Economic Benefits of Long Term No-till Cropping in Central Saskatchewan

CARP 2012.4 – Component 1

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Long term no-till (LTNT) soils have been shown to convert nitrogen into higher crop yields for more than 10 years. The accrued economic advantage of a long term no-till system is \$120 ha^{-1} relative to a short term no-till (STNT) system. The longer term system also provides lower down side yield risks. The benefits that arise from following a no-till practice in the long term show that it is important to minimize soil disturbance to enable soil micro flora to optimally utilize available nutrients.

1. Background

There are numerous research studies that have shown the financial advantages of no-till farming practices versus conventional farming systems (Zentner, 1991; Gray, Taylor and Brown, 1996). The benefits include greater water infiltration, reduced evaporation via stubble retention, reduced machinery drag which results in fuel and capital savings, reduced weed incursion (Holm et al, 2006) and greater nitrogen efficiency (Soon and Clayton 2003; Lafond and Clayton 2010). Some researchers have reported little or no difference between short-term reduced till and no till programs when compared to conventional programs (Grant, et al, 2001 and 2002) over time frames of less than five years. In short term studies, the results were variable and dependent upon factors including soil type, crop type, fertilizer type, fertilizer application methods and rate, and precipitation (Grant, et al, 2001 and 2002). The aim of this paper is to reveal the benefits of persisting with a no-till system over a longer period of time.

The data used in this analysis were from research trials on two adjacent fields located south of Indian Head, Saskatchewan. Full details of the project and the agronomic results of this project were presented in Lafond (2011). The soil type was Oxbow loam. The mean annual temperature was 2.5 ^{o}C and mean participation was 427 mm and the evapo-transpiration was 607 mm (Lafond, et al, 2010.)

There were two data sources available for this analysis. The first is plot level data with a set rotation of spring wheat and canola using treatments of five rates of nitrogen fertilizer (0, 30, 60, 90 and 120 kg N ha^{-1}) on both the LTNT and STNT site. The second source of data is from crops produced on the LTNT and STNT sites using commercial fertilizer rates.

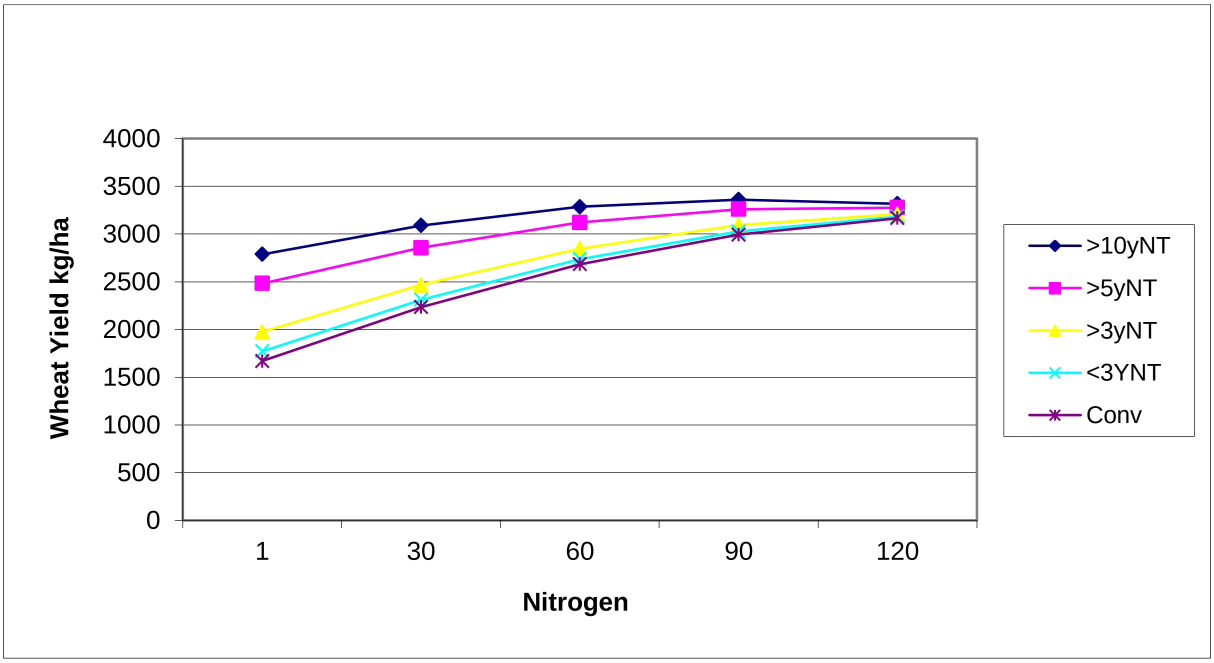
The LTNT land had been in no-till production since 1978 before entering the trial in 2002. This 24 year period included an annual cropping regime and a brome grass production period of 5 years, and hay period of 2 years from 1984-1990. The STNT land was conventionally tilled from 1984 with a wheat/fallow system until 1998. Following a summer fallow in 1999 and conventional barley crop in 2000, the field was brought into no-till production in 2001. With the exception of a field pea crop on the short –term site in 2003, all other crops produced included the spring wheat – canola rotation until 2008. In 2009 spring wheat was planted for a second year and then the spring wheat-canola rotation continued until 2011 which is the last year in the data series. The trial data included five spring wheat years and five canola years.

2. Fertilizer Application

Nitrogen was applied as granular urea (46-0-0), mono-ammonium phosphate (11-52-0) and potassium sulphate (0-0-51-17, which was surface applied only to canola crops). The prices for the fertilizers have been calculated at the farm gate.

The uptake of fertilizer by the crops is a function of the temperature and precipitation, predominantly in the first two months after seeding. Previous research indicates that the nitrogen utilization function is quadratic in structure, which produces a maximum yield response at 90 kg/ha.

Figure 1. Nitrogen-yield response by number of no-till years compared to conventional cropping



Precipitation is modelled in two distinct periods, 0-60 days and 61 days to harvest, to measure its influence on yield.

The variety of wheat changed through the research period (Lafond et al, 2011) and the results of a variety comparison trial were used to index the yield response to remove the effect of varying wheat varieties (Sask. Ministry of Agriculture, 2008).

3. Model of Productivity

Crop production models have been used for economic analyses since the 1950's (Heady and Dillon, 1961). Production refers to the method in which inputs such as land, labour, fertilizer, seed and water are converted into crop yields, or outputs.

Productivity analysis measures the efficiency of crop production in one of two ways. The first option is to examine the efficiency of farms which use minimal inputs to achieve a set level of outputs. For example, we may aim to identify the lowest fertilizer input level used to produce a set yield of 3 tonne ha^{-1} of wheat. Alternatively we could consider the maximum output achieved for a set level of inputs. An example of this approach would be to consider the maximum canola yield for a set level of 200mm of soil moisture.

Duality theory provides a set of conditions where input costs and output incomes can be used to estimate productivity and efficiency rather than using the actual quantities of inputs or outputs. This methodology provides a measure of productivity in dollar terms rather than a ratio of physical quantities of inputs to outputs.

In actual farm level data, it is very difficult to control either the input levels or outputs. The parameters must be estimated and then adjusted to specified levels. This process requires substantially more data to accommodate the wide range of management practices and input uses. The advantage of the research data provided in this study is that the levels of fertilizer and management inputs were controlled and the yield responses recorded, which removes a degree of error from the input efficiency measure.

Crop yield simulation models have been built on experimental data where input variability was controlled across various input levels (Zonter, Sonntag and Lee, 1978). Productivity modelling theory has developed over time to enable more complex analyses of inputs and outputs under a range of environmental situations (Chambers and Quiggin, 2002). However, there have been very few cropping systems research data sets that have spanned more than five years to enable productivity analysis to be applied to crop models over time. Typically, the data sets have good within year data but poor time series data.

Chambers and Quiggin, 2002 and O'Donnell and Griffiths (2006) were amongst the first economic researchers to account for outputs produced under different states of nature in productivity models. The method accounted for uncertainty in one or more of the input variables by adding an error adjustment term. In more recent years, the models have been applied to the analysis of more complex input variables and systems (Jalota, Sood, Vitale and Srinivasan, 2007) and more explicitly to cereal crops with considerable agronomic, cost and income data over extended periods of time (Tozer, 2010).

Stochastic frontier analyses are a methodology that shows the change in the productivity of a field, treatment or farm over time. Over time we expect the frontier that envelopes the set of efficient producers to expand for outputs or contract for inputs. A farmer could become more efficient by using fewer inputs to produce the same level of outputs over time. In this analysis we show that the trial plots have become more efficient over time by increasing output while utilizing the same level of inputs.

O’Donnell (2014) has argued that while a producer may be found to be efficient in one year, this event may not be indicative of a long term trend in productivity or efficiency over time. The cross section data with varying levels of nitrogen applied in each year show that the efficient level of fertilizer may change depending on the other input combinations that exist within the season. In-crop precipitation, for example, will impact on the available nitrogen and this may increase or decrease output. The time series of data show the most efficient combination of inputs over time, taking into account a wide range of environmental inputs and management decisions.

Precipitation, temperature and frost each influence the yield of a crop and have an economic cost if they are missing from the production system but do have a direct cost that can be entered into a crop gross margin budget. The value of land incorporates the value of these environmental variables and the risks.

4.a Model Results

The multivariate crop yield model shows the variation in crop yield for each of the traits analyzed. The model structure was as follows:

$$\text{Yield} = f\,(\text{crop, year, nitrogen rate, phosphate treatment, crop history, precipitation in May, June, July and August and the temperature in May, June, July and August}) \qquad (1)$$

Where the crop was fixed as either canola or wheat, year was treated as a trend variable, nitrogen rate was fixed at 0, 30, 60, 90 or 120 kg ha^{-1}, phosphate was the application method, crop history was fixed at LTNT versus STNT, rainfall was variable in mm per month, and average temperature for the month was variable. Overall, the model has an F-value of 248.13 which is significant, and an R-Square of 0.86 which is high. The mean number of output was 1935.50 kg.

Table 1. Type III Sums of Squares results

```
    Source                      DF      Type III SS      Mean Square    F Value    Pr > F

  YEAR                          1       24253025.0       24253025.0     154.59    <.0001
  Nitrogen                      4      171483372.1       42870843.0     273.26    <.0001
  Phosphate                     1         148542.6         148542.6       0.95    0.3309
  History                       1       20515518.8       20515518.8     130.76    <.0001
  PrecMay                       1       21093683.5       21093683.5     134.45    <.0001
  PrecJune                      1       19674747.2       19674747.2     125.41    <.0001
  PrecJuly                      1       18767817.9       18767817.9     119.62    <.0001
  PrecAugust                    1       27455925.2       27455925.2     175.00    <.0001
  TempMay                       1        7393747.1        7393747.1      47.13    <.0001
  TempJune                      1       26391186.5       26391186.5     168.22    <.0001
  TempJuly                      1       22649243.1       22649243.1     144.36    <.0001
  TempAug                       1      112646540.1      112646540.1     718.00    <.0001
```

Results in Table 1 show that only the phosphate treatment effect was non-significant. The remaining effects were significant at the 99 per cent level. The fact that fertilizer treatment was not significant has been reported in previous studies and is consistent with those results (Lafond et al, 2011).

Table 2. Parameter estimates, standard errors and t-values for the model parameters.

```
                                   Standard
Parameter                 Estimate                Error    t Value    Pr > |t|
________________________________________________________________________________
Intercept              -914648.0106 B     73838.15329     -12.39      <.0001
Crop        C             -370.1409 B        32.36849     -11.44      <.0001
Crop        W                0.0000 B          .            .           .
YEAR                       434.2768          34.92853      12.43      <.0001
Nitrogen    0            -1402.9289 B        51.24465     -27.38      <.0001
Nitrogen    30           -1033.6645 B        51.24604     -20.17      <.0001
Nitrogen    60            -529.9369 B        51.24465     -10.34      <.0001
Nitrogen    90            -114.1865 B        51.24895      -2.23      0.0263
Nitrogen    120              0.0000 B          .            .           .
Phosphate   SB              31.5027 B        32.37570       0.97      0.3309
Phosphate   SP               0.0000 B          .            .           .
History     LT             370.1409 B        32.36849      11.44      <.0001
History     ST               0.0000 B          .            .           .
PrecMay                    186.2515          16.06276      11.60      <.0001
PrecJune                  -102.7448           9.17491     -11.20      <.0001
PrecJuly                   213.8719          19.55436      10.94      <.0001
PrecAugust                 -98.1604           7.42019     -13.23      <.0001
TempMay                    381.5832          55.58447       6.86      <.0001
TempJune                  8972.7554         691.81976      12.97      <.0001
TempJuly                 -5113.3448         425.57374     -12.02      <.0001
TempAug                   -479.9441          17.91135     -26.80      <.0001
```

The year variable was significant suggesting that over time, the yield has been increasing at about 434 kg ha^{-1} per annum. The rate of gain per year is interesting and is discussed further below.

The responses from the fertilizer rates are similar to other reports. Relative to nitrogen rates of 120 kg ha^{-1}, applying zero fertilizer resulted in yields reduced by 1,402 kg ha^{-1}, 30 kg ha^{-1} of nitrogen reduced yields by 1,033 kg ha^{-1}, 60 kg ha^{-1} of nitrogen resulted in 529 kg ha^{-1} less yield, and 90 kg ha^{-1} of nitrogen only reduced yields by 114 kg ha^{-1}. This result also confirms previous findings that the optimal fertilizer rate was in close proximity to 90 kg ha^{-1} in continuous cropping systems.

As reported above, there was no statistical difference between the phosphate treatments.

The crop history effect shows that the yield from the long term no-till land is 370 kg ha^{-1} higher than the STNT land after ten years.

The precipitation results are significant but their interpretation is complex. Higher precipitation in May had a significant positive influence on the crop, while rain in June had a negative effect as it most likely increased canopy growth. In July, the precipitation effect turned positive again as the plant moves into the heading and reproductive stages. The final precipitation result is that more rain at harvest reduced yield. These results are open to interpretation; however, the effects are all significant.

The temperature results, like precipitation, were linear and they require more modelling work as they are currently confounded with year. The results indicate that a warmer spring and a cooler summer have a positive influence on the yields and this makes very good agronomic sense. But the temperature level of influence on yield appears too high.

Table 3. Year effects on crop yield.

```
                                    Standard
Parameter                 Estimate             Error    t Value    Pr > |t|

Intercept              1971.271830 B     64.73787078      30.45      <.0001
YEAR       2002        1700.490637 B     72.31626150      23.51      <.0001
YEAR       2003        -460.726029 B     72.31626150      -6.37      <.0001
YEAR       2004         425.640637 B     72.31626150       5.89      <.0001
YEAR       2005         367.407304 B     72.31626150       5.08      <.0001
YEAR       2006        1599.757304 B     72.31626150      22.12      <.0001
YEAR       2007         -49.609363 B     72.31626150      -0.69      0.4930
YEAR       2008        1563.071403 B     72.62517498      21.52      <.0001
YEAR       2009         491.490637 B     72.31626150       6.80      <.0001
YEAR       2010        1886.640637 B     72.31626150      26.09      <.0001
YEAR       2011           0.000000 B       .                .          .

 Split      1         -1454.05492 B      116.948448     -12.43       <.0001
Split      2            0.00000 B         .               .          .
```

The results shown in Table 3 are relative to the final year of the project data (2011).

4.b Five year split test

The combined yields of the crops in the first five years were modelled against the combined yields in the second five year period. The split result in Table 3 shows that the second five year period produced 1.454 tonnes ha^{-1} more than the first five year period, at a highly significant level.

5. Economic Data

Input costs data have been sourced from the Guide to Crop Production for the years of 2003 to 2011. The cost of fertilizers vary by time and timing of the application.

Table 4. Fertilizer prices for various products 2007 and 2008.

Fertilizer	May-07	May-08
Urea	\$ 0.18 lb^{-1} N	\$ 0.40 lb^{-1} N
UAN Solution	\$ 0.36 lb^{-1} N	\$ 0.48 lb^{-1} N
Ammonium Nitrate	\$ 0.36 lb^{-1} N	\$ 0.53 lb^{-1} N
Ammonium Sulphate	\$ 0.40 lb^{-1} N	\$ 0.69 lb^{-1} N
Di-ammonium phosphate	\$340 tonne^{-1}	\$1,200 tonne^{-1}
Mono-ammonium phosphate	\$340 tonne^{-1}	\$1,000 tonne^{-1}

Source: Lafond 2008.

The economic model has a composite income term which is based on Canadian Wheat Board reported price data in-store Vancouver, with protein premium and adjusted to local price by subtracting freight rates.

Table 5. CWB Pro rates 2002 to 2011.

March PRO Grade	Protein	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
		----------	----------	----------	----------	$ tonne^{-1}	----------	----------	----------	----------	----------
1CWRS	14.5			219	224	203	219	228	397	310	287
1CWRS	13.5	224	211	211	217	195	207	220	388	297	273
1CWRS	12.5	214	203	205	211	189	199	215	382	290	210
1CWRS	11.5	207	196	199	205	183	192	210	376	282	204

Source: CWB 2011 Prorates for various years

Table 6. Gross margin result for 5 year period

```
                                        Standard
            Parameter             Estimate            Error    t Value    Pr > |t|

            Intercept           420.1648548 B     25.15565559      16.70      <.0001
            Split      1       -119.2344266 B     18.92056988      -6.30      <.0001
            Split      2          0.0000000 B       .                .          .
            Crop       C       -103.1144445 B     18.92056988      -5.45      <.0001
            Crop       W          0.0000000 B       .                .          .
            Nitrogen   0       -348.6299161 B     29.95379670     -11.64      <.0001
            Nitrogen   30      -261.4488771 B     29.95379670      -8.73      <.0001
            Nitrogen   60      -142.8683357 B     29.95379670      -4.77      <.0001
            Nitrogen   90       -30.0094929 B     29.95379670      -1.00      0.3168
            Nitrogen   120        0.0000000 B       .                .          .
            History    1          0.0000000 B       .                .          .
            History    2          0.0000000 B       .                .
.
```

The explanatory power in the gross margin model was significantly less than the biological model. The parameters of the model are shown in Table 6. By splitting the sample period in two, the results show that the second five year period was \$119.23 ha^{-1}more profitable then the first five year period. The profitability of the Canola crop was \$103 ha^{-1} less than the wheat gross margin.

The gross margin model indicates a loss of \$348.62 ha^{-1} from not applying nitrogen fertilizer, a loss of \$261 ha^{-1} where only applying 30 kg ha^{-1} of nitrogen, and a loss of \$142.86 ha^{-1} if 60 kg ha^{-1} of nitrogen were applied. The 90 and 120 kg ha^{-1} nitrogen rate were not significantly different. The benefits of the LTNT was not significantly different to the STNT once the year split has been accounted for as other variables had picked up the benefits.

6. Summary

This study clearly shows the agronomic and financial benefits of maintaining LTNT management practices. It would appear that fewer soil disturbance operations encourage soil organic matter to reach a level where it can assist the release of nitrogen to the plants which increases yield and reduces yield variability.

This analysis confirms that the benefits from LTNT are at least \$120 ha^{-1} more profitable than the earlier five year STNT period. These results indicate that the industry should encourage the management practice and examine ways to continue the studies to see when the STNT will be as productive as the LTNT site. There are approximately 15 million acres (6.07 million hectares) which could potentially be producing a further $728 million which directly benefits the producers, and which also can have numerous benefits to the community in terms of less nitrogen leaching, and nutrient runoff. Research projects that aim to identify the soil microstructures and organisms would enable producers and society to collect these potential gains more quickly.

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