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Value of Map Sharing between Multiple Vehicles using Automated Section Control in the Same Field

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Abstract. Large area farms and even moderate sized farms employing custom applicators and harvesters have multiple machines in the same field at the same time conducting the same field operation. As a method to control input costs and minimize application overlap, these machines have been equipped with automatic section control (ASC). Over application is a concern especially for more irregularly shaped fields; however modern technology including automated guidance combined with automatic section control allow reduced doubling of input application including seeds, fertilizer, and spray. Automatic section control depends on coverage maps stored locally on each vehicle to determine whether or not to apply input products and up to now, there has not been a clear method to share these maps between vehicles in the same field. Telematics utilizes a cloud computing platform and cellular connectivity which in rural areas is known to have limited service levels. Planting operations were simulated for two 16-row planters, each using two John Deere GreenStar3 2630 monitors, simulated GPS location data stream, electronic rate control units, and individual row unit clutches to have control at the finest granularity. Each simulated planting unit is equipped with automatic section control and telematics gateways to share coverage map data from the first planting unit to JDLink cloud infrastructure then out to the second. This study evaluates seed cost savings from reducing over application because coverage maps are shared between planting units. Each field was run twice using parallel tracking, once each with and without coverage map sharing to observe the extent of over application. The field level data were then taken to examine a fictional 1,215 hectare farming operation where the field level data was used as a partial composition of the farm operation. The average farm savings was $58,909 per year. Additionally, using the 8,008 scenarios, time value of money was examined to determine the minimum area required annually for a five year breakeven for the technology. As farm input costs increase relative to crop prices, reducing over application will be critical to sustainability.

Keywords. *coverage map sharing, wireless, telematics, automated section control.*

Introduction

Precision agriculture has evolved over the years from yield data collection to manual machine guidance, automatic machine guidance and electronic application rate control. Instead of enabling and disabling the planter's row units all at one time, it is possible to control each row unit individually. Automatic section control (ASC) has reduced seed waste by reducing the occurrence of double planting. At today's seed cost, this reduction of waste can lead to significant savings to a farmer's balance sheet.

The farm equipment industry is entering an era where bigger may not always be better. Larger equipment can take longer to set up and prepare to run in the field. Additionally, larger equipment can be difficult to transport between farm fields. In some cases, farmers turn to multiple machines operating in the same field to be more productive. However, with multiple machines running in the same farm field, some economic efficiency is lost due to ASC only understanding where the individual planter has been, not the others running in the same field.

Precision agriculture manufacturers are starting to offer connected machine solutions which enable sharing coverage map data between machines operating in the same field for automatic section control. This study determines the seed cost savings from two identical planters in the same field sharing coverage maps.

Seven different fields are used in an effort to correlate seed cost savings and differing field shapes and sizes measured as perimeter to area ratios. Data on surplus areas were collected using real-time farm equipment simulators. These data were analyzed by determining how differing proportions of each field type impact the optimal decision for a representative sized row crop farm. Using the identified cost savings, an annual amount of farmland area is calculated for breakeven returns in addition to positive five-year payback periods for farms comprised of different proportions of the seven field types.

Background

ASC Coverage Map and Why Sharing is Important

The ASC coverage map includes information regarding where work has been completed. It is a record of where product has been applied or seed has been planted. The coverage map is stored locally on the machine or implement associated with performing the work. When one ASC compatible implement is operating in a field, the resulting coverage map is similar to the one in Figure 1.

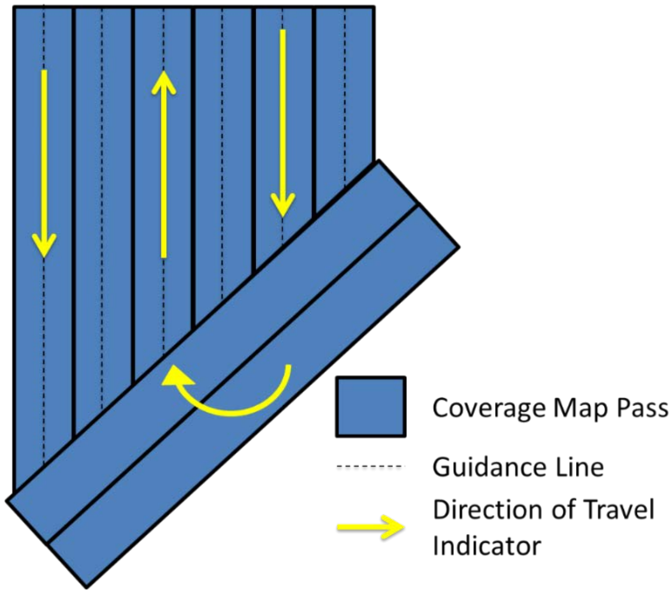


Figure 1 Coverage map example for 1 ASC implement in a single field

There are challenges when two (or more) ASC capable farm implements are performing the same operation in the same field at the same time. The individual machines have information relative to where they have applied product, but do not understand where the other has applied product without a way to share their individual coverage maps. The individual coverage maps will likely include areas of unintended product application similar to the hypothetical maps in Figure 2.

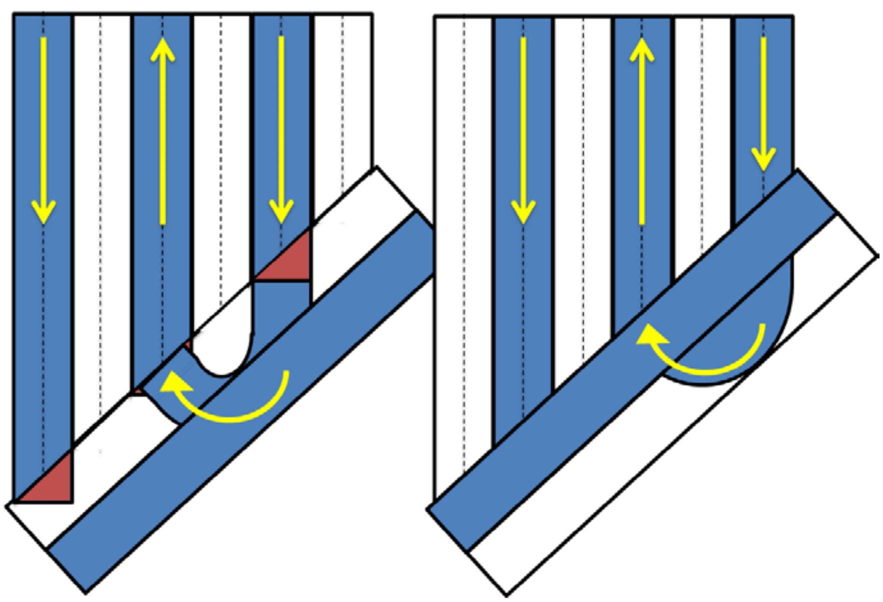


Figure 2 Two ASC implements operating in the same field, not sharing coverage maps

Deere and Company offers cellular networks as a communication solution to share the ASC coverage map between units in the same field. For cellular connected farm vehicles equipped with a telematics gateway, coverage map sharing can use existing infrastructure with no additional hardware required for purchase. When coverage map sharing is possible, the resulting coverage map is expected to be similar to Figure 3 where the dark blue represents the locally applied product and the cyan coverage is the work completed by the partner machine.

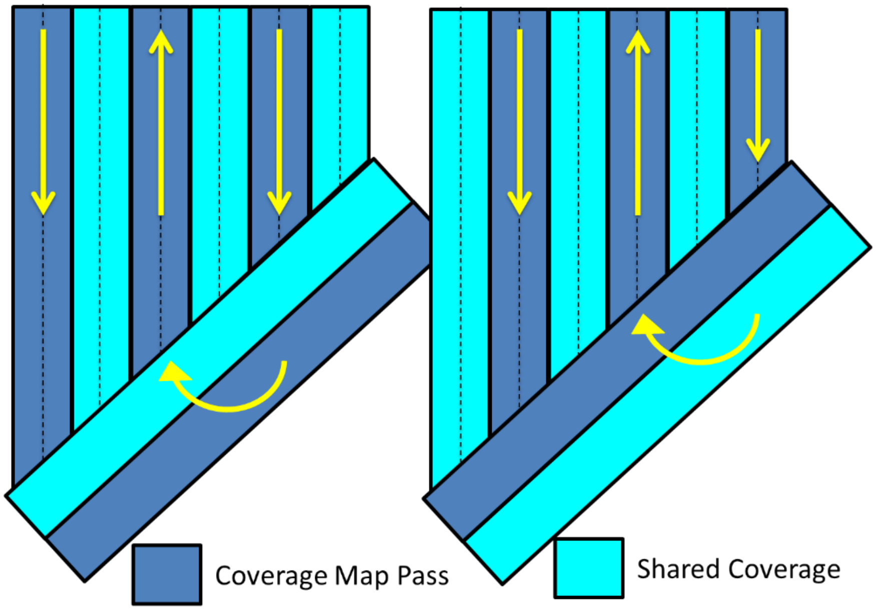


Figure 3 Coverage maps from two ASC implements in the same field

When using the cellular solution, planting units can come and go as needed because the coverage map is stored on the telematics server. The coverage map data is retained for 60 days. Topography plays a factor in cellular network signal reliability. It is possible that specific areas of fields that planting units could drop in and out of network coverage resulting in a delay in the coverage map being sent to or received by the partner planting unit. The ASC coverage map data builds a holding queue locally on the planting unit until a network connection can be obtained and the coverage map is sent or received. This delayed communication could result in the planting units transmitting or receiving coverage map data after an area has been planted.

Given a review of the technology, a literature search was conducted and is presented in the following chapter. Specific literature for coverage map was not found. However, literature was reviewed for the individual technology components to coverage map sharing.

ASC Economics for Row Crop Planters

Precision agriculture companies have marketed automatic section control (ASC) as a tool to reduce input overlap, therefore reducing input costs. The ASC savings have commonly been understated due to studies focusing exclusively on a single farm task, such as spraying. Shockley et al. (2012) studied the impact on sprayers separate from planters. They inspected the role of field shape along with an economic analysis including rate of return and payback period (Shockley, Dillon, Stombaugh, & Shearer, 2012).

Shockley et al. (2012) evaluated a 24-meter sprayer equipped with ten equal width nozzle control sections and a 16-row planter with each row independently controlled. A desktop computer tool (Field Coverage Analysis Tool, FieldCAT) simulated coverage within each of these fields, using parallel guidance lines and documenting overlap within each field (Shockley, Dillon, Stombaugh, & Shearer, 2012). Smaller, irregular fields resulted in greater increases in average net returns, greater returns on investment and shorter payback period (Shockley, Dillon, Stombaugh, & Shearer, 2012).

Smith et al. (2013) built upon Shockley et al. (2012) by expanding the analysis to 553 real fields totaling 19,868 hectares. The importance of field size and shape was confirmed to be important to payback period. In northwest Kansas fields, the investment in ASC payback period was less than a year. As field sizes increased, the net benefits of ASC decreased because the field area to headland area ratio decreased. Automatic section control payback period was even shorter when the same area was sprayed during the same growing season. Additional applications on the same field gave the opportunity to spread costs over more area. If a 404 hectare farm is sprayed three times per year, the opportunity for reduced system costs per hectare due to more application area to cover is possible.

As demonstrated in previous ASC studies (Smith et al., 2013; Runge et al., 2014), payback period is highly dependent on field size and shape. The larger the field, the less impact ASC has on profitability. This indicates that the potential profitability of ASC is directly related to the number of on/off cycles commanded by the ASC application (Runge, Fulton, Griffin, Virk, & Brooke, 2014).

Telematics Data in Agriculture

Telematics and telemetric data is broadly described as data measured remotely. The adoption of telematics has sharply increased in the last 3 years in the agricultural industry. In their 2015 Precision Agricultural Services Dealership Survey results, Erickson and Widmar (2015) report that 20% of respondents are using telematics to transfer data for their precision agriculture business up from 15% and 7% in 2013 and 2011, respectively. This technology shares a quick adoption rate with machine guidance (Erickson & Widmar, 2015). What is interesting is that there is very little research and literature on how telematics data is being used by the end user and others for primary and secondary uses of data in agriculture (Griffin, et al., 2016).

JDLink is Deere & Company's cloud system for telemetric data. JDLink allows machine owners to remotely monitor a single machine or fleets from a single computer or mobile device. JDLink data is transmitted using the machine's modular telematics gateway and displayed in a web based portal. Types of data transmitted by machines include machine usage statistics (fuel consumption, utilization, idle time and more), machine health information (diagnostic trouble codes), and machine location information for location services. If properly configured, electronic alerts can be sent to take action such as notifying a dealer technician of a diagnostic trouble code or alerting law enforcement authorities that a machine has been moved outside the expected work area. Wireless Data Transfer uses the machine's telematics gateway to move agronomic data and guidance lines to the user's MyJohnDeere.com account for post processing. A JDLink Connect subscription costs $600 for the first machine; and up to ten machines costs an additional $400 per machine (Sloan Implement, 2016). Coverage map sharing using the MTG builds an additional value proposition in Deere's telematics product offering.

Economic Methods

In previous auto section control (ASC) studies, a marginal analysis was conducted to estimate the savings in seed costs per hectare and yield loss per hectare due to over-planting

(Shockley, Dillon, Stombaugh, & Shearer, 2012) (Smith, Dhuyvetter, Kastens, Kastens, & Smith, 2013) . Methods and economic theory similar to Shockley and Smith will be applied to the scenario where two ASC compatible planters equipped with map sharing coverage operate in the same field. Coverage map sharing using cellular connectivity costs $1,495 per planting unit and requires the farmer to have an active JDLink subscription for an additional $1,000 per year per farm.

Economic Returns of Coverage Map Sharing

The economic analysis will be reported as savings or cost per hectare across hypothetical farm operations using a partial budgeting tool. Net returns on investment will be considered by dividing the new net earnings (savings) by the investment cost. Payback period is the length of time required to pay back the investment in coverage map sharing with an assumed interest rate and a no salvage value (100% depreciation after the payback period). In addition to calculating the number of breakeven area required of each farm scenario, time value of money will be considered to determine if the purchase produces a positive net present value for a five-year investment schedule at a seven percent interest rate.

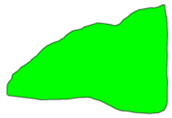
Data

The benefits of automated section control (ASC) are partially lost when two or more planters are operating as a team in the same field because without coverage map sharing, each individual planter unit only has information relative to where that specific planter has been. This results in ASC only turning on/off sections based on the locally stored coverage map for the specific planter unit. Figure 4 provides the geometric shape and a summary of the fields selected for this study. The farm fields were selected randomly based on their varying areas and shape.

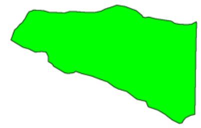
To evaluate technology over a range of field geometries, fields ranging from regular rectangular shapes with relatively consistent pass lengths to irregularly shaped fields with varying pass lengths were considered. East Field contains 96 guidance passes and the smallest perimeter to area ratio, 4.23E-03. East Field’s area is 89 hectares. Northwest contains 14 guidance passes and the highest perimeter to area ratio is 2.00E-02. Northwest’s area is 5 hectares. The data collection for each field shape will include testing with and without external boundaries. Each field variation will be completed with and without coverage map sharing to quantify the number of times ASC intersects with local coverage and shared coverage. Double planted areas are considered wasted seed. When collecting data, the mission plan was to complete two headland passes and then parallel track on the pre-loaded guidance lines. The primary area of interest is when the interior field passes intersect with the exterior headland passes. For additional details see (Bennett, 2016).

Analysis and Results

Automated guidance systems gain their efficiencies in the middle of fields as opposed to the gains from ASC that are on the ends of the field where machinery are turned around. In square and rectangle shaped fields, ASC has limited impact relative to irregularly shaped fields where it has the greatest impact. Field perimeter to field area ratio (p/a) is a field shape irregularity metric that allows numerical comparison instead of comparing fields based only on area. Field size, perimeter, and p/a ratio were computed for field boundary and coverage boundary (Table 1).

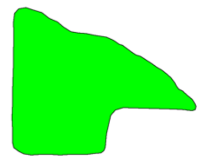


Name: Mid-South
Perimeter: 1160 meters
Area: 5.5 hectares
Perimeter to Area ratio: 1.68E-02
Longest guidance line: 297 meters
Guidance pass total: 18

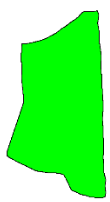


Name: Mid-North
Perimeter: 1008 meters
Area: 6.3 hectares
Perimeter to Area ratio: 1.74E-02
Longest guidance line: 361 meters
Guidance pass total: 17

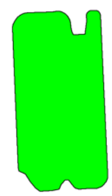
Name: Northwest
Perimeter: 1049 meters
Area: 5 hectares
Perimeter to Area ratio: 2.00E-02
Longest guidance line: 320 meters
Guidance pass total: 14



Name: South
Perimeter: 1273 meters
Area: 9.3 hectares
Perimeter to Area ratio: 1.41E-02
Longest guidance line: 365 meters
Guidance pass total: 26



Name: Neb-West
Perimeter: 1879 meters
Area: 18.1 hectares
Perimeter to Area ratio: 1.02E-02
Longest guidance line: 651 meters
Guidance pass total: 33



Name: Neb-East
Perimeter: 2523 meters
Area: 31.3 hectares
Perimeter to Area ratio: 7.89E-03
Longest guidance Line: 769 meters
Guidance pass total: 31

Name: East Field
Perimeter: 3767 meters
Area: 89 hectares
Perimeter to Area ratio: 4.23E-03
Longest guidance line: 762 meters
Guidance pass total: 96

Figure 4 Characteristics for fields under consideration

Table 1 Field Perimeter, Area, and Perimeter to Area ratio

	Perimeter (m)	Field boundary		Coverage boundary	
		Area (ha)	Perimeter to area $(m/m^2)*1000$	Area (ha)	Perimeter to area $(m/m^2)*1000$
East Field	3767.3	89.1	4.2	88.4	4.3
MidNorth	1017.3	5.9	17.4	5.7	17.9
MidSouth	1160.5	6.9	16.8	6.6	17.6
NorthWest	1048.9	5.2	20	5.2	20.2
South	1373	9.8	14.1	9.5	14.4
NebEast	2523.8	32	7.9	31.5	8
NebWest	1879.5	18.5	10.2	18.2	10.3

For both cases when ASC utilizes field boundary or coverage boundary, the relative ranking of fields by p/a ratio remain constant. When the ASC utilizes field boundary, East Field results in the lowest p/a ratio at 4.23E-03 due to its high area of 89.1 hectares and 3767.3 meter perimeter, i.e., a regularly shaped field. The highest p/a ratio is in NorthWest, 2.00E-02. Its area is 5.2 hectares and 1048.9 meters perimeter indicating a highly irregularly shaped field. When the ASC utilized coverage boundary, East Field had p/a ratio of 4.26E-03 while NorthWest had 2.02E-02.

The field shapes were specifically selected for this study to observe the relationship between field shape and size to the amount of double-planted area. Surplus area is defined as the difference between two planting units working together in the same field with and without coverage map sharing. Full results from the data runs with respect to surplus area are presented in Table 2.

The results indicate that difference in area between using a pre-loaded field boundary and the planting unit drivers creating the boundary by planting the field headlands range from 0.7% to 4.41% (Table 2). East field resulted in the smallest percent difference between using the field boundary and the coverage boundary. Mid-South resulted in the highest error between field boundary and coverage boundary, 4.41%. It is possible that the observed error is related to the simulation error when collecting data. In all data collection runs, the coverage boundary use case resulted in a lower surplus area.

Field boundaries pre-loaded for planting have an advantage for the planter operator as it clearly defines the intended area to be planted. This is especially beneficial when the operator is not familiar with the field's surroundings. The downside is if the field's farming area changes, increase or decrease, due to field boundaries not easily edited in the tractor cab. It would be less time consuming to redrive the field boundary, matching the new farmable area, rather than edit on the desktop computer in the farm office. If the field area decreases then there is a chance of ASC applying product or seed in an area unintentionally. If the field area increases then ASC will prevent application in the new area. The observed error between the field boundary use case and the coverage boundary use case decreases as field sizes increase.

Table 2 Area Comparison for Coverage Map Sharing of Field Boundary to Coverage Boundary

		Field boundary			Coverage boundary				
	Planted area without map sharing (ha)	Planted area with map sharing (ha)	Surplus area (ha)	Overlap area (%)	Planted area with map sharing (ha)	Surplus area (ha)	Overlap area (%)	Area difference (ha)	Area Difference (%)
East Field	96.3	89.1	7.2	8.1%	88.4	7.9	8.9%	0.6	0.7%
MidNorth	6.8	5.9	0.9	15.8%	5.7	1.1	19.2%	0.2	2.9%
MidSouth	8.2	6.9	1.3	18.9%	6.6	1.6	24.4%	0.3	4.4%
NorthWest	6.3	5.2	1.1	20.9%	5.2	1.2	22.3%	0.1	1.2%
South	11.3	9.8	1.6	16.1%	9.5	1.8	19.1%	0.2	2.5%
NebEast	34	32	2	6.3%	31.5	2.5	7.9%	0.5	1.5%
NebWest	20.8	18.5	2.4	12.8%	18.2	2.6	14.2%	0.2	1.3%

A linear relationship between p/a ratio and surplus area was observed. As field shapes become more irregular, i.e. p/a ratio increases, larger surplus areas were expected when ASC and coverage map sharing was not utilized (Figure 5). Data presented on the y-axis of Figure 5 come from Table 2. Based on the estimated coefficients from an ordinary least squares (OLS) estimation, a regression line was calculated for both field boundary and coverage boundary (Figure 5). A substantial portion of the variability in the data were accounted for in this binary relationship. The r-squared values for field boundaries and coverage boundaries were 0.865 and 0.893, respectively. These r-squared values indicate that the estimated line explains nearly 90% of the variability in the data and can be loosely interpreted as a close fit between the observed data and the estimated regression line.

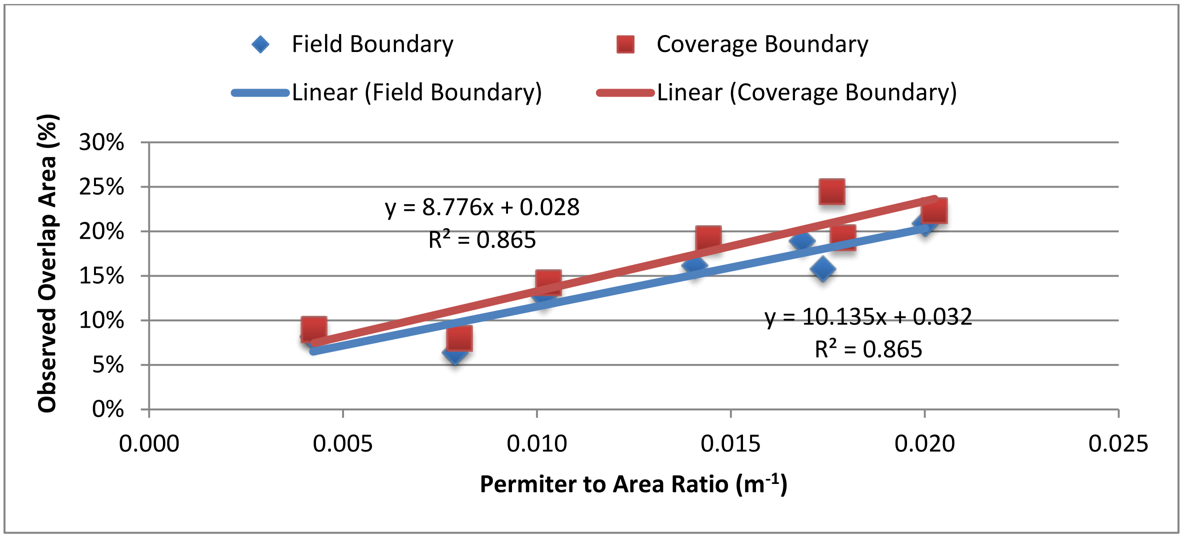


Figure 5 Relationship between Perimeter to Area Ratio and % Overlap Area

The number of planted hectares required for the cellular coverage map sharing using the previously determined cost savings per hectare to breakeven was evaluated. The number of hectares annually required for each field such that a positive payback is realized in one year are presented in Table 3. NorthWest using a field boundary results in the fewest hectares to use the service for one year payback at 55.6 hectares. Northwest also has the highest p/a ratio of any of the seven fields evaluated. For the scenario of coverage boundary, NebEast had the greatest area requirement of 183.4 hectares to achieve a positive payback in the first year of operation. These results are relevant if the entire farming operation is comprised of fields with identical p/a ratios; however in practice farms have several fields representing a range of p/a ratios.

As an alternative to considering that each farming operation consists of fields with identical p/a ratios, a series of hypothetical 1,215 hectare farms comprised of differing combinations of the seven fields were considered. These proportions were iterated using ten percent granularity that resulted in 8,008 different scenarios. Using the 8,008 farm composition scenarios, annual savings and net present value were calculated using an assumed constant 88,900 seeds per hectare and $3.86 per 1,000 seeds (Plastina, 2016). An excerpt of these combinations are presented in Table 4.

Table 3 Area required for 1 year system payback

Field Boundary	Perimeter to Area ratio (m/m^2)	Savings per hectare (cost savings)	Required Area (hectares) for 1 year payback
East Field	4.230E-03	$27.93	142.9
MidNorth	1.738E-02	$54.09	73.8
MidSouth	1.684E-02	$64.95	61.4
NorthWest	2.002E-02	$71.73	55.6
South	1.407E-02	$55.40	72.0
NebEast	7.888E-03	$21.76	183.4
NebWest	1.018E-02	$43.80	91.1
Coverage Boundary	Perimeter to Area ratio (m/m^2)	Savings per hectare (cost savings)	Required Area (hectares) for 1 year payback
East Field	4.261E-03	$15.70	254.1
MidNorth	1.790E-02	$52.73	75.7
MidSouth	1.762E-02	$58.39	68.3
NorthWest	2.025E-02	$58.88	67.8
South	1.444E-02	$44.27	90.1
NebEast	8.005E-03	$12.61	316.5
NebWest	1.031E-02	$39.03	102.2

Table 4 Sample of Proportions of the Seven Fields for a 1,215 Hectare Farm

	East Field	MidNorth	MidSouth	NorthWest	South	NebEast	NebWest	Total
	$27.93	$54.09	$64.95	$71.73	$55.40	$21.76	$43.80	
FarmOp3932	10%	10%	10%	10%	10%	50%	0%	
Savings per hectare	$2.79	$5.41	$6.49	$7.17	$5.54	$10.88	$-	$38.29
Farm Savings	$3,390.65	$6,566.70	$7,885.07	$8,708.47	$6,726.10	$13,208.76	$-	$46,485.75
FarmOp3933	10%	10%	10%	10%	20%	0%	40%	
Savings per hectare	$2.79	$5.41	$6.49	$7.17	$11.08	$-	$17.52	$50.47
Farm Savings	$3,390.65	$6,566.70	$7,885.07	$8,708.47	$13,452.20	$-	$21,268.83	$61,271.92
FarmOp3934	10%	10%	10%	10%	20%	10%	30%	
Savings per hectare	$2.79	$5.41	$6.49	$7.17	$11.08	$2.18	$13.14	$48.27
Farm Savings	$3,390.65	$6,566.70	$7,885.07	$8,708.47	$13,452.20	$2,641.75	$15,951.62	$58,596.47
FarmOp3935	10%	10%	10%	10%	20%	20%	20%	
Savings per hectare	$2.79	$5.41	$6.49	$7.17	$11.08	$4.35	$8.76	$46.06
Farm Savings	$3,390.65	$6,566.70	$7,885.07	$8,708.47	$13,452.20	$5,283.50	$10,634.41	$55,921.01
FarmOp3936	10%	10%	10%	10%	20%	30%	10%	
Savings per hectare	$2.79	$5.41	$6.49	$7.17	$11.08	$6.53	$4.38	$43.86
Farm Savings	$3,390.65	$6,566.70	$7,885.07	$8,708.47	$13,452.20	$7,925.25	$5,317.21	$53,245.56
FarmOp3937	10%	10%	10%	10%	20%	40%	0%	
Savings per hectare	$2.79	$5.41	$6.49	$7.17	$11.08	$8.70	$-	$41.65
Farm Savings	$3,390.65	$6,566.70	$7,885.07	$8,708.47	$13,452.20	$10,567.01	$-	$50,570.10

A summary of the calculations are presented in Table 5. It was identified that the average cost savings for a whole farm operation was $58,909 and maximum savings of $87,085 and minimum savings of $26,418 resulting in a range of $60,667 for the cellular option.

Table 5 Estimated annual whole farm cost savings for scenarios

1,215	hectares			**Min**	**Max**	**count**
Min	$	26,418	1	$26,418	$32,484	23
Max	$	87,085	2	$32,484	$38,551	144
Diff	$	60,667	3	$38,551	$44,618	452
Total Savings for Farm Op			4	$44,618	$50,684	982
Mean	$	58,909	5	$50,684	$56,751	1585
			6	$56,751	$62,818	1940
			7	$62,818	$68,885	1673
			8	$68,885	$74,951	899
			9	$74,951	$81,018	274
			10	$81,018	$87,085	35

In addition to the estimated seed cost savings for farms composed of fields of similar shapes, net present value (NPV) was calculated using seven percent interest and a five year cash flow. Each of the 8,008 scenarios resulted in a positive NPV relative to not using coverage map sharing. Considering a NPV of zero is a good investment, the Goal Seek tool in Microsoft Excel was used to calculate the number of hectares for each farm composition scenario that resulted in a zero NPV for cellular communication. These results were broken down into ten ranges (Table 6). The ranges are equally spaced between the minimum value and maximum value. By examining the Accumulating percentage in Table 9, 91.12% of the scenarios required 45 hectares per year for 5 years to result in a net zero NPV. Compared to typical sized Midwestern farms, these results demonstrate that Coverage Map Sharing requires a relatively small usage annually for five years for two planting units working together to result in a good investment.

Table 6 Required hectares annually for 5 years for NPV to result in zero using cellular

Area (hectares)			Min	Max	Count	Population Distribution	Cumulative
Min	23	1	23	29	834	10%	10.42%
Max	77	2	29	34	3057	38%	48.59%
Diff	54	3	34	40	2325	29%	77.63%
		4	40	45	1080	13%	91.12%
		5	45	50	443	6%	96.65%
		6	50	56	171	2%	98.79%
		7	56	61	63	1%	99.58%
		8	61	67	24	0.3%	99.88%
		9	67	72	8	0.1%	99.98%
		10	72	77	2	0.02%	100.00%

If the farmer's equipment costs remain constant, technologies such as machine guidance, automatic section control and coverage map sharing unlock new economic potential resulting in the farmer's equipment costs being less expensive per hectares and new opportunities to pay more for cash rent. Any identified savings for a specific farm operation highly depends, not only on farm operation size and field shapes, but also on driving patterns and in-field obstacles. For this study and several previous ones, it was assumed there were no obstacles in the field to farm around and that all guidance lines are straight. Varying angle of approach into the headlands was done just by field shape, but infield obstacles would also influence approach angles too. This study is a conservative estimate of the potential cost savings from coverage map sharing because it only takes into consideration seed costs while planting and using automated section control. Automated section control has other use cases while performing additional farm operations such as nutrient application and spraying. It has been previously demonstrated that from proper implement control along with good seed and product placement, increased yields were observed.

Conclusion or Summary

Automatic section control has been saving farmers money for nearly ten years by reducing overlap while applying product. This has been enabled by having finer control over the machine and implement and through machine guidance. If a farmer desires to be more productive, he/she should consider two mid-sized planters instead of one very large one. Larger planters have longer setup time and are more difficult to transport. Additionally, it should not be assumed the two planters are the same width. Field shape could make it possible where a smaller planter could be more efficient in specific field areas where a larger planter is more efficient in the middle. Given p/a ratios of many farmers' fields, two mid-sized planters or sprayers have higher field efficiency than one larger machine and are able to cover more hectares per hour. Custom applicators are likely to devote multiple machines to the same field at the same time and can benefit from shared coverage map technology.

Seven different fields had simulated planting operations performed with two planting units in the field at the same time. Each field was run twice, once without coverage map sharing between the planting units and once with coverage map sharing enabled with the goal of calculating the amount double planted area in each field. With seed costs, the seed savings per hectare was determined for each field. As with any farm investment, it is important that there are economic advantages to making the purchase. The study demonstrated there are tangible economic benefits to investing with annual hectare requirement that can be attained by farmers for through a positive net present value of a five year investment. The seed savings per hectare is dependent on the field size, perimeter and the shape irregularity.

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