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Crop management recommendations: Agroptimizer decision support tool vs. local experts

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IN A BEAN POD:

- Agroptimizer recommendations for **soybean** resulted in increased yield and similar profit compared to expert recommendations
- Agroptimizer recommendations for **corn** resulted in similar yield and profit compared to expert recommendations
- There was no yield and profit risk difference between Agroptimizer-based and typical cropping systems for both crops
- Agroptimizer successfully identified cropping systems that resulted in high yield and profit for both crops

INTRODUCTION

There is a wide range of optimal management practices in farmers' fields which inevitably results in large crop yield variability (Rattalino Edreira et al., 2017; Mourtzinis et al., 2018). When yield variability due to crop management is coupled with farm characteristics such as soil types, available equipment and weather effects (e.g., drought, extended heat, etc.), total crop production may vary substantially. Therefore, the management practices that can result in the greatest yield may vary among different fields, even within the same region. Additionally, when considering the varying production costs among farms (e.g., seed and fertilizer costs, etc.), and the myriad of decisions a farmer must make before and during each growing season (Mourtzinis and Conley, 2023) the combined effect of all the above can substantially affect gross farm revenue. Clearly, identifying the cropping system for maximum profit under such uncertainty is a very difficult task.

To assist farmers with the decision-making process, decision support tools (DSTs) for major crops and management practices have been developed. To date the available DSTs typically assist farmers in choosing products, optimizing single management practices, planning operations etc. There is minimal information about the effectiveness of these tools to identify optimum management practices and increase farmer yield and profit in independent field trials. The lack of studies, that compare DSTs recommendations with farmers practices or with management recommendations of local experts, is an important issue for the adoption and use of such tools from farmers as there is no information about their effectiveness in providing accurate recommendations.

Although there are decision support tools that provide recommendations for single management practices (e.g., N rate for corn using MRTN (Illinois Fertilizer & Chemical Association, (2024)) or optimum maturity group for soybean using the Soybean Planting Decision Tool (Iowa State University of Science and Technology, (2018)), there are no tools that recommend optimum cropping systems (combination of multiple management practices) at the field level. Given all the well-known deficiencies of current agricultural research methods and current state of available DSTs, a machine learning cloud-based DST (Agroptimizer | **www.agroptimizer.com**), was developed to identify optimum corn and soybean cropping systems for greatest yield and profitability from among thousands of possible cropping systems a farmer can choose from in a single field. Agroptimizer, which leverages the power of artificial intelligence algorithms, estimates yield and projected profit by accounting for field location, soil type, weather conditions, and several management practices and associated costs. After computation, Agroptimizer goes beyond optimizing a single management practice and the cropping systems (interaction of several management practices) with highest probability of success are recommended to the farmer. The spatial coverage of Agroptimizer is extensive and coincides with the regions where most of corn and soybean are grown in the US (Fig 1).

Evaluation of algorithm-based DSTs in field conditions, which involve unexpected and unmanageable yield adversities, across a range of growing conditions is important. This approach is necessary for determining the adaptability and robustness of DSTs in real-world scenarios to ensure their practical utility and effectiveness in addressing the complexities of modern agriculture. The objective of this work was to assess the effectiveness of Agroptimizer to provide high yield and profitable corn and soybean cropping systems across Wisconsin.

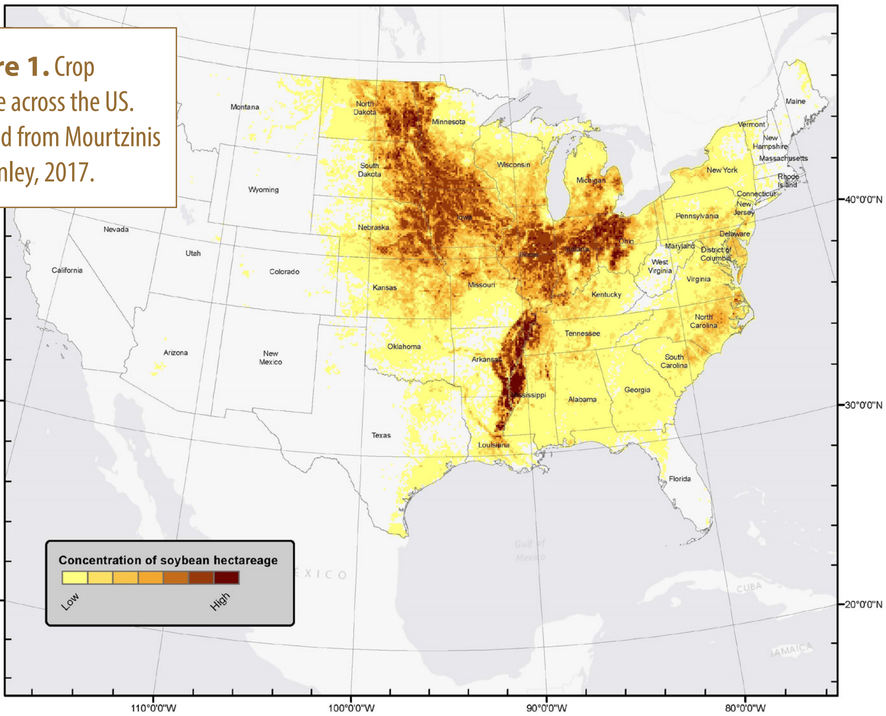

Figure 1. Crop acreage across the US. Adapted from Mourtzinis and Conley, 2017.

METHODS

Agroptimizer is a machine learning cloud-based DST that was developed by Agstat P.C. (**www.agstat.com**) with the objective to help farmers understand how different management practices (single and interactions) drive yield and profit at their farm. The tool utilizes algorithms, that were trained on vast amounts of synthetic data and combines them with historical weather data to optimize management practices for the entire cropping system to maximize yield and profit. The synthetic corn and soybean management and yield data were generated by proprietary algorithms and data augmentation techniques. The user-friendly interface allows users to input the location of their field (using google maps) and information about soil type and management practices they typically use along with associated costs and prices (Table 1). The tool allows the user to simulate the results of replicated field trials like they have been performed on their farm for 5 consecutive years adjusted for soil type, typical weather conditions and management practices that cannot change (e.g., irrigation) or management practices that the farmer does not want to change (e.g., tillage). Depending on the objective of the user (optimize a single or multiple management decisions), the tool identifies the management practices with the greatest probabilities to increase yield and profit in that field.

Seven experiments were conducted between 2021 and 2023 across WI (7 site-years) to evaluate the effectiveness of Agroptimizer-recommended corn cropping systems (Table 2) to increase yield and profit compared to UW-recommended systems ("Typical"). For soybean, seventeen experiments were conducted between 2021 and 2023 across WI (17 site-years) (Table 3). For each site-year, Agroptimizer provided cropping system recommendations for maximum yield ("Yield") or maximum profit ("Profit") cropping system depending on the objective. Yield and revenue differences between Agroptimizer and typical UW-recommended systems were evaluated in each, and across all site-years.

Table 1. Information incorporated in Agroptimizer decision support tool for corn and soybean management recommendations.

Current information incorporated for both crops
Coordinates using google maps
Weather information
Soil type (12 categories)
Irrigation (yes, no)
Tillage practices (conventional, no-till, reduced, strip-till)
Previous crop (10 categories)
Seed maturity
Seed treatment (None, Fungicide, Fungicide + Insecticide, Fungicide + Insecticide + Nematicide)
Planting date
Row spacing (inches)
Seeding rate (seeds/ac)
Projected selling price ($/bu)

Current information specific to each crop	
Corn	**Soybean**
Seed cost ($/80,000 seeds)	Seed cost ($/140,000 seeds)
Seed trait (conventional, GMO, Rootworm resistant)	Seed trait (conventional, GMO)
Fertilizer formula (N-P-K-S-Zn)*	Nitrogen fertilizer (lb/ac)
Fertilizer application time* (Fall, Spring, At planting, Post planting)	Nitrogen cost ($/lb)
Fertilizer application rate (lb/ac)*	Nitrogen application cost ($/ac)
Fertilizer cost ($/ton)*	Foliar fungicide/insecticide application cost ($/ac)
Fertilizer application cost ($/ac)*	Use of foliar fungicide/insecticide (yes, no)
Soil pH	Artificial drainage (yes, no)
Soil Phosphorus (4 levels)	
Soil Potassium (4 levels)	
Manure application (yes, no)	

* For up to three different fertilizers

Soil pH, Phosphorous and Potassium information for soybean will be incorporated in the next major update

Use of foliar fungicide/insecticide will be incorporated in the next major update

Table 2. Typical and Agroptimizer-recommended **corn cropping systems** for maximum yield and profit in each location.

	Location	Cropping System	Planting date	Seeding rate (seeds/ac)	RM	Seed Traits	Starter Fert (N-P-K-S-Zn lbs/ac)	Pre N (lbs/ac)	Post N (lbs/ac)	Seed cost ($/80,000 seeds)	Pre/Post N cost ($/ton)	Selling price ($/bu)
2021	ARL	Typical	29-Apr	36,000	107	GM+RW+F+I	30-76-60-0-0	0	207	280.59	378	4.00
	ARL	Yield	29-Apr	38,000	105	GM+F+I	30-76-60-0-0	37	55	245.87		
	ARL	Profit	29-Apr	34,000	99	GM+F+I	30-76-60-0-0	64	0	213.38		
	LAN	Typical	26-Apr	35,000	105	GM+F+I	14-35-45-0-0	120	0	250	378	4.22
	LAN	Yield	26-Apr	40,000	105	GM+F+I	14-35-45-0-0	101	0			
	LAN	Profit	26-Apr	30,000	105	GM+F+I	14-35-45-0-0	101	0			
	DAL	Typical	15-May	32,500	100	GM+RW+F+I	39-80-60-0-0	0	141	200	215	4.75
	DAL	Yield	8-May	39,000	104	GM+RW+F+I	39-80-60-0-0	0	176			
	DAL	Profit	8-May	39,000	104	GM+RW+F+I	39-80-60-0-0	0	71			
2022	ARL	Typical	12-May	36,000	102	GM+RW+F+I	18-22-60-12-10	125	53	294.6	670	5.50
	ARL	Yield	12-May	40,000	102	GM+RW+F+I	18-22-60-12-10	125	70			
	ARL	Profit	12-May	40,000	102	GM+RW+F+I	18-22-60-12-10	125	0			
	LAN	Typical	11-May	35,000	105	GM+F+I	14-35-45-0-0	106	0	303.5	800	5.37
	LAN	Yield	11-May	40,000	105	GM+F+I	14-35-45-0-0	115	0			
	LAN	Profit	11-May	35,000	105	GM+F+I	14-35-45-0-0	115	0			
2023	ARL	Typical	12-May	36,000	102	GM+RW+F+I	18-22-60-12-10	125	53	305	567	5.26
	ARL	Yield	12-May	40,000	102	GM+RW+F+I	18-22-60-12-10	125	70			
	ARL	Profit	12-May	40,000	102	GM+RW+F+I	18-22-60-12-10	125	0			
	LAN	Typical	11-May	35,000	105	GM+F+I	14-35-45-0-0	106	0	294.8	659	5.25
	LAN	Yield	11-May	40,000	105	GM+F+I	14-35-45-0-0	115	0			
	LAN	Profit	11-May	35,000	105	GM+F+I	14-35-45-0-0	115	0			

Note: GM= Genetically modified, RW=rootworm, F=fungicide, I=insecticide.
An additional $5 to $10/ac application cost was assumed when additional fertilizer was applied before or after planting.

Table 3. Typical and Agroptimizer-recommended **soybean cropping systems** for maximum yield and profit in each location.

	Location	Cropping system	Planting date	Seeding rate (seeds/ac)	Seed treatment	RM	Fungicide at R3	Pre-plant N (lbs/ac)	Seed cost ($/140,000 seeds)	Fungicide cost (product + application $/ac)	Nitrogen cost ($/ac)	Selling price ($/bu)
2021	ARL	Typical	11-May	140,000	F+I	2.3	No	0	60	30	322	10.89
	ARL	Yield	29-Apr	160,000	F+I	2.6	Yes	0	65			
	ARL	Profit	29-Apr	160,000	F+I	2.6	No	0	65			
	PLT	Typical	27-Apr	140,000	F+I	2.3	No	0	60	30	322	11.08
	PLT	Yield	27-Apr	240,000	F+I	2.6	Yes	50				
	PLT	Profit	27-Apr	160,000	F+I	2.6	No	0				
	HAN	Typical	30-Apr	140,000	F+I	2.0	No	0	60	30	322	11.08
	HAN	Yield	30-Apr	240,000	F+I	2.3	Yes	50				
	HAN	Profit	30-Apr	165,000	F+I	2.3	No	0				
	MAR	Typical	7-May	140,000	F+I	1.4	No	0	60	30	322	11.08
	MAR	Yield	7-May	240,000	None	1.4	Yes	50	55			
	MAR	Profit	7-May	160,000	None	1.4	Yes	0	55			

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2021	SPO	Typical	15-May	140,000	None	1.1	No	0	52.3	25	313	11.57
	SPO	Yield	20-Apr	200,000	None	1.0	Yes	50	50.9			
	SPO	Profit	20-Apr	160,000	None	1.0	No	0	50.9			
2022	ARL	Typical	9-May	140,000	F+I	2.4	No	0	77	35	920	12.75
	ARL	Yield	9-May	200,000	F+I	2.4	Yes	75				
	ARL	Profit	9-May	170,000	F+I	2.4	No	0				
	PLT	Typical	10-May	140,000	F+I	2.4	No	0	77	35	920	12.75
	PLT	Yield	10-May	190,000	F+I	2.4	Yes	75				
	PLT	Profit	10-May	160,000	F+I	2.4	No	0				
	HAN	Typical	4-May	140,000	F+I	2.0	No	0	70	35	920	12.50
	HAN	Yield	4-May	200,000	F+I	2.0	Yes	75				
	HAN	Profit	4-May	160,000	F+I	2.0	No	0				
	MAR	Typical	13-May	140,000	F+I	1.4	No	0	70	35	920	12.50
	MAR	Yield	13-May	200,000	F+I	1.4	Yes	75				
	MAR	Profit	13-May	180,000	F+I	1.4	No	0				
	SPO	Typical	24-May	140,000	F+I	1.1	No	0	65	35	920	12.50
	SPO	Yield	5-May	200,000	F+I	1.1	Yes	50				
	SPO	Profit	5-May	160,000	F+I	1.1	No	0				
	LAN	Typical	27-Apr	140,000	F+I	1.2	No	0	61	35	911	11.50
	LAN	Yield	27-Apr	200,000	F+I	1.2	Yes	50				
	LAN	Profit	27-Apr	170,000	F+I	1.2	No	0				
2023	ARL	Typical	11-May	140,000	F+I	2.2	No	0	70	40	570	12.90
	ARL	Yield	11-May	140,000	F+I	2.2	Yes	100				
	ARL	Profit	11-May	110,000	F+I	2.2	No	0				
	PLT	Typical	5-May	140,000	F+I	2.1	No	0	70	40	570	12.90
	PLT	Yield	5-May	160,000	F+I	2.1	Yes	100				
	PLT	Profit	5-May	160,000	F+I	2.1	Yes	0				
	WAU	Typical	3-May	140,000	F+I	2.0	No	0	70	40	570	12.80
	WAU	Yield	3-May	150,000	F+I	2.0	Yes	100				
	WAU	Profit	3-May	150,000	F+I	2.0	Yes	0				
	MAR	Typical	18-May	140,000	F+I	1.5	No	0	70	35	570	12.80
	MAR	Yield	18-May	170,000	F+I	1.5	Yes	100				
	MAR	Profit	18-May	170,000	F+I	1.5	Yes	0				
	SPO	Typical	8-May	140,000	F+I	1.1	No	0	65	35	570	12.85
	SPO	Yield	8-May	170,000	F+I	1.1	No	0				
	SPO	Profit	8-May	90,000	F+I	1.1	No	0				
	LAN	Typical	28-Apr	140,000	F+I	2.1	No	0	61	40	570	12.90
	LAN	Yield	28-Apr	120,000	F+I	2.1	No	0				
	LAN	Profit	28-Apr	90,000	F+I	2.1	No	0				

Note: F=fungicide, I=insecticide. An additional $5 to $10/ac application cost was assumed when additional fertilizer was applied before or after planting.

RESULTS

Yield comparison

Among the seven site-years for corn, Agroptimizer recommendations resulted in significantly increased yield in two site-years (p-value<0.001, Fig. 2). For soybean, Agroptimizer recommendations resulted in significantly increased yield in six site-years out of the seventeen. No other significant yield differences were observed in the remaining site-years. When treating site-years as a random sample of the population, across all seven site-years for corn, Agroptimizer-recommended systems increased yield by 2.3 bu/ac (p-value=0.9 with frequentist approach). Bayesian analysis resulted in 91.4% probability that the yield difference was greater than zero compared to typically used cropping systems (Fig 3). However, there was no strong indication that the difference was statistically significant. Across all 17 site-years, for soybean Agroptimizer-recommended systems increased yield by 3.9 bu/ac (p-value=0.0069 with frequentist approach). Bayesian analysis resulted in 100% probability that yield difference was greater than zero compared to typically used cropping systems with strong indication that the difference was statistically significant.

Figure 2. Corn (left) and soybean (right) yield comparison between algorithm-recommended (Agroptimizer) cropping systems for maximum yield and UW-recommended systems (Typical) within each site-year. Black dashed and red dotted lines represent x=y and ±5% yield differences, respectively. Black circles indicate significantly different yield at alpha=0.05. Errors represent standard error of the mean.

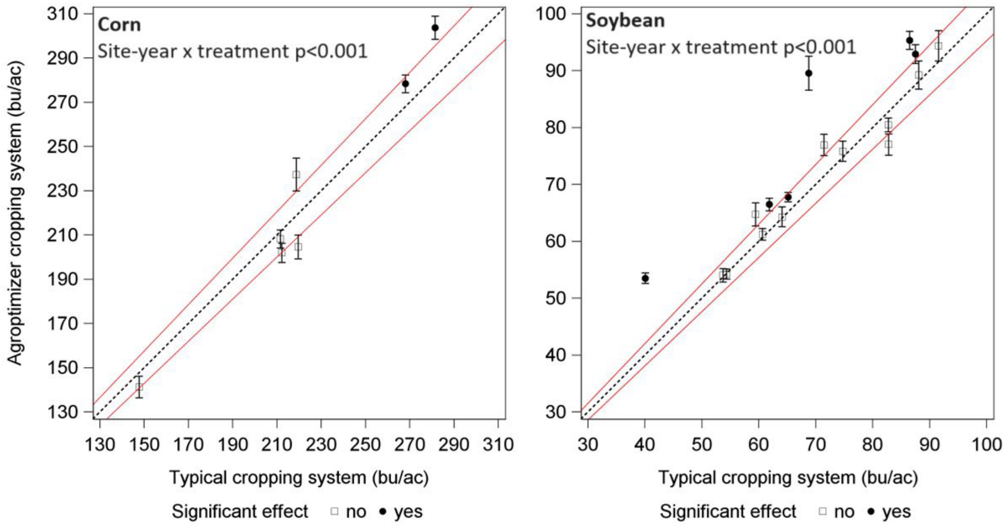
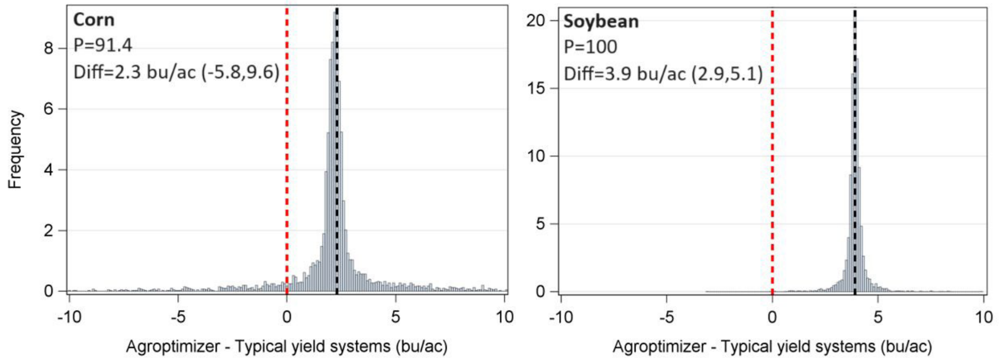


Figure 3. Distribution of corn (left) and soybean (right) yield difference between algorithm-recommended (Agroptimizer) cropping systems for maximum yield and UW-recommended systems (Typical) and the probability (P) as a percentage that the yield difference > 0 in the posterior sample distribution (n = 4060). Red dashed line shows zero yield difference and black dashed line shows the mean yield difference (Diff in the graph with 95% credible intervals).



Profit comparison

Among the seven site-years for corn, Agroptimizer recommendations resulted in significantly increased profit in two site-years and resulted in lower profit in one (p-value<0.001, Fig. 4). For soybean, Agroptimizer recommendations resulted in significantly increased profit in one site-year and resulted in lower profit in one site-year. No other significant profit differences were observed in the remaining site-years. When treating site-years as a random sample of the population, across all seven site-years for corn, Agroptimizer-recommended systems increased profit by 6.7 $/ac (p-value=0.84 with frequentist approach). Bayesian analysis resulted in 84.8% probability

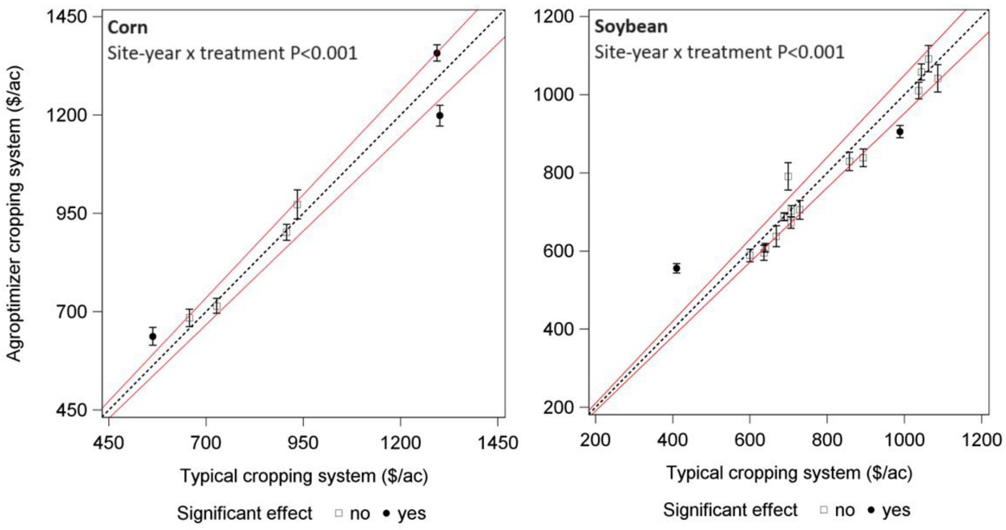


Figure 4. Corn (left) and soybean (right) revenue comparison between algorithm-recommended (Agroptimizer) cropping systems for maximum profit and UW-recommended systems (Typical) within each site-year. Black dashed and red dotted lines represent x=y and ±5% profit differences, respectively. Black circles indicate significantly different yield at alpha=0.05. Errors represent standard error of the mean.

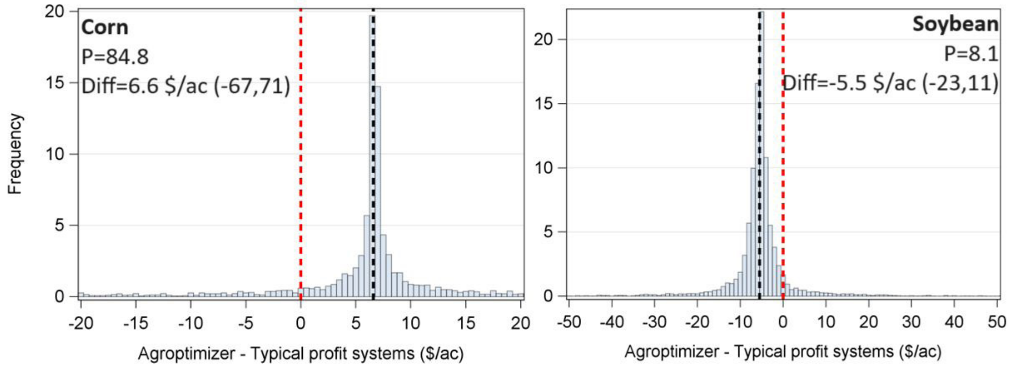


Figure 5. Distribution of corn (left) and soybean (right) profit difference between algorithm-recommended (Agroptimizer) cropping systems for maximum profit and UW-recommended systems (Typical) and the probability (P) as a percentage that the profit difference > 0 in the posterior sample distribution (n = 4060). Red dashed line shows zero profit difference and black dashed line shows the mean profit difference (Diff in the graph with 95% credible intervals).

that profit difference was greater than zero compared to typically used cropping systems (Fig 5). However, there was no strong indication that the difference was statistically significant. Across all 17 site-years for soybean, profitability of Agroptimizer-recommended systems resulted in 5.5 $/ac lower profit than typically used cropping systems (p-value=0.84 with frequentist approach). Similarly to corn, there was no strong indication that the difference was statistically significant. Overall, none of the observed profit differences across site-years were significant.

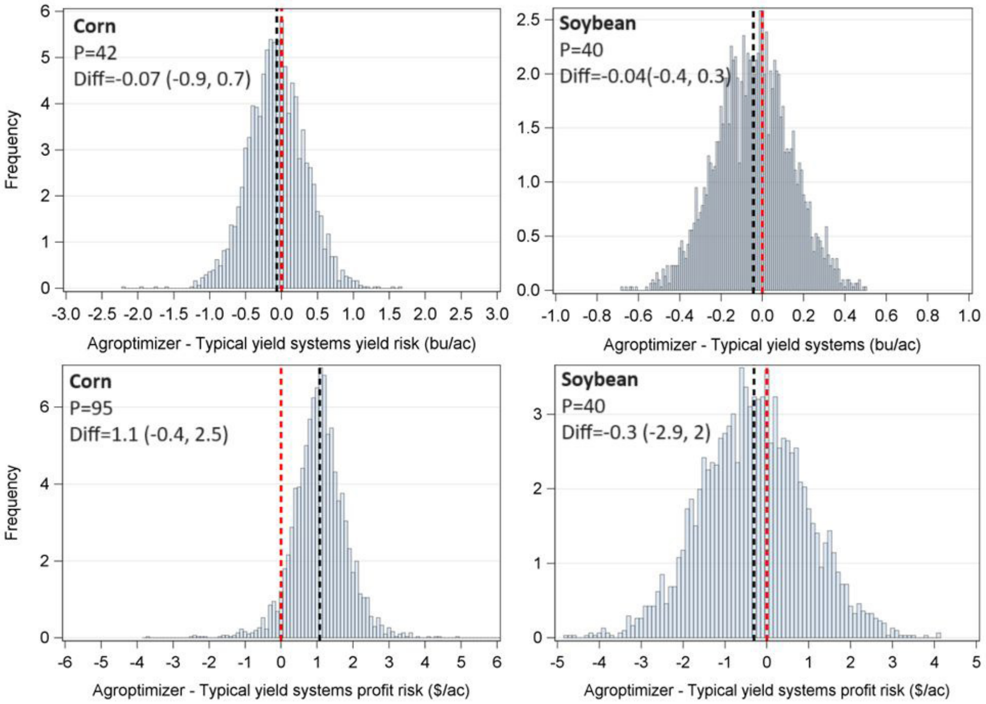
Risk comparison

Downside yield risk difference across all site-years for both crops was less than 0.1 bu/ac for both crops. The corn and soybean respective profit risk differences between Agroptimizer and typical cropping systems were less than 1.1 $/ac. All differences were minimal and none were significant (Fig. 6).

DISCUSSION

Algorithm-based decision making will likely play an important role in grower management decisions in the future. Currently, the user-friendly DSTs that exist, and are available to farmers, recommend optimum management practices for single management practices. For example, the MRTN tool recommends optimum corn Nitrogen rate without accounting for important management practices (e.g., planting date, seeding rate etc.). Similarly, the Soybean Planting Decision Tool recommends optimum soybean planting date or seed maturity separately without accounting for management interactions with strong effect on yield and profit. Other private sector DSTs provide information about proprietary product selection or in-season interventions (e.g., spray pesticide) but do not provide information about the effect of multiple management interactions on yield. Agroptimizer is a unique and novel tool that can recommend single and/or multiple optimum management practices (cropping

Figure 6. Distribution of corn yield risk (upper left) and profit risk (lower left) and soybean yield risk (upper right) and profit risk (lower right) difference between algorithm-recommended (Agroptimizer) cropping systems and UW-recommended systems (Typical) and the probability (P) as a percentage that the risk difference > 0 in the posterior sample distribution (n = 4060). Red dashed line shows zero risk difference and black dashed line shows the mean risk difference (Diff in the graph with 95% credible intervals).



systems) for increased yield and profit for both corn and soybean across the entire US by accounting for soil properties, weather conditions and several management practices at the field level.

In this study, we tested the effectiveness of Agroptimizer to identify high yielding and highly profitable corn and soybean management practices across Wisconsin. We compared the yield and profit derived from Agroptimizer-recommended systems with typical UW-recommended management. Overall, Agroptimizer systems resulted in greater soybean yield and similar corn yield and profit for both crops. Also, there was no difference in downside yield and profit risk associated with the recommended management. We note that typical cropping systems for both crops have been developed by UW researchers after years of research in the specific locations and are already optimized (e.g., early planting dates were used by both systems in both crops in every location), making identification of even more improved cropping systems a very challenging task. These results suggest that Agroptimizer can successfully recommend management practices for both crops that can result in yield and profit similar to what would be recommended by UW-researchers.

One of the limitations associated with Agroptimizer is the recommendations regarding pesticides. Firstly, it is assumed that farmers will use an adequate weed control program as Agroptimizer does not make recommendations about weed control. Current available data does not allow the development of robust weed control recommendation tool for both crops across the US. Regarding the use of foliar fungicide/insecticide, the recommendation (apply *vs* do not apply) is based on what would have protect yield (and increase profit) in the specific growing environment in previous years (via simulation using previous years weather conditions). Therefore, if the recommendation is 'apply' but weather conditions in the following season do not favor increased pest pressure, then the recommendation will be wrong. This was the case in 2023, which was a dry season, which may have impacted the overall profit results of the experiments. This suggests that Agroptimizer alone cannot account for in-season integrated pest management decisions and should be paired with scouting which can further increase the profitability of the recommended management practices.

Other limitations of Agroptimizer include its ability to compare yield potential of different varieties and to provide variable within-field recommendations. Agroptimizer was not designed to generate management zones and to provide within field variable management but to provide recommendations for the entire field (field

average). As far as variety selection, Agroptimizer can be used to identify optimum maturity but cannot be used to compare yield potential between specific varieties. Typically, two years of multi-location trials are required to compare varieties in terms of yield potential and stability across environments. However, in the following year many of these varieties may be obsolete and new varieties with improved genetics will be on the market. Therefore, given the very short life cycle of corn and soybean varieties in the market, we argue that data-driven variety selection is an elusive goal.

Overall, most observed differences between Agroptimizer and typical systems were not statistically significant. Considering the UW systems as the optimum in these environments, results suggest that Agroptimizer can identify profitable corn and soybean cropping systems across Wisconsin. We argue that in suboptimal cropping systems that frequently exist in farmer's fields (Edreira et al., 2017; Mourtzinis et al., 2018), the algorithm-based recommendation approach has potential to increase farmer's yield and profit, especially when coupled with local experts' knowledge. We note that the performance of Agroptimizer has not been tested in other agricultural regions and its effectiveness to identify best management practices may differ from what was observed in Wisconsin. Therefore, the algorithms are being constantly updated and will be evaluated in additional locations across the US in subsequent years.

CONCLUSIONS

Optimizing field-specific management practices to increase a crop's yield is an important but complicated task. Even more complicated is optimization of profit that involves consideration of multiple costs and prices that change constantly. Machine learning algorithms can capture complex relationships that, if the contained information is properly extracted and analyzed, can result in accurate crop management recommendations. User friendly interfaces of machine learning-based DSTs can provide recommendations to farmers that can help increase yield and profit. To date, Agroptimizer is the only machine learning-based user-friendly DST that accounts for multiple soil, weather and management parameters at the field level to help US corn and soybean farmers increase yield and profit by optimizing single management practices and cropping systems. The evaluation across Wisconsin showed that Agroptimizer can provide management recommendations that can result in similar yield and profit with what is recommended by UW-researchers which shows it can be a useful tool to farmers. The results of this work highlight that data-driven approaches, if properly developed, can benefit farmers and allow for increased revenue and food production.

Adapted from: Mourtzinis, S., and Conley, S. 2024. Crop management recommendations: Agroptimizer decision support tool vs local experts. Crop Forage & Turfgrass Mgmt. 2024;10:e20277

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