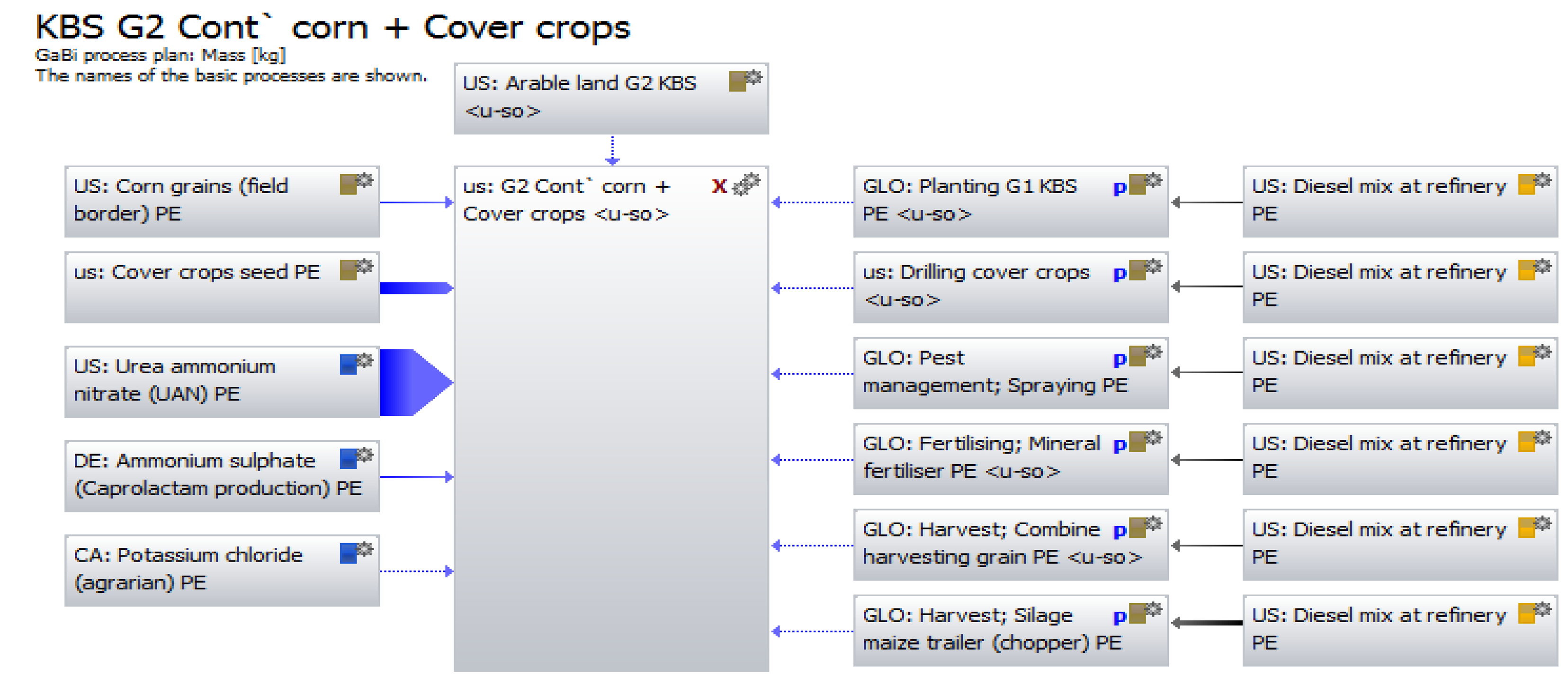

Figure 12. KBS G2 Continuous Corn + Cover Crops Cultivation flow diagram

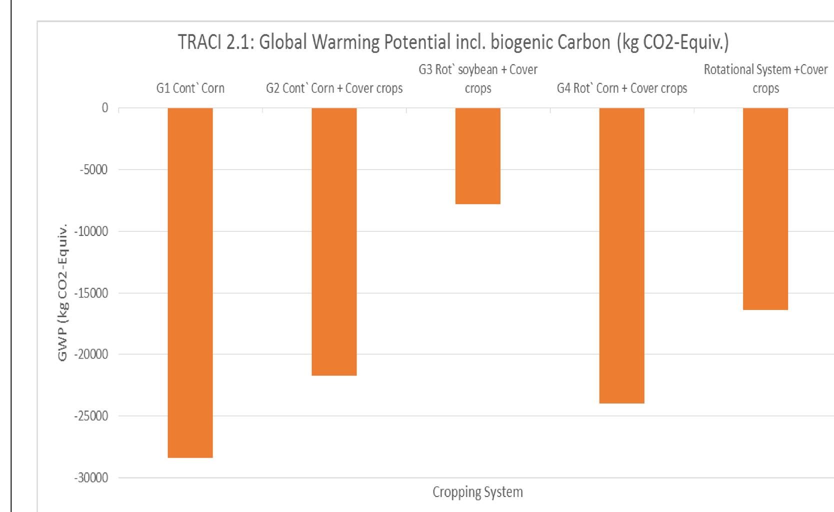

Figure 13. Global Warming Potential of different cropping systems

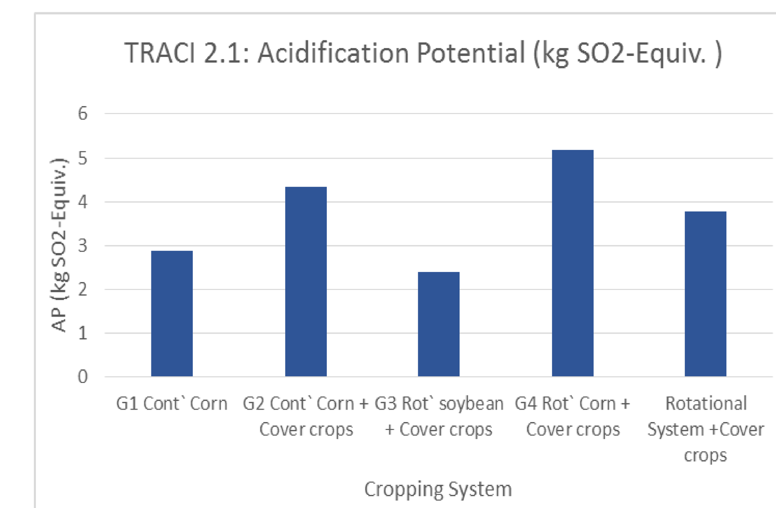

Figure 14. Acidification Potential of different cropping systems

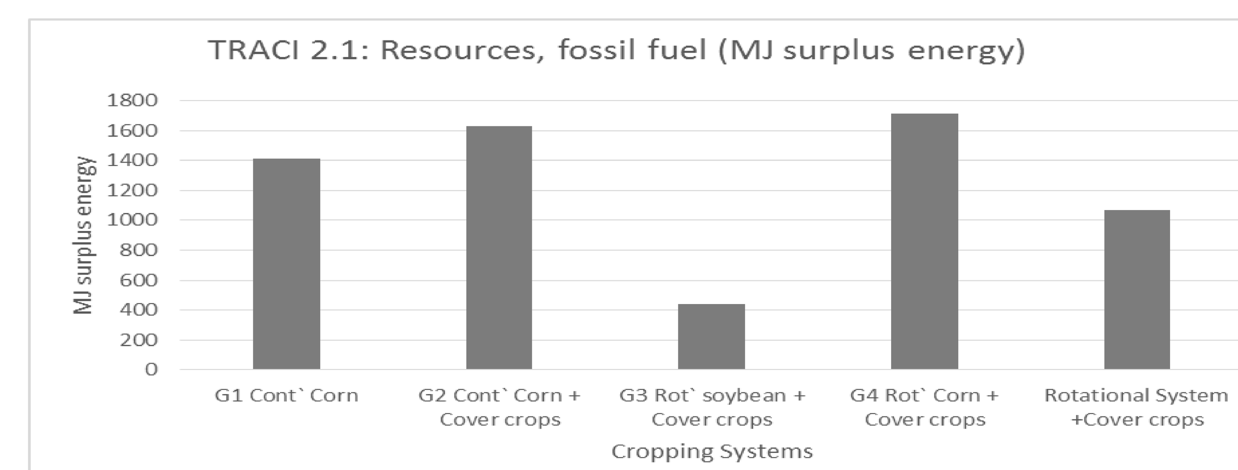

Figure 15. Resources, fuel of different cropping systems

Conclusions:

The temporal scope of this LCA study was limited to only one growing season. Preliminary (1 yr) results indicate that the continuous corn system w/o cover crops tended to have overall better GWP, and AP metrics. These are primarily driven by yield (full season hybrid) and the number of mechanized field activities respectively.

Acknowledgements:

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