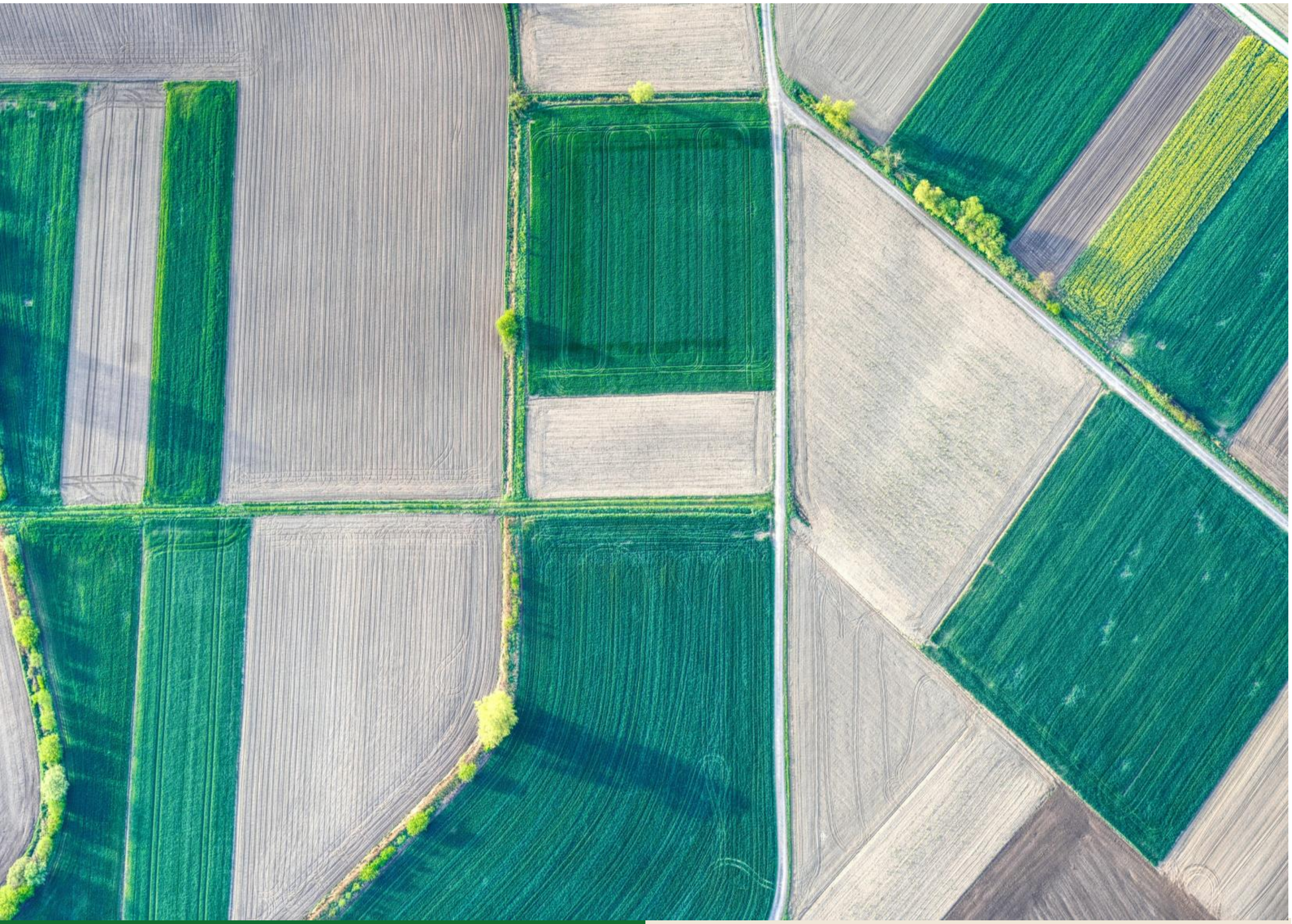

Profitability of site-specific fertilization based on Sure Growth Solutions - A Canadian case study

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briefing paper 2024/10

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The profitability of site-specific fertilization based on Sure Growth Solutions – A Canadian case study*

Yelto Zimmer[1], Konstantin Kockerols[2], Leon Ranscht[3]

This paper presents the outcome from a case study analysis for a Canadian farm that does site-specific fertilization (SSF), a precision farming approach which takes into consideration the spatial variability of soils. The economic results for three years of wheat and canola production are compared to a neighbouring farm, which is practicing conventional broadcast application of fertilisers. Since no additional investments in machinery are needed, the annual variable cost is 6 CAD/acre. In the standard case, the average profit is 30 CAD/acre. The rather pronounced difference in the effects from SSF application in wheat vs. canola leads one to question whether this is a crop-related systematic outcome or instead represents something more random. Sensitivity analyses generated two main insights. First, the economics of SSF are sensitive to a modification in commodity prices – a 50% cut would reduce the average profit to about 9 CAD/acre. Second, another scenario calculation in which no-till is assumed to generate a 5% increase in yields suggests that the net profit would be just 7 CAD/acre. Given the existence of so many uncertainties, this paper calls for more farm-based economic analysis of SSF, one which should also include a comparison of different service providers for application maps.

Keywords: precision farming, profitability, site-specific fertilization, case study, Sure Growth Solutions

JEL classifications: Q12, Q16

* This paper was initially published in Studies in Agricultural Economics 126 (2024) 1-7; download is here: https://doi.org/10.7896/j.2743

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1 Introduction

Practitioners and agricultural scientists around the world are contemplating the profitability of site-specific fertilization (SSF), with a particular focus on nitrogen. A few research projects have been conducted and published – however, real-world assessments at the farm level are rather rare – yet the most important issue has not been addressed by the scientific community: the performance of SSF is determined by the quality of the application maps (provided sensor-based technologies are not considered). This is in turn a function of the quality of the data (including weather data) entered and the agronomic expertise of those, who – based on the data available – generate the application maps. Explicit reference must therefore be made to the origin of application maps used in the comparison.

While technology providers as well as scientists often claim that a massive increase in profits can be realised by running a SSF system – be it through cost savings and/or yield improvements – it is difficult for producers to assess the economics of respective investments. A particular challenge includes weather conditions from year to year, something which massively influences outcomes. However, the most significant problem is that normal growers do not have a clearly defined “with” and “without” data set, since usually they will not conduct a large field trial by only converting parts of their farms to the new system. From a scientific perspective, it is difficult to draw meaningful comparisons between individual farms, due to quality fluctuations in crop management practices. These characteristics significantly impact the performance of individual farms and thereby on the comparison between SSF and conventional fertilization.

Against this background, this paper is providing the outcome of the comparison of two case study farms in Canada. The international network of agricultural economists, agri benchmark is closely connected to consultants and growers globally. Therefore, the data analysed subsequently has been provided through this network. The research question we seek to address is: how efficient and profitable is site-specific fertilization at the whole-farm level when using the Sure Growth Solution algorithm?

In the first part of this paper, the concept of the case study is presented including the key features of the region as well as those of the two farms which are compared. The SSF employed is then described in the second part which includes a description of the associated costs, such as input cost, machinery, equipment, and consulting costs. In the next section, fertiliser input and crop output of the two farms are laid out. In Chapter 3, the main findings are discussed, including the outcome from a sensitivity analysis regarding the prices for outputs and how changes of these figures impact the profitability of SSF. A variation caused by differences in fertilization rates and tillage systems will also be analysed. The paper ends with a discussion of results and some conclusions.

2 Case study description

The case study is based on data that is available from two farms which are located next to each other. They are situated at Langenburg, in south-eastern Saskatchewan, on the border to Manitoba. This is a so-called black soil zone which is characterised by loamy chernozemic soils. The average annual precipitation is 463 mm, of which 123 mm is snow. During the period from which data was available (2015 to 2017), the annual precipitation ranged from 282 to 475 mm.

The farm which represents the "with" scenario in the comparison is the Aberhart farm. The farm employs SSF based on application maps, which have been generated and supplied by Sure Growth Solutions[4]. Adjacent to this farm, the Hill Well farm did not adopt this practice, hence it is used to represent the "with-out" data set in this comparison. While the Aberhart farm did employ a rotation including barley, beans and peas, the benchmarking farm only produced wheat and canola. Since all main field operations on the Hill Well farm were contracted to Aberhart farms during the time span analysed here, management quality is assumed not to have influenced the outcome.

However, there was one important difference in crop management, that may have an impact on the outcome of the comparison: While Hill Well was applying conservation tillage the Aberhart farm is a no-till farm. The conservation tillage was carried out in the autumn using a cultivator to incorporate fertiliser and manage crop residue at a shallow depth of 4 inches. At Aberhart Farm, no-till is practiced following one heavy harrow pass in the autumn to manage crop residue at a shallow depth of 0.25-0.5 inches. In the spring, a seed hoe opener is used for direct sowing. In special excursus of this paper, it will be elaborated whether or not this difference is likely to influence the performance of Aberhart farms compared to Hill Well farm.

To generate a straight "with vs. without" situation, prices for inputs and outputs have to be normalised; without this measure it would be possible that the outcome is driven by differences in these prices.

3 Key features and elements of site-specific fertilization

Site-specific application of fertilisers is defined as the adjustment of farm management to the spatial variability of soils through variable-rate application of inputs enabled by GPS or GNSS (global navigation satellite system) (Pedersen and Lind, 2017b). According to Pedersen and Lind (2017a), this technological concept comprises geographical positioning, yield mapping, acquisition of information, decision support and variable treatment. However, the machines

[4] The website of the company offering the maps can visited with this link: www.suregrowth.ca

such as a spreader to apply inputs in a variable rate are just the tools to apply the decisions that have been taken in advance (Balafoutis et al., 2017).

The basis for that decision making are soil maps which link soil samples to a tracked position and shows all relevant soil properties like soil texture, available nutrients, chemical properties compaction and moisture content (Wollenhaupt et al., 2015). The second important input data are yield maps, which are generated by combine harvesters. It combines GNSS position data with crop yield data (Auernhammer and Demmel, 2016). By combining this data, so-called management zones are defined as homogenous conditions within the zone and significant heterogeneity between the zones (Balafoutis et al., 2017). The zones are agronomically treated in the same way. The size of the management zones should be applicable to respective machines while still being small enough to be homogeneous.

For Bullock and Bullock (2000), the connection of the technical possibility of SSF application on the one hand and knowledge about small-scale decision rules on the other is a complementary relationship. Crucial for decision making is a comprehensive knowledge of the relationship between crop yields, input quantities, soil properties and weather conditions (Bullock and Bullock, 2000). In case information on these factors is unsatisfactory, decision making is error-prone (Pierce and Nowak, 1999). Assuming that the quality of input data can easily be checked, the key challenge is to assess the quality of the decision-making process or the application maps.

4 Definition of normalised prices

The economic analysis of SSF is influenced by two main factors: improved yields and improved fertiliser productivity. Of course, improved yields must be valued by prices of the outputs. Since they fluctuate between the years, those changes would influence the outcome from the economic analysis of the technology. It is therefore necessary to hold prices constant. The way forward is to define so-called normalised prices.

The normalised prices for outputs and inputs have been generated by a simple average over the values observed throughout the timespan in which data has been gathered (2015 to 2017). The outcome is listed in Table 1.

Table 1: Normalised prices for output and inputs

Product	**Price** (in CAD)
Wheat	237.30 /t
Canola	479.18 /t
N	0.46 /lb*
P	0.52 /lb
K	0.33 /lb

* One lb equals 0.45 kg.

Source: Own calculation

5 Cost associated with site-specific fertilization

To spread fertiliser in a site-specific manner, a grower needs to have a machine that (a) can be steered for individual sections and (b) that can be managed by an external device with an application map. Based on the information received from the manager of the Aberhart farm, we assume that these features are a standard feature of modern spreaders and sprayers. Hence, no additional machinery investment cost is needed to realise SSF.

However, what is needed is (a) an activation and (b) time consuming training – both for the manager as well as for operators. For (a), respective cost is included in the service fee, that Aberhart farms pays to Sure Growth Solutions. The company also provides coaching services, soil sampling and analysis as well as a license for the farm management software. Table 2 displays all the cost items per acre[5] and at the whole farm level.

Table 2: Aberhart Farms cost for SSF

Matter of expense	Value
Coaching services, CAD/ac	2.50
Analytical (Soil sampling and analyses) CAD/ac	2.41
Software fees CAD/ac	0.14
Variable Costs, CAD/ac	5.05
Acreage, ac	10,357.13
Total cost consulting by SGS, CAD/year	52,303.52
Internal training, CAD/year	2,880
Trials, CAD/year	2,025
Data transfer, CAD/year	600
Fees for service provider, CAD/year	2,500
Total annual overhead costs, CAD/year	8,005
Management cost PF total, CAD/year	60,308.52
Management cost PF per, CAD/ac	5.82

Source: Aberhart farm data

In addition to the consulting costs of SGS, other costs are incurred in operations. Eight employees are trained for six hours twice a year to make the best use of the SSF systems. At an hourly wage of 30 CAD, this training results in training costs of 2,880.00 CAD/year. To test and further develop the existing zoning system, Terry Aberhart conducts regular field trials. 25% of the costs are borne by Aberhart Farms, with the remaining 75% paid by SGS. Those field trials incur 2,025 CAD per year for Aberhart Farms. Data transfer between the farm office and the machines in the field requires 20 working hours per year. At an hourly wage rate of 30 CAD, the costs of additional work and trials amount to 5,505 CAD. Additionally, activation and running fees for software within the agricultural machinery add up to 2,500 CAD annually.

[5] All data is presented in Canadian dollar per acre. 1 acre equals 0.4 ha; Over the period analysed in this paper, the average exchange rate was approximately 0.68 CAD/ EUR or 0.8 CAD/USD.

In our analysis we have been using 6 CAD/acre as the additional cost for the entire package of fees and cost to implement and run the SSF. When comparing this to a conventional system there is one minor item which sticks out: the annual overhead cost is fixed cost. That means the cost per acre is dependent on the size of the farm. However, since this cost item only accounts for less than 15% of the total, we suggest that this inaccuracy is reasonable and does not have the potential to significantly impact the outcome of the study.

6 Yields and fertilization rates comparison

The economics of SSF are driven by two potential factors: (1) cost savings and (2) yield improvements. Therefore, in this section respective figures for the two farms are displayed. Table 3 contains all the relevant data yield. To put results into perspective, the official regional yield statistics for the Langenburg region are shown as well.

Table 3: Canola and wheat yields at case study farms

Year, crop	Aberhart (t/ac)	Hill Well (t/ac)	HW rel. to AF	Langenburg region (t/ac)
2015, canola	1.10	0.98	–11%	0.91
2015, wheat	1.41	1.56	11%	1.03
2016, canola	1.03	0.95	–8%	0.92
2016, wheat	1.60	1.32	–18%	1.00
2017, canola	1.09	0.89	–18%	0.92
2017, wheat	1.81	1.71	–6%	1.22
Avg. (2007-2017), canola	1.07	0.94	–12%	0.92
Avg. (2007-2017), wheat	1.61	1.53	–5%	1.08

Source: Aberhart farm data

Table 3 shows that yield levels are higher at the Aberhart farm compared to the Hill Will farm. The only exception: wheat yields in 2015 were 11% higher at the Hill Will farm. Additionally, the yield advantage of the Aberhart farm is much more pronounced in canola than in wheat. Finally, it is worth noting that regional wheat yield levels are much lower than on the two case study farms. This is significant because it proves that the Hill Will farm was not exceptionally poorly managed and that yield difference between the two case study farms can therefore be explained primarily by the advantages generated by site-specific crop management.

Table 4 shows the average amounts of nitrogen (N), phosphorus (P) and potassium (K) applied at the two case study farms. The Saskatchewan government does not publish any numbers on average fertiliser use in the region, hence no chance to benchmark this farm data against regional standards.

Table 4: Fertilization rates Aberhart (AF) and Hill Well (HW) farm (in lb/ac)

	Canola			**Wheat**		
	N	**P**	**K**	**N**	**P**	**K**
2015, AF	103.7	33.8	24.3	113.8	31.6	21.0
2015, HW	93.6	41.8	23.4	108.8	38.7	28.6
2016, AF	113.3	35.5	19.7	113.3	38.2	21.0
2016, HW	99.6	39.3	24.7	98.3	38.0	27.0
2017, AF	117.4	40.7	36.2	86.3	41.1	37.7
2017, HW	99.6	39.3	24.7	98.3	38.0	27.0

Source: Aberhart farm data

When one examines the fertilization figures more closely, it appears that in canola, the Aberhart farm on average applied 14% more nitrogen than the Hill Will farm and 10% more K. However, in P the Hill Will farm was 10% more intensive than the Aberhart farm. Depending on the nutrients, the difference in wheat were only rather moderate: -4 to +3%. This finding coincides with the yield differences discussed in the previous section of the paper: canola yields on average were 14% higher at the Aberhart farm; in wheat the gap was only 5%. This raises the question, whether the significant difference in canola fertilization can be attributed to the use of SSF or whether this is due to different farm management.

7 Economics of site-specific fertilization

In this chapter, the results from a gross margin calculation are presented. As explained in the concept, this is reasonable, because no additional investments are associated with the implementation of SSF, hence no changes in fixed cost. There is however one deviation from the standard gross margin calculation: in the case of the Aberhart farm we added the 6 CAD/acre of additional cost caused by the various services and fees (see Table 2) to the direct cost (see Table 5).

Table 5: Gross margin data for Aberhart (AF) and Hill Well (HW) farms (in CAD/acre)

		Gross revenue		Direct cost*		Gross margin		Margin
		AF	HW	AF	HW	AF	HW	AF vs. HW
2015	Wheat	335	370	158	154	176	216	–39
	Canola	527	472	182	173	345	299	46
2016	Wheat	380	313	162	139	218	174	45
	Canola	494	455	197	184	297	271	26
2017	Wheat	429	405	158	150	271	255	16
	Canola	522	429	202	193	320	236	84
Av.	Wheat	381	363	159	148	222	215	7
	Canola	514	452	194	183	321	269	52

* For Aberhart farm in addition to the expenditures for seed, fertilisers and crop care the cost of SSF-trainings, trial, fees and alike of about 6 CAD/acre have been added.

Source: Aberhart farm data

As can be seen in Table 5, except for one crop/year event in 2015 in wheat, the SSF was superior over the conventional fertilization. The advantage is particularly high for rapeseed (53 CAD/acre) but even in wheat the 7 CAD/acre translate to more than 70,000 CAD for the whole farm. Across the entire rotation the average benefit per acre is 29.50 CAD.

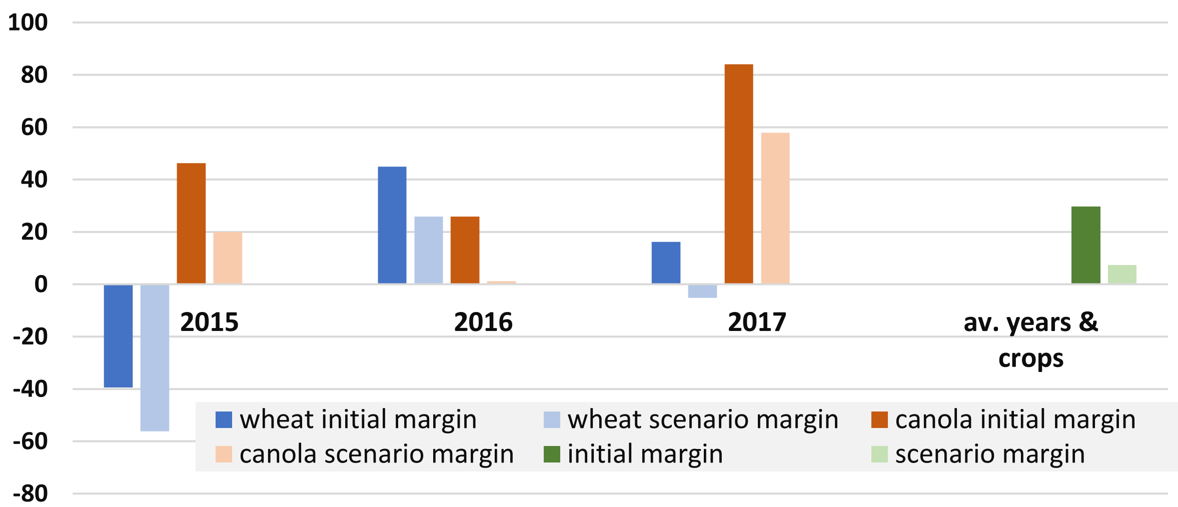
However, as mentioned in the concept section of this paper, the economic performance of this precision farming concept is likely to fluctuate in line with changes in output and input prices. Hence, the following sensitivity analysis we are going to check how exactly different price levels modify this outcome. We also must evaluate the issue of significantly higher nitrogen fertilization rates at the Aberhart farm (see Table 4).

8 Sensitivity analysis

A sensitivity analysis of the results from the previous chapter will now be executed. The variables to be varied are the prices of wheat and rapeseed. Furthermore, we need to address the issue of higher fertilization rates of the Aberhart farm in canola as well as the possible impact from the differences in tillage systems.

Since we want to address the riskiness of SSF, we only modify figures in a way that causes the outcome to be less profitable than the standard situation. Consequently, we will be analysing lower commodity prices, because under such conditions, the yield advantage from SSF will be less valuable. Considering the evolution of Canadian commodity prices over the last decade, it appears that a 50% cut in commodity prices might be a realistic option. Considering normalised prices (see Table 1), this implies a wheat price of 118 and canola prices of 240 CAD/t. When implementing these scenario prices into the gross margin calculation, the outcome can be presented as in Figure 1.

Figure 1: Gross margin gap AF vs. HL farm - Initial and low commodity price scenario (in CAD/acre)



Source: Own calculations

This calculation reveals that a 50% cut in output prices does lead to a massive reduction in the economic value of SSF, but there is still a relevant economic benefit. On average across the entire rotation, the benefit is 9 CAD/acre. More importantly, in wheat the net benefit would be -7 CAD/acre.

In addition, we need to address the issue of significant differences in nitrogen fertilization between the two farms in canola. Provided this gap is just driven by a different mindset of the two farm managements, the respective gap in gross margin cannot totally be attributed to the use of SSF. We therefore make up the following calculation - we assume that the Hill Will farm would have applied the same amount of nitrogen as the Aberhart farm. The key question is: what would have been the impact on yield and gross margin? First, we calculated the average nitrogen productivity in canola which is 9.6 kg canola per lb of N. Since we care about the marginal productivity of nitrogen, we assumed that this is 50% of the average productivity (4.8 kg of nitrogen per lb of N). We than calculate the gap in nitrogen fertilization (13.8 lb N/ac) and multiplied that by 4.8 which yielded an average increase in canola output of about 66.9 kg/ac. Multiplied by the canola price of 479 CAD/t, the additional revenue is 32 CAD/ac. The additional cost for the increase in nitrogen fertilization is 19.1 CAD/ac. When implementing these changes to the figures in Table 5, it appears that the increase in gross margin of the SSF system goes down to 26 CAD/ac (about 50% of the initial value). The average gross margin improvement across the entire rotation would be 16 CAD/ac.

Excursus: Tillage system impact on yields

The analysis of the case study farms revealed that SSF is more profitable than flat rate application. However, since the two farms practice different tillage systems, it needs to be checked whether this difference could have significantly impacted that finding. There is an assumption that no-till causes higher yields vs. conventional tillage in the semiarid region. This concept is due to the presence of higher reserves of plant-accessible water in the no-till system on account of the fact that the soil is not mechanically disturbed and exposed to drying up. The higher soil albedo covered by mulch offers more reflection and reduces soil warming. Furthermore, it might allow to catch winter snow (Earl May et al., 2020; Lafond et al., 1992).

An increase of plant-accessible water was shown by Brandt (1992) in a wheat-canola-wheat rotation for Scott, Saskatchewan. During the 12-year trial period the no-till system compared to the non-inversion tillage showed higher soil moisture content in nine years, and no difference in the others. Subsequently, the yield was higher in nine years while it decreased in three years by using no-till. The arithmetic average depicts a yield benefit for no-till of 9.2% for stubble wheat, 4.9% for wheat following canola and 0.9% for canola. Amongst the three crops, the average advantage was 5.0%.

Other studies under approximately comparable climatic conditions from Smith et al. (2012), McConkey et al. (2012) and Xin et al. (2021) did not reveal any systematic yield advantages for no-till over conventional tillage. Under more humid conditions, Khakbazan and Hamilton (2012) report 7.3% higher yields for wheat (not statistically significant) and 1.6% less yield for canola (statistically significant) when grown in a no-till system compared to a conservation tillage environment.

Overall, it seems unclear whether and to what degree under semi-arid conditions a no-till system can be said to provide a yield benefit. On the other hand, some results indicate a substantial effect. We therefore did a scenario analysis: In a worst-case scenario we have assumed a yield advantage for no-till of about 5%. We therefore reduced AF yield data by 5%. Based on this, we concluded that SSF in wheat would no longer be profitable. However, for the whole farm the net benefit is about 6 CAD/ac.

9 Discussion and Conclusions

Given the key challenge in economic assessment of SSF is to compare the quality of application maps, it is difficult to put results from this analysis into perspective. This is because the economic literature currently does not address this issue. The only study to use different agronomic logics to steer SSF is Knight et al. (2009). However, regarding SSF of nitrogen, the study only evaluated basic concepts such as (a) historical yield data or (b) shoot density and (c) canopy size.

Lambert and Lowenberg-DeBoer (2000) reviewed 108 studies in a meta study to summarise information on the profitability of precision farming tools. Of those studies reporting numerical estimates at all for SSF, 72% of corn studies and 20% of wheat studies showed profits. Furthermore, the range of net returns for this technology when applied in wheat goes from 4.7 USD/ac to 31.3 USD/ac. For corn (7 to 9 USD/ac) and sugar beets (48 USD/ac) respective values tend to be higher (Lambert and Lowenberg-De Boer, 2000). In 2007, Griffin conducted field trials on 90 farms across the UK. In each location two fields with similar levels of soil variation were compared. The benefits of SSF ranged from -115 €/ha to +172 €/ha depending on site characteristics (Griffin, 2007).

Thrikawala et al. (1999) confirmed that site-specific heterogeneity influences SSF profitability in corn cultivation. Their study concluded that SSF of nitrogen is less profitable than uniform application on fields with low overall fertility and low average heterogeneity. Where soil heterogeneity increases, SSF of nitrogen creates higher net returns than those with uniform application. In a three-year empirical model, Liu et al. (2006) examined data of on-farm corn yield experiments. As they took weather and precipitation into account, the authors found that rain-fed areas' yield functions could hardly be predetermined. They showed that SSF of nitrogen was not able to cover the additional costs it creates. Schimmelpfennig (2016) conducted a regression analysis and found that compared to other precision ag technologies, variable rate application in general has a positive but lesser impact on net returns of US corn farms, assuming that “higher capital expenditures (are) likely offsetting some of the gains from using the technology”.

Against this backdrop, the finding from this study is in a reasonable range. Moreover, a negative outcome – which seems possible based on the scenario calculations – would also be in line with other results.

Under the conditions of the two case study farms in Canada, SSF based on the Sure Growth application maps is profitable under all considered scenarios. The return-on-investment ranges from 117% to 500%. In a situation where the gap in canola N-fertilization is not associated with the SSF and the no-till system does indeed generate an advantage for the Aberhart farm, SSF is no longer profitable. However, since the innovation is not associated with a massive long-term increase in cost of production, and the annual cost is rather marginal compared to total cost (6 CAD/ac vs. about 160 CAD/ac across all crops and years), the risk is not significant. It seems reasonable to conclude that trying SSF is a strategy worth considering for crop producers.

Given all the uncertainties and open questions, the study underpins the need for more in-depth applied research at the farm level on the economics of SSF and related digital tools. A systematic comparison of different service providers for application maps is also badly needed, since their quality as well as the quality of data used is of decisive importance for the outcome of the economic performance of SSF.

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Profitability of Site-Specific Fertilization based on Sure Growth Solutions -
A Canadian Case Study (2024/10)

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