Modelling Soil Dynamics and the Effect of Nitrogen Levels on Potato Yield Function

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Abstract

Crop yield is maximized when optimal levels of nutrients, water, and other inputs are available to the crop and the influence of disease and weeds has been minimized. While each crop has differing responses to nutrient availability, modelling soil dynamics and the effect of nitrogen levels on potato yield is very important. The objective of this study was to model several environmental components of potato yield function including soil characteristics and organic matter content, soil nitrogen, temperature component, moisture component, solum and nitrogen mineralization, nitrogen fertilizer, and nitrogen sufficiency. The interaction of these components with moisture availability and nitrogen sufficiency was shown to impact potato yield.

Introduction

Potato production in Manitoba has rapidly increased in recent years and became the second largest potato producer in Canada producing about 22.2% of the total Canada's potato production as of 2004. With large areas of land suitable for irrigated potato production, the industry has potential to be expanded further. There has been, however, considerable concern over optimal application of nitrogen and the environmental impacts of over use of nitrogen in recent years. Potato production is very highly input intensive requiring high levels of fertilizer and chemicals. Although there have been experimental studies in Canada examining the impacts of nutrient and nitrogen availability on crop yield and quality, there is limited research in systematically modelling such relations and addressing short and long term production and environmental impacts. Irrigation potato is fairly new in Manitoba with recent expansion in potato processing industry. More research is required to understand biophysical components and address production and environmental concerns. This paper discusses the components of a soil and nitrogen module and its complexities and how it is linked into a potato rotation model to address such impacts.

Although crop rotation is one of the oldest methods for managing pests, diseases, and soil fertility, emphasis on crop rotation continues because of its beneficial effects on crop yield and soil fertility. Crop rotation may affect crop yield and improve soil properties, including soil organic matter and nutrient availability (Heady 1957, Lazarus and White 1984; Honeycutt et al

1995; Guertal et al 1997). Crop rotation may center on a primary crop such as potato, while the other crops of the rotation may be selected for diversity and fertilizer and nutrient management. Potato farming systems generally use excessive tillage and produce low levels of crop residue in the potato year, which is the most important factor of soil quality (Carter and Sanderson, 2001). A major concern in potato cultivation is the sustainability of the production system. Therefore, it is important to maintain soil quality in order to obtain higher return for the invested capital.

This study has developed a potato rotation model in STELLA (7.0.2) dynamic programming for seven different potato rotations (potato-wheat, potato-canola, potato-canola-wheat, potato-oat-wheat, potato-wheat-canola-wheat, potato-canola underseeded with alfalfa-alfalfa-alfalfa, potato-corn-wheat) to investigate agro-environmental and economic impacts of such rotations. The potato rotation model was based upon the model created by Belcher et al (2003) which looked at economics and changes in soil quality. Several changes were made to the Belcher model in an attempt to better simulate agro-environmental relations and economic returns. The agro-environmental module consists of several sub-modules, interconnected to create the dynamic model. The sub-modules include erosion, soil organic matter carbon, water, historical weather data, precipitation and irrigation, residue reducing practices and farming operations, nitrogen, phosphorus, and yield. Crop yield in the model is determined from interconnecting key elements of above modules based on availability of nutrients, water, soil and soil organic carbon content, and other bio-physical components. The potato model was developed to simulate potato rotations in an experiment near Carberry, MB. Data for variables used in the model are specific to the Wellwood soils in the potato rotation experiment; however, they could be modified in future versions of the model to be applicable to other soil series. The description of the Wellwood soil series was taken from a partial Manitoba soil survey (Mills and Haluschak 1995), describing the soil as a moderately well drained Orthic Black clay loam, with medium organic matter and high natural fertility. The soil has good soil aggregation (structure) which reduces the potential for erosion. Soil properties are described in Table 1.

Table 1. Description of Wellwood Soil.

Horizon	Depth cm	Texture	Silt %	Clay %	Bulk Density g/cm^3	SOMC t/ha	OM %	FC %	PWP %
Ap	0 to 14	clay loam	34	30	1.08	63.2	7.19	28.8	11
Ah	14 to 29	clay loam	41	32	1.27	59.06	5.33	27.4	11.1
Bm	29 to 52	silty clay loam	49	31	1.29	38.87	2.26	25	10.6
Cca	52 to 78	silty loam	55	38	1.28	23.63	1.22	27	13.1
Ck	78 to 110	clay loam	54	24	1.28	11.88	0.5	26.2	8
2Ck	110 to 120	fine sand	5	5	1.64	0.82	0.09	7.4	2.5

Adapted from Mills and Haluschak 1995

Erosion Sub-Module

The erosion sub-module was developed to estimate annual loss of soil due to wind and water erosion and farming practices. The set up of the module can be seen in Figure 1. The module calculates rates of erosion and soil formation, which affect the solum depth.

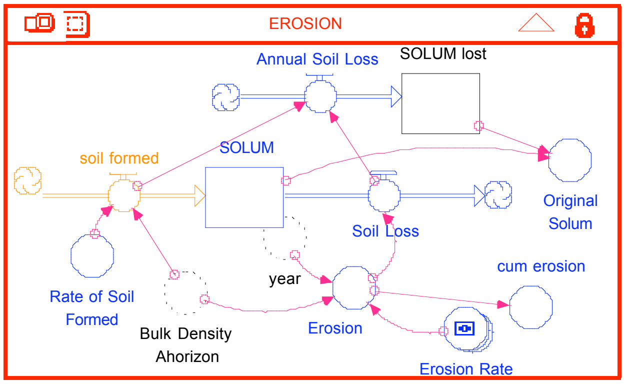

Figure 1. Erosion module schematic.

Erosion Rate

The rate of erosion in this model depends upon the rotation and the crop management. In general, erosion rates were higher in potato production years due to intensive tillage and low levels of crop residue compared to years where an established alfalfa stand was present. Rates of erosion vary between rotations for the same crop due to effect of tillage management on aggregate size distribution and cover of crop residue.

Erosion diminishes the surface of the soil, usually the A-horizon (Bauer and Black 1992). As such, erosion will have an influence on plant growth as most of the nutrients and OM are found in the topsoil.

The values used in the model were determined through a literature review. The main causes of erosion are: wind, water, ice and agricultural machinery, with wind erosion being the main source of soil loss on the Canadian prairies (Larney et al 1992). In the model, the erosion rates used were dependent upon the crop and the rotation. In heavily tilled crops, such as potatoes, erosion rates were higher than in zero tilled crops, like alfalfa in the potato-canola (alfalfa)-alfalfa-alfalfa rotation. The values of the erosion rates used are listed in Table 2.

Table 2. Erosion Rates of the Potato Rotation Model.

Rotation	Erosion Rate Mg/ha/yr	Rotation	Erosion Rate Mg/ha/yr
Potato	15	Potato	15
Wheat	11	Wheat	11
Potato	15	Canola	9
Canola	11	Wheat	9
Potato	15	Potato	15
Canola	11	Canola(Alfalfa)	11
Wheat	9	Alfalfa	5
Potato	15	Alfalfa	5
Oat	11	Potato	15
Wheat	9	Corn	11
		Wheat	11

Erosion

Erosion was calculated from the rate of erosion using the following equation:

$$E = \frac{E_{rate}}{100 * BD}$$

where E is erosion in cm/yr; E_{rate} is erosion rate in Mg/ha/yr; BD is bulk density in Mg/m^3; and the factor of 100 converts erosion in m^3/ha/yr to cm/yr.

Rate of Soil Formation

According to Sutherland and de Jong (1990), the rate of soil formation in Canada is generally accepted to range from 0.25 to 1.0 tonnes per ha per year; however, research has found that rates can be greater than that for Dark Brown Chernozemic soils in Saskatchewan. The value used in the model was 1.0 tonne/ha/yr.

Solum

The Wellwood soil of the potato study has a solum depth of approximately 60 cm (Mills and Haluschak 1995), which is the value used in the model. Soil depth in the model changes with erosion and soil formation annually.

Soil Organic Matter Carbon Sub-Module

The soil organic matter carbon sub-module was used to determine the change in SOM under differing tillage practices in the Belcher et al (2003) model. Soil organic matter losses were determined as erosion and mineralization based, with additions to SOM coming in the form of surface crop residue. The sub-module output of OM%, surface residue and SOMC, used in sub-modules, play important roles in water management and nutrient availability in the determination of crop yield and economic costs and returns. Figure 2 shows the SOMC sub-module concept.

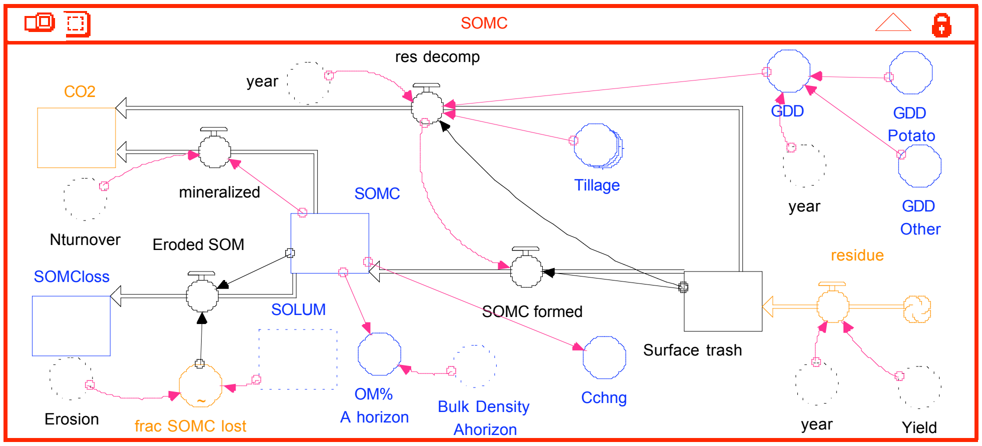

Figure 2. Soil organic matter module schematic.

Crop Residue

Residue remaining after harvest contributes to the soil's organic matter levels and quality (Greer and Schoenau 1992). The added value of residue, according to Canola Council of Canada (2001) is increased infiltration, shading of the soil to protect against evaporation of valuable water, and reduced wind speed, which affects both erosion and evaporation. Our model assumes that only the grain/tuber portion of the crop is removed from the system, leaving the remaining biomass to contribute to soil organic matter. The harvest index of a crop is used to determine the amount of biomass remaining after harvesting the crop. By knowing the previous years yield, the amount of crop residue can be calculated from product of yield and the inverse of harvest index (HI). Harvest index (mass of residue/mass of grain) values used in the model are in Table 3.

Table 3. Crop Residue Index Values $(HI)^{-1}$ used in the Potato Rotation Model.

Crop	(HI)-1 value kg residue/kg yield
Potato	0.15
Wheat	2.2
Oat	2.2
Canola	2.2
Alfalfa	0
Corn	1.5

As this section of the model relates to the levels of soil organic carbon, the contribution of the residue to the SOMC stock is determined through the assumption that the carbon content of the residue, on a dry weight basis, is 45% (Belcher et al 2003)

Residue Decomposition

Rates of residue decomposition are estimated using the equation developed by Douglas and Rickman (1992):

$$Rr = Ir \exp\left(fN * fW * k * GDD\right)$$

where Rr is remaining residue; Ir is initial residue; f N is a coefficient based on initial residue nitrogen; f W is a water coefficient based on residue and field management; and k is a general decomposition coefficient, set to a value of –0.0004. The factor f N accounts for the fact that residue high in N content decays at a higher rate as compared with residue with low N content (Douglas and Rickman 1992). The value of f N is generally between 0.8 and 1.4, is unitless and is calculated from another equation from Douglas and Rickman (1992):

$$fN = 0.570 + 0.126N$$

where N is in kg N/kg residue.

The values of f N used in the model for wheat, oat, canola and alfalfa were taken from the Belcher et al (2003) model and generally agreed with values found in literature. The value for potato f N was taken as 2.58 which was near the average of the values found in literature; this value should be higher than that for wheat and oat, and similar to that of alfalfa. The values used in the model are listed in Table 4.

Table 4. Values of f N used in the Potato Rotation Model.

Crop	f N
Potato	2.58
Wheat	2.07
Oat	2.07
Canola	1.43
Alfalfa	2.36
Corn	2.46

The factor f W expresses the difference in decay rates under wet versus dry conditions, influenced by tillage practices. Values used in this model for this unitless factor are listed in Table 5. Douglas and Rickman (1992) suggested that the values of f W ranges from 0.2 to 1.0, depending upon the farming system.

Table 5. Values of f W (tillage factor in the model).

Tillage	f W
Potato	0.9
Conventional tillage	0.7
Minimum tillage	0.2
Zero tillage	0.1

Growing Degree Days

Growing degree days are a measure of accumulated heat above a threshold temperature. The GDD for Brandon and Portage are 1441 to 1595 and 1529 to 1692, respectively (Mills and Haluschak 1995). The GDD for potato and corn (May through September) was in the range of 1550 to 1650, and for all other crops of the rotation (May through August) 1400 to 1500.

The amount of carbon lost to the atmosphere through the decomposition process is then calculated as:

$$CO_{2decomp} = C_{surface} * \left[1 - \exp\left(fN * fW * k * GDD\right)\right]$$

where $CO_{2decomp}$ is the amount of CO_2-C that is released to the atmosphere as a result of the decomposition process; $C_{surface}$ is the amount of crop residue carbon, dependent upon crop type and yield.

SOMC Formation

The formation of soil organic matter carbon was taken as the difference between the amount of crop residue carbon left on the surface and the amount of carbon lost to the atmosphere through decomposition.

SOMC

The initial amount of soil organic matter carbon (100000 kg) was taken from Mills and Haluschak's data (1995) for Wellwood soil to approximately 30 cm depth. The amount of SOMC is depleted by mineralization losses to the atmosphere and through erosion of the solum. The SOMC stock is maintained through the decomposition of surface residue.

Mineralization

Mineralization losses of SOMC as CO_2 is calculated as:

$$CO_2 = SOMC * N_{turnover}$$

where CO_2 is the amount of CO_2-C removed from the SOMC stock to the atmosphere; SOMC is the amount of soil organic matter; and $N_{turnover}$ is the nitrogen mineralization rate (too be discussed in the ***Soil Nitrogen Sub-Module***). $N_{turnover}$ is determined from soil moisture and temperature.

Eroded SOM

Loss of SOMC can also occur through the removal of soil due to erosion. Solum depth and erosion rate are used to determine SOMC loss, as described by Belcher et al (2003). The relation, shown in Figure 3, states that at low erosion rates, the amount of SOMC lost is small; at high erosion rates, after the solum has been depleted, the loss of SOMC is very high.

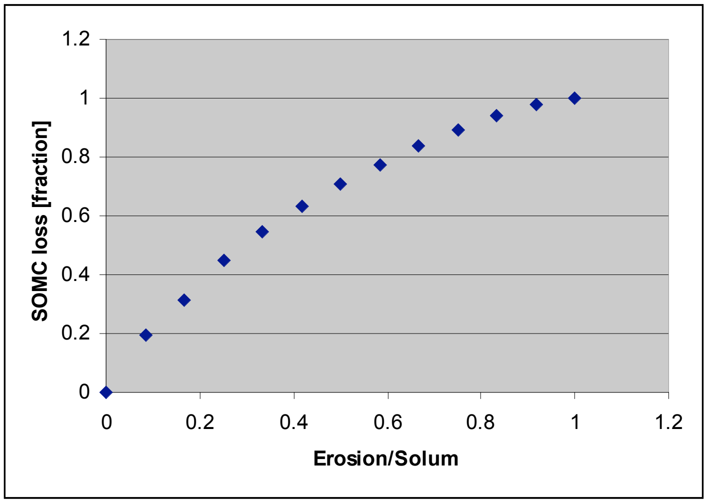

Figure 3. The relation between erosion, solum and the fraction of SOMC lost. Adapted from Belcher et al 2003.

Soil Nitrogen Sub-Module

The nitrogen sub-module, shown in Figure 4, was used to examine nitrogen soil dynamics and the effect of nitrogen levels on yield. Soil nitrogen turnover during the growing season is calculated and applied N fertilizer is determined from the N turnover and SOMC levels. As with the crop water sub-module, it is assumed that there is no carry over of soil N within the model.

Soil Nitrogen

Nitrogen left in the soil available for the following crop depends on several factors (Errebhi et al 1998). Factors include the amount removed by the crop, the amount of N applied as fertilizer, the amount of nitrogen mineralized, the amount of N lost to leaching and the initial concentration in the soil. Other factors/processes that play a role are denitrification, volatization and level of SOM (Ojala et al 1990).

Soil nitrogen can be determined from the levels of SOM and the factors which influence the rate of microbial activity, such as soil moisture and temperature (Bowen et al 1998, de Neve et al 2003, Knoepp and Swank 1998, Alva et al 2002), Stanford and Epstein 1974, Walse et al 1998, Myers et al 1982). Additional factors, which influence microbial activity, but were not included in the model are soil pH, soil compaction, salinity, concentrations of soil nutrients (de Neve et al 2003, Purdy 2004).

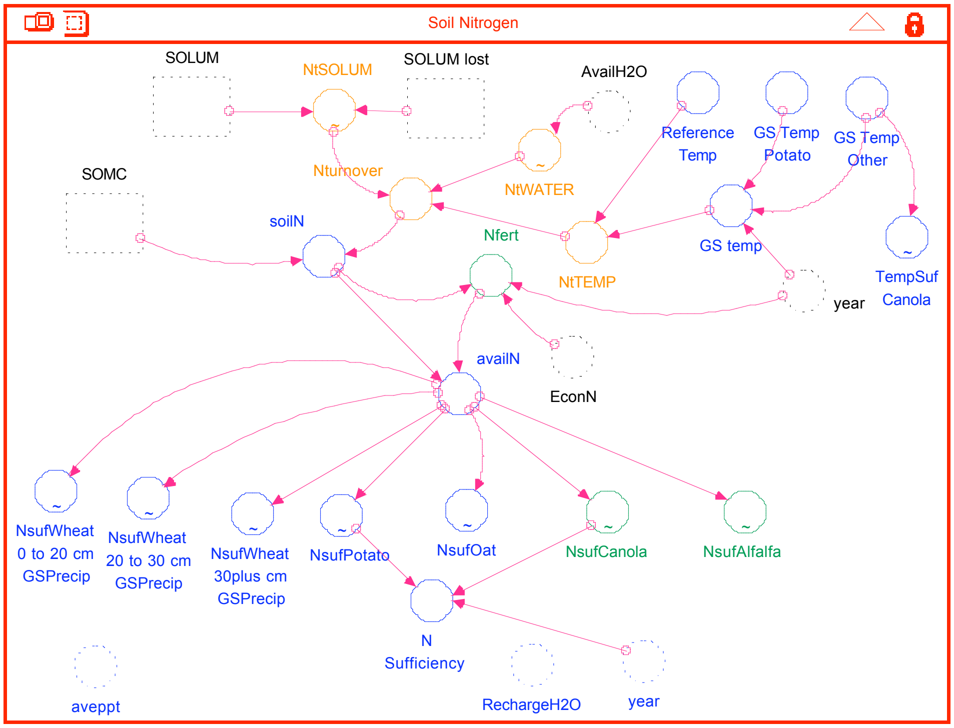

Figure 4. Soil nitrogen module schematic.

As the only N removed from the system is in the grain or tuber (Alva et al 2001), the contribution of the residue or crop residue is taken into account by including a fraction of SOM in the turnover process. In Manitoba, as much as 9 kg NO_3-N/ha may result from mineralization between harvest and seeding (MAFRI 2001).

The relation of decomposition rate has been widely studied. The general concept is that SOM decomposition can be calculated as (Paul 2001):

$$N_{\min} = kT_m W_m \beta$$

where N_{min} is the net mineralization rate; K is the net mineralization under optimal conditions; T_m is the effect of soil temperature on microbial activity; W_m is the effect of soil moisture on microbial activity; and β are other factors. Both T_m and W_m have values between 0 and 1 in this model.

Temperature Component

The optimal temperature for microbial activity is between 35 and 45°C, with mineralization practically ceasing near freezing and activity generally increasing rapidly to 30°C (Paul 2001, Stanford et al 1973, Parton et al 1987, de Neve et al 1996). Over a limited temperature range, most models of microbial activity response to temperature are linear (Paul 2001). The effect of temperature on decomposition rates has been modeled under several concepts, from daily temperatures to monthly or even annual temperatures, using linear, power and Arrhenius functions (Lloyd and Taylor 1994, de Neve et al 1996, 2003, Tanji 1982).

The relation utilized in the model related the mean growing season temperature (GS_{temp}) to a reference temperature, as found in the McCaskil and Blair (1990) and Cooksley et al (1993) equation. While the reference temperature (T_{ref}) is set to 30°C, there is a slider, which allows for user control. The relation to the nitrogen mineralization coefficient (T_m) is:

$$T_m = \frac{GS_{temp}}{T_{ref}}$$

Moisture Component

Most mineralization models make use of a unitless function for the effect of moisture on mineralization rates (Paul et al 2003). The potato model assumes that in the case of soil moisture and nitrogen turnover, that there is a linear relation, following the equation:

$$\mathrm{W_m} = 0.02425\mathrm{Avail_{H_2O}} - 0.08541$$

where W_m is the coefficient of mineralization related to moisture and $Avail_{H2O}$ is the amount of available water as determined in the Soil Water sub-module.

SOM Component

The C:N ratio is fairly consistent at 10:1 in most soil.

Soil Nitrogen

The value of soil N in the model was determined as:

$$Soil_N = \frac{SOMC}{10} * Nt_{SOLUM} * Nt_{TEMP} * Nt_{WATER}$$

where $Soil_N$ is the amount of nitrogen made available through decomposition processes of SOM (in kg N/ha); Nt_{SOLUM} is the turnover with respect to the solum; Nt_{TEMP} is the turnover with respect to temperature; and Nt_{WATER} is the turnover with respect to moisture. Nt_{TEMP} and Nt_{WATER} would be T_m and W_m, respectively, of the Paul (2001) equation.

Nitrogen Fertilizer

Recommended fertilizer rates are based upon the concept that the amount of N fertilizer to be applied can be determined by the difference between crop requirements and the amount of N provided by the soil (Bowen et al 1998).

Nitrogen application should match available water to be economically efficient (Curwen 1993) since plant response to nitrogen is water dependent. To take into account the concept that it would be economically impractical to apply large amounts of nitrogen to a field under drought conditions, a soil-water based component was added into the model to determine how much nitrogen should be applied. The component, EconN, is determined as:

$$EconN = N_{opt} * Econ_{H_2O}$$

where EconN is in kg N/ha; N_{opt} is the crop specific amount of nitrogen required to produce peak yield; and $Econ_{H2O}$ is determined from Figure 5, using the calculated soil water ratio of:

$$Spring_{H_2O} = \frac{aveppt + ppt\,\mathrm{var} + Irrigation}{GS_{ppt} + SWE_{ppt} + Irrigation_{YEAR1}}$$

where aveppt is the growing season precipitation in cm; pptvar is the snowwater equivalent in cm; Irrigation is the amount of applied irrigation; GS_{ppt} is the user defined first year of growing season water in cm; SWE_{ppt} is the user defined first year of snowwater equivalent in cm; and $Irrigation_{YEAR1}$ is the user defined first year of irrigation water in cm. The ratio compares the first year "control", or average, to subsequent years for determining the amount of nitrogen to apply.

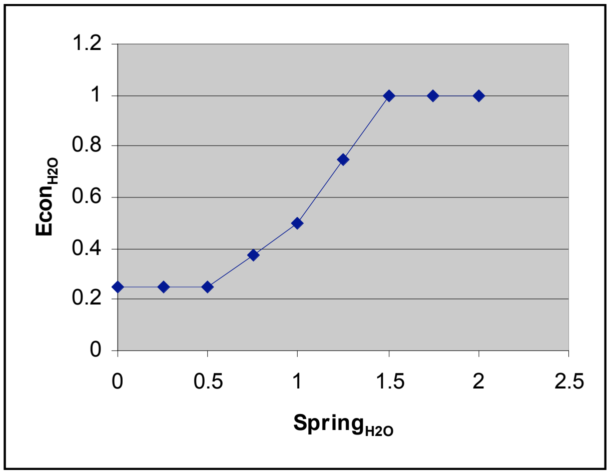

Figure 5. Relation between $Econ_{H2O}$ and $Spring_{H2O}$.
Source: Belcher et al 2003.

The model assumes that no nitrogen fertilizer is required for alfalfa in an attempt to incorporate the nitrogen fixation by alfalfa.

Nitrogen Sufficiency

The response functions were normalized for each crop to reflect the effect of an excess or deficiency in nitrogen on the total potential crop yield.

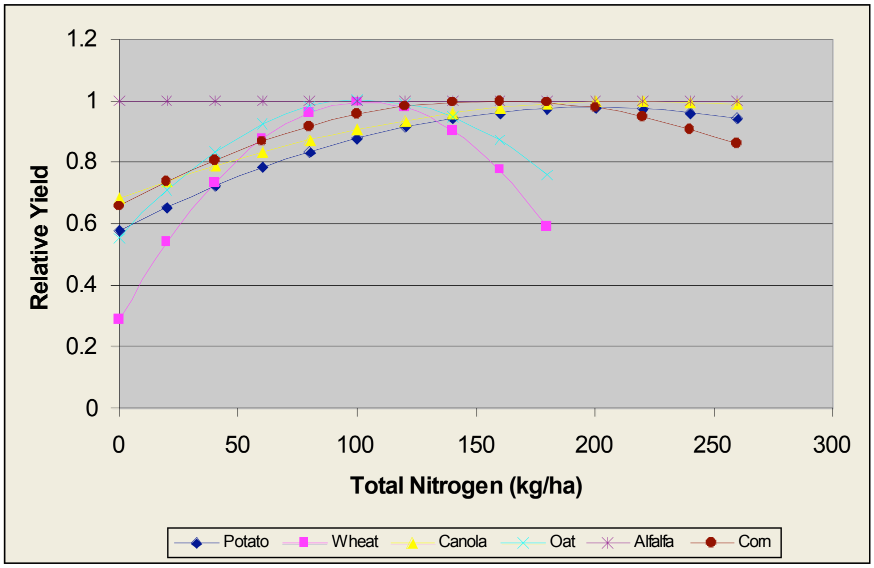

Figure 6. Crop Nitrogen Sufficiency

Nitrogen Sufficiency – Potato

Potatoes require relatively large quantities of nitrogen for optimal yields (Racz 1995), with yields and size increasing with increased nitrogen rates (Tomasiewicz 1995, Rykbost et al 1993). Nitrogen deficient productions see lowered yields, through reduced numbers of tubers and reduced tuber size (Griffin and Hestermann 1991, Belanger et al 2000) and the creation of favourable conditions for certain diseases such as early blight and Verticillium wilt (Rosen 1991). Response of potato to nitrogen is often determined through a quadratic regression curve (Belanger et al 2000(b)). The model makes use of the N response curve described by Mohr 2003 as shown in Figure 6, with a optimal N level at 200 kg N/ha.

Nitrogen Sufficiency – Wheat

Wheat response to nitrogen is moisture dependent, according to a study by McKenzie et al (2000); in dry years response to N is low while in wet years increased N increases yield. Soil N levels influence the likelihood of crop response to applied N fertilizer (McKenzie 2001). In the model wheat response to nitrogen was taken to be water dependent as described by McKenzie et al (2000). Soil moisture, taken as growing season precipitation and snow water equivalent, was incorporated into the sufficiency calculation, making wheat sufficiency water dependent. In general, with the McKenzie et al (2000) equations, optimal N levels for wheat are around 105 kg N/ha, regardless of water levels (Figure 6).

Nitrogen Sufficiency – Oat

Limited data was found for oat response to nitrogen. Overall, oat yield was optimized at total N levels (soil N plus fertilizer N) between 100 and 110 kg N/ha, though Mohr et al (2003) reported a peak N at 140 kg N/ha. When total N exceeds 112 kg N/ha, yield increases do not occur and yield losses are possible due to lodging (Heard and Mohr 2004). For oat response to nitrogen, the model makes use of the response curve of Heard and Mohr (2004). With this data, optimal N levels for optimal yield are 104 kg N/ha.

Nitrogen Sufficiency – Canola

The model utilizes the data of Karamanos et al (2002) with an optimal N level of 219.17 kg N/ha for hybrid canola. Canola N requirements are quite high as compared to other crops in the study, thus using this data set places peak N levels higher than those for wheat and oat.

Nitrogen Sufficiency – Alfalfa

The literature review of data for the response to nitrogen turned out a few sources, however, the data indicates that quite a wide range of peak values are possible for the response curve. Alfalfa response to nitrogen in the model was set to be 1.000 as to represent the nitrogen fixation capabilities of the forage/legume crop.

Nitrogen Sufficiency – Corn

The data set from McDonald (2004) was selected to represent corn response to nitrogen. The data has optimal yield at about 160 kg N/ha (Figure 6).

Results

The change in solum depth within the model was dependent upon the soil erosion and formation rates of the rotation in question. In general, potato had the highest associated erosion, thus it would be expected that in shorter rotations with a higher frequency of potato crop the change in solum would be the greatest. Figure 7 shows the average change in solum as a function of time as the system is run over a 50 year span. Both the P-C and P-W, overlayed data in the figure, show an increased rate of solum loss as compared to the other rotation of the experimental model. Only the P-Corn-W rotation, which was not part of the experimental research, showed higher rates of change due to the higher erosion rates predicted for the soil under corn. Over the 50 years, average losses were 5.000 cm for two-year rotations, 4.525 cm for three-year rotations, with the exception of the P-Corn-W, which has average solum losses of 5.068 cm, and 4.390 cm for the four-year rotations.

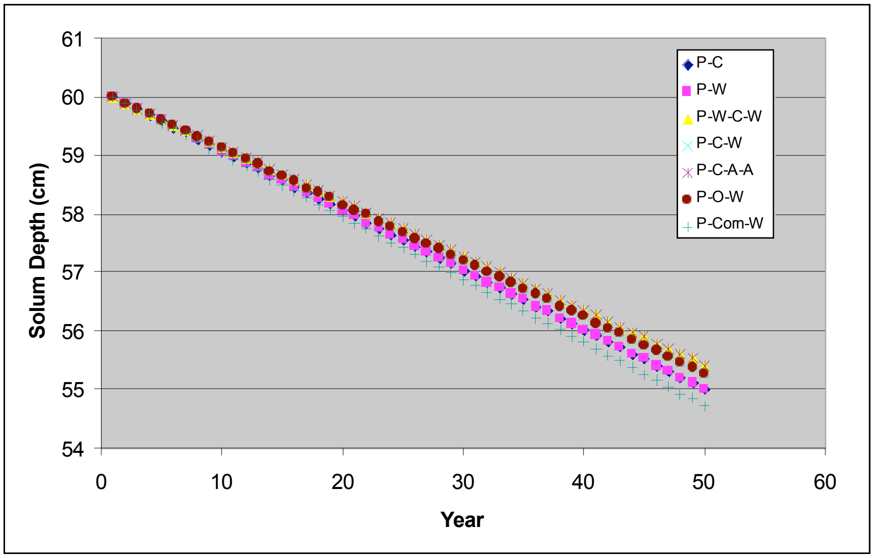

Figure 7. Change in solum depth

The model tracks the changes in soil organic matter carbon (SOMC). The system starts with 100000 kg C/ha, based on the study by Mills and Haluschuk (1995). Figure 8 shows how the levels of SOMC changes as the model progresses through 50 years of the rotation. SOMC changes were observed to increase or decrease, at differing rates, depending upon rotation. The model was built in such a way that the SOMC stock is replenished through crop residue and depleted through mineralization and erosion losses. Rotations which saw a decrease in SOMC were P-C and P-W. For the P-C-A-A rotation, the SOMC level remains near the original value. In terms of the P-C and P-W rotations, the SOMC losses were developed through the higher erosion rates found in these two rotations combines with lower canola and wheat yields, as compared to other rotations, which in turn produce decreased levels of crop residue.

The remaining rotations produced increased SOMC levels over the course of the study. Aside from the P-C-W rotation, these rotations increased SOMC by 12000 to 15000 kg C/ha. The average increase in the P-C-W rotation, over the 50 years of simulation was about 8000 kg C/ha. These results would suggest that these rotations are beneficial to soil quality and thus soil productivity.

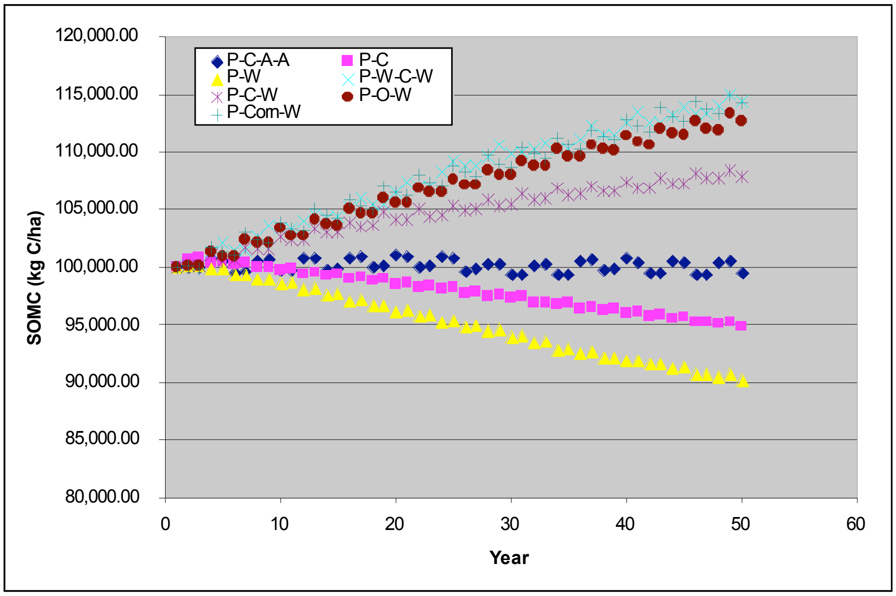

Figure 8. Change in SOMC

Annual soil loss did not change over the course of the model run. The values were selected based upon the crop in question and the following crop. The annual soil loss was determined as the difference between soil formation and the soil erosion. In terms of average annual soil loss, the greatest rate of soil loss was found in the P-Corn-W rotation. As discussed in the section on solum, in general, the higher the frequency of potato in the rotation, the greater the average annual soil loss. This concept is shown in Figure 9, with the four-year rotations showing the least amount of annual soil loss and the shorter rotations showing increased losses.

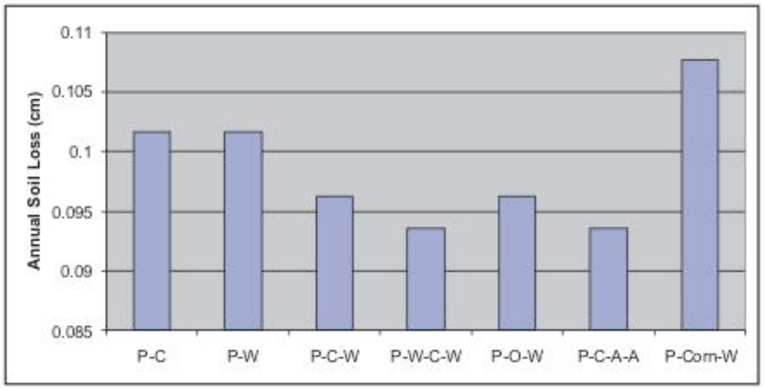

Figure 9. Average annual soil loss by rotation

The statistics on the simulated nitrogen sufficiency of each of the rotations is shown in Table 6. In potato years, there is not much difference between rotations, with yield losses being no greater than 1.59% due to shortages in nitrogen. This low yield loss in potato can be attributed to the model determining that there was sufficient water to warrant the application of optimal levels of nitrogen fertilizer as a result of moisture being added to the system through irrigation. With the exception of alfalfa for which the model assumed 100% nitrogen sufficiency with no applied nitrogen fertilizer, the other crops of the rotation did show reduced yields due to the selection of nitrogen fertilizer rates and the level of soil nitrogen. In canola, average sufficiency didn't change greatly between rotations, but there was on average 11 to 12% yield loss due to nitrogen deficiency. Maximum sufficiency in canola was 92.73%, resulting in the best case a yield loss of 7.27%. In the worst case scenario, yield losses in canola were as high as 20% due to nitrogen levels.

Average yield loss in wheat, due to nitrogen, was no greater than 5%, however, there were years of the simulation where yield losses were as high as 27.2%. In oat, average yield loss was 2%, with maximum losses of 12.5% in some years. Maximum yield losses in corn were 10%, though on average, yield losses due to nitrogen deficiency were 1.6%.

Table 6. Statistical Nitrogen Sufficiency Data (fraction)

Rotation	Crop	Average	St. Dev.
	Potato	0.9968	0.0037
P-C	Canola	0.8821	0.0278
	Potato	0.9967	0.0041
P-W	Wheat	0.9412	0.0701
	Potato	0.9975	0.0035
	Wheat	0.951	0.067
	Canola	0.8939	0.0266
P-W-C-W	Wheat	0.9594	0.0635
	Potato	0.9975	0.0041
	Canola	0.8886	0.0268
P-C-W	Wheat	0.9697	0.0395
	Potato	0.9953	0.0049
	Canola(alfalfa)	0.8757	0.03
	Alfalfa	1	0
P-C(A)-A-A	Alfalfa	1	0
	Potato	0.9976	0.0035
	Oat	0.9805	0.0262
P-O-W	Wheat	0.9576	0.0543
	Potato	0.9987	0.0022
	Corn	0.9839	0.0247
P-Corn-W	Wheat	0.9613	0.0446

Conclusions

The potato rotation model simulates soil and nitrogen dynamics in an attempt to show crop growth and the economics of a number of potato based rotations. The soil dynamics portion of the model simulates soil erosion and soil organic matter. Soil erosion was found to be highest in the simulation for a potato-corn-wheat rotation. In general, shorter rotations of two to three years showed high annual soil loss though this is believed to be due to a greater occurrence potato with its field intensive operations. As a result of the higher annual soil loss in the potato-corn-wheat, solum loss was high in this rotation, with more than five centimetres lost over fifty years of production. The solum loss in this rotation would be related to a greater number of field intensive operations.

The potato-canola (underseeded with alfalfa)-alfalfa-alfalfa rotation showed very little change in SOMC. This suggests that losses due to erosion and mineralization were balanced by SOMC formation through residue left on the field. In rotations of three years or more in length, SOMC levels were found to increase, suggesting that residue left on the surface and lowered erosion rates would contribute to improved soil quality over fifty years.

In the model, yield losses due to nitrogen were low. On average less than 2% yield loss could be attributed to nitrogen deficiencies in all crops with the exception of wheat and canola. Losses in these crops were around 5 and 10% respectively. In general, the model simulates soil and nitrogen dynamics in a manner that falls in line with theoretical concepts.

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