An Economic Feasibility Analysis of Manure Applications and No-Tillage for Soil Carbon Sequestration in Corn Production

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Problem Statement

- Is it economically feasible to alter corn production strategies with no-till and/or manure applications in NE Kansas to enhance soil carbon sequestration?

- What is the $ value (carbon credit) needed to encourage adoption of these systems which enhance soil carbon sequestration in NE Kansas?

Objectives

- This study presents an economic analysis of eight continuous corn production strategies using data from the KSU North Agronomy Experiment Field in Manhattan, Kansas.

Questions

- What are the:

1. Costs and net returns from each production strategy?

2. Soil C sequestration rates, C emissions, and Net C gain?

3. Carbon credit values for implementing carbon sequestering strategies using either no-tillage and/or manure applications?

Crop Production Strategies

- **CT 84 N - conventional tillage 84 kg/ha N***
- **CT 168 N - conventional tillage 168 kg/ha N**
- **CT 84 M - conventional tillage 84 kg/ha M***
- **CT 168 M - conventional tillage 168 kg/ha M**
- **NT 84 N - no-tillage 84 kg/ha N**
- **NT 168 N - no-tillage 168 kg/ha N**
- **NT 84 M - no-tillage 84 kg/ha M**
- **NT 168 M - no-tillage 168 kg/ha M**

*N = NH_4NO_3

*M = equivalent kg of N from manure

Data

- Annual corn yields, 1991-1999
- Field operations, inputs, and rates, 1991-1999
- Soil C sequestration rates based on post harvest soil carbon data, 1992 and 2002
- Weighted average annual estimated C emissions from inputs, 1991-1999

Net Returns

- Net Returns = ($price_t$*$yield_t$)-($costs_{2002}$)
  - Government commodity payments and land costs were not considered as they would not alter the results. Currently examining EQIP & CSP program impacts.
- Simulate net return distributions (SIMETAR©)
  - Correlated empirical yield distributions based on historical yields, 1991-1999
  - Simulated price distribution based on historical prices, 1991-1999

Net Carbon Sequestration

- Net C Sequestration = soil C gain – C emissions
- Atmospheric C emissions from field operations and inputs reduce the overall effect of C being sequestered by the soil

Net Carbon Sequestration, cont'd.

- CO_2 emissions result from:

  1) Fossil fuel (primarily diesel fuel) combustion in field operations (Direct energy)

  2) Energy consumption (natural gas, electricity, fuel oil) required for manufacturing fertilizers and herbicides and pesticides (Embodied energy)

  3) Releases from hydrocarbons used in fertilizers (Feedstock energy)

Carbon Credit Values

- Credit needed to make a system with higher sequestration rate (C $Rate_j$), but lower net returns (NR_j) economically equivalent to a system with a lower sequestration rate (C $Rate_i$), but with higher net returns (NR_i)

- C value to make NR_j equivalent to NR_i

$$C\ (\$/\text{metric ton}) = (NR_i - NR_j)/(C\ Rate_j - C\ Rate_i)$$

Yield Results

Annual Mean Corn Yield by Production Strategies

	Strategy							
	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
Simulated Mean Corn Yield	4,924	5,387	4,317	4,891	4,720	5,498	4,340	4,665
Actual	4,943	5,396	4,310	4,869	4,740	5,501	4,298	4,665

Kg/Hectare

Average Yield Differences Results

- **By Tillage Treatment**
  - **NT 84 N < CT 84 N (188 kg/ha or 3 bu/ac)**
  - **NT 84 M > CT 84 M (<63 kg/ha or <1 bu/ac)**
  - **NT 168 N > CT 168 M (126 kg/ha)**
  - **NT 168 M < CT 168 M (251 kg/ha)**

- **Little difference due to tillage**

Average Yield Differences Results, cont.

- By Fertilizer Treatment
  - CT 84 N > CT 84 M (628 kg/ha)
  - CT 168 N > CT 168 M (502 kg/ha)
  - NT 84 N > NT 84 M (377 kg/ha)
  - NT 168 N > NT 168 M (816 kg/ha)

- N systems had higher yields

Cost Results

Annual Average Costs

	Strategy							
	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
Avg. Costs	388.23	435.62	376.54	428.31	314.22	363.05	303.52	354.03

$/Hectare

Costs Results

Average Costs

- NT < CT
  - 3.6 more field operations/year occurred in CT than in NT (32 operations over 9 years)
  - 0.2 more herbicide applications/year occurred in NT than in CT (2 applications over 9 years)
- N > M
  - Ammonium nitrate fertilized systems had higher costs
    - 84 N ($55.28/ha) > 84 M ($46.97/ha)
    - 168 N ($98.62/ha) > 168 M ($93.97/ha)

Mean Net Return Results

Annual Average Net Return to Land and Management

	Strategy							
	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
Avg. Net Return	98.57	96.84	50.16	56.49	156.86	181.08	127.09	108.83

$/Hectare

Mean Net Return Results

Average Net Returns

- **NT > CT**
  - **CT had much higher total costs than NT**
  - **The difference in net returns between tillage operations was mainly due to the difference costs**
- **N > M**
  - **N had higher yields than M resulting in a larger $ margin than the difference in costs**

Soil Carbon Results

Annual Soil Carbon Gains 0-30 cm

	Strategy							
	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
	1.1594	1.4676	1.3982	2.4807	1.6125	2.5273	1.6815	2.6663

Metric Tons/Hectare/Year

- NT > CT
- M > N

Carbon Emission Results

Annual Carbon Emissions

	Strategy							
	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
Carbon Emissions	0.2589	0.4712	0.0639	0.0811	0.2394	0.4517	0.0444	0.0616

Metric Tons/Hectare/Year

Carbon Emissions Results

- NT < CT
  - Emissions from energy attributed to additional herbicides for the NT systems were smaller than that from direct energy used in tillage operations they replaced in CT systems
- N > M
  - This is due to the embodied and/or feedstock energy from the production of nitrogen

Results

Annual Net Carbon Gain

	Strategy							
	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
Net Carbon Gain	0.9005	0.9967	1.3343	2.3995	1.3730	2.0758	1.6371	2.6046

Metric Tons/Hectare/Year

Net Carbon Sequestration Results

- NT > CT
  - NT is relatively larger when emissions are accounted for

- M > N
  - M is relatively larger when emissions are accounted for

Annual Average Characteristics

	Strategy							
	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
Corn Mean Yield	4,924	5,387	4,317	4,891	4,720	5,498	4,340	4,665
Mean Price	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20
Net Mean Return	98.57	96.84	50.16	56.49	156.86	181.08	127.09	108.83
Soil Carbon Gains	1.1594	1.4676	1.3982	2.4807	1.6125	2.5273	1.6815	2.6662
Carbon Emissions	0.2589	0.4712	0.0639	0.0811	0.2394	0.4517	0.0444	0.0616
Net Carbon Gain	0.9005	0.9967	1.3343	2.3995	1.3730	2.0758	1.6371	2.6046

Carbon Credit Values

- C value to make NR_j Equivalent to NR_i

$$C(\$/\text{metric ton}) = (NR_i - NR_j)/(C\ Rate_j - C\ Rate_i)$$

Carbon Credit Values

Example

- $(NR_{NT\ 84\ M} - NR_{NT\ 84\ N})/(C\ Rate_{NT\ 84\ N} - C\ Rate_{NT\ 84\ M})$

  ($127.09 – $156.86)/(1.3730 – 1.6371) =$252.74

- $(NR_{NT\ 84\ N} - NR_{CT\ 84\ N})/(C\ Rate_{CT\ 84\ N} - C\ Rate_{NT\ 84\ N})$

  ($156.86 – $98.57)/(0.9005 – 1.3730) =-$276.54

  - No Credit

Carbon Credit Values with emissions included ($/metric ton C/year)

	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
CT 84 N	$0.00	NA	NA	NA	NA	NA	NA	NA
CT 168 N	$17.69	$0.00	NA	NA	NA	NA	NA	NA
CT 84 M	$111.65	$138.22	$0.00	NA	NA	NA	NA	NA
CT 168 M	$28.09	$28.76	-$5.94	$0.00	$97.81	$384.87	$92.63	NA
NT 84 N	-$123.36	-$158.44	-$2,748.63	NA	$0.00	NA	NA	NA
NT 168 N	-$70.21	-$78.07	-$176.58	NA	-$34.46	$0.00	-$123.10	NA
NT 84 M	-$38.71	-$47.23	-$254.02	NA	$112.74	NA	$0.00	NA
NT 168 M	-$6.01	-$7.45	-$46.18	-$255.00	$39.01	$136.61	$18.89	$0.00

-Dollar values are the amount required for the system in the row to be equivalent to a system in a column

-Negatives are the penalty the system in the row would need to equal the system in the column because the system in the row has a higher net return and sequesters more carbon

-NA appears when the system in the row sequesters less carbon than the system in the column, therefore, a carbon credit is not feasible

Conclusions

- Carbon credit payments for NT are not needed for corn in NE Kansas
  - NT preferred to CT (Net returns and sequestration rates are higher)

- Carbon credit payments for M are needed for corn in NE Kansas
  - M > N (Sequestration rates)
  - M < N (Net returns)

Questions?

With Emissions vs. Without Emissions

	W/E CT 84 N		W/Out E CT 84 N
• CT 84 M	$111.65	CT 84 M	$202.90

	NT 168 N		NT 168 N
• NT 168 M	$136.61	NT 168 M	$520.29

Carbon Credit Values w/out emissions included ($/metric ton C/year)

	CT 84 N	CT 168 N	CT 84 M	CT 168 M	NT 84 N	NT 168 N	NT 84 M	NT 168 M
CT 84 N	$0.00	NA	NA	NA	NA	NA	NA	NA
CT 168 N	$5.67	$0.00	-$670.90	NA	NA	NA	NA	NA
CT 84 M	$202.90	NA	$0.00	NA	NA	NA	NA	NA
CT 168 M	$31.87	$39.84	-$5.85	$0.00	$115.64	NA	$88.37	NA
NT 84 N	-$128.67	-$414.68	-$497.85	NA	$0.00	NA	NA	NA
NT 168 N	-$60.31	-$79.50	-$115.94	-$2660.01	-$26.47	$0.00	-$63.82	NA
NT 84 M	-$54.62	-$141.54	-$271.50	NA	$431.26	NA	$0.00	NA
NT 168 M	-$6.80	-$9.96	-$46.26	-$281.78	$45.60	$520.29	$18.56	$0.00

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