Evaluating the potential of an algorithm-based decision-making tool (Agroptimizer) to increase farmers' profitability in Wisconsin

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IN A BEAN POD:

- Agroptimizer-based soybean cropping system recommendations were successful to increase yield and profit compared to typical systems.
- Agroptimizer-based corn cropping systems did not increase yield, but increased profit.
- Across site-years, Agroptimizer-based soybean recommended systems resulted in greater yield (99% probability) with an average difference of 4.2 bu/ac and greater profit (60% probability) with an average difference of $2.60/ac compared to typically used cropping systems.
- Across site-years, Agroptimizer-based corn recommended systems resulted in 3.9 bu/ac lower yield but increased profit (97% probability) with an average difference of $26.30/ac compared to typical cropping systems by applying substantially less nitrogen fertilizer.

INTRODUCTION

Substantial crop yield variability arises from a wide range of optimal to sub-optimal management practices in soybean farmers' fields. Replicated field crop experiments have been used to identify best management practices since agricultural research began. Most commonly, the effectiveness of up to three management factors and their interactions are evaluated in a single or several locations. Restrictions such as cost and logistics contains the ability to establish numerous trials over many years. It is assumed that standard management practices are optimal or at least relevant to what most farmers use in the region, which in fact may not be realistic for many farmers.

Given all the well-known deficiencies of current agricultural research methods, a new decision support tool Agroptimizer (www.agroptimizer.com), claims that it has the potential to identify optimum cropping system for greatest yield and for greatest 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, uses a combination of methods to estimate yield and projected profit by accounting for field location, soil type, weather conditions, and several management practices and associated costs. After computation, the cropping systems 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 (Figure 1).

The objective of the presented work is to compare yield and profitability of University of Wisconsin-recommended soybean and corn cropping systems with Agroptimizer-recommended systems in WI in three growing seasons (2021, 2022, and 2023). Here we present results of 2021 and 2022 growing seasons.

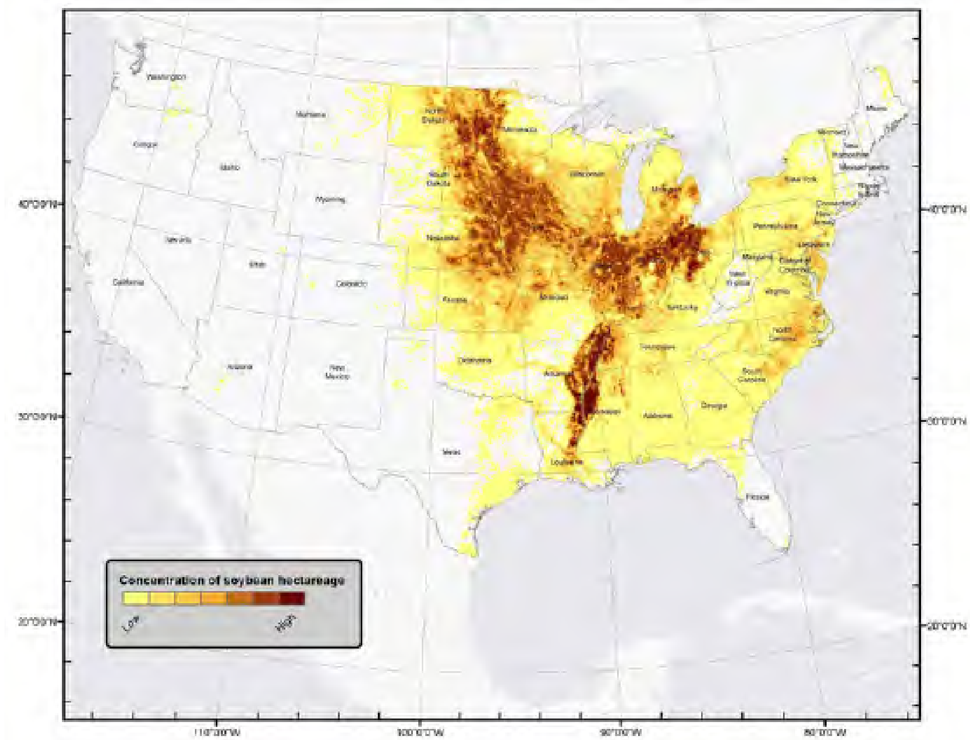
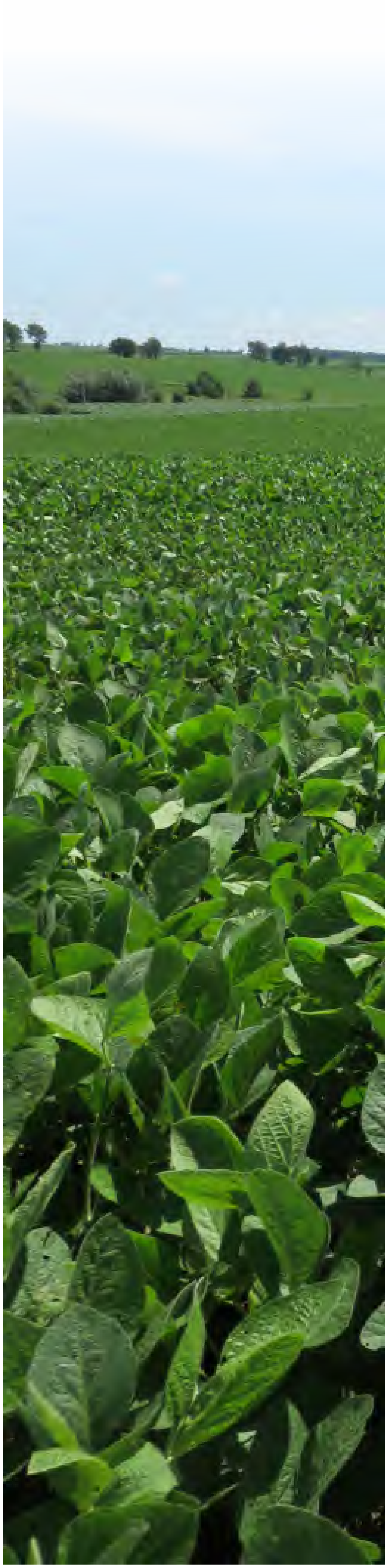


Figure 1. Crop hectareage across the US. Adapted from Mourtzinis and Conley, 2017.



METHODS

Yield and revenue differences between Agroptimizer and UW recommended systems were evaluated in each, and across, all site-years. Input costs and crop prices were based on local pricing for each collaborator in each specific year and location. This would mimic the local input availably, pricing, and buying power of a typical farm operation. Data were analyzed using the frequentist approach (using p-values) which can show us which site-years had strong indications for yield and profit differences. We also obtained probabilities that a yield or profit difference will occur through the use of Bayesian analysis. Bayesian analysis creates a distribution of the estimates and provides the associated probabilities (e.g., average yield difference=10 bu/ac with 70% probability for difference > 0), instead of providing a single estimate (e.g., yield difference=10 bu/ac). The combined site-years data were analyzed using Bayesian approach.

RESULTS

Soybean

Five experiments were conducted in 2021 and six experiments were conducted in 2022 across WI (11 site-years) to evaluate the effectiveness of Agroptimizer-recommended soybean cropping systems to increase yield and profit compared to UW-recommended systems ("Typical"). Agroptimizer provided maximum yield ("Yield") or maximum profit ("Profit") cropping systems recommendations depending on the objective (Table 1).

Among the 11 site-years, Agroptimizer recommendations resulted in increased yield (Fig. 2) and profit (Fig. 3) in two site-years whereas no other differences were observed. Across all 11 site-years, Agroptimizer-recommended systems resulted in greater yield (99% probability) with an average difference of 4.2 bu/ac (Fig. 4) and greater profit (60% probability) with an average difference of \$2.6/ac (Fig. 5) compared to typically used cropping systems.

Table 1. Agroptimizer-recommended and typical cropping systems used in each location.

Year	Location	Cropping system name	Planting date	Seeing rate (seeds/ac)	RM	Fungicide at R3	Pre-plant N (lbs/a)
2021	ARL	Typical	11-May	140,000	2.3	No	0
		Yield	29-Apr	160,000	2.6	Yes	0
		Profit	29-Apr	160,000	2.6	No	0
	PLT	Typical	27-Apr	140,000	2.3	No	0
		Yield	27-Apr	240,000	2.6	Yes	50
		Profit	27-Apr	160,000	2.6	No	0
	HAN	Typical	30-Apr	140,000	2.0	No	0
		Yield	30-Apr	240,000	2.3	Yes	50
		Profit	30-Apr	165,000	2.3	No	0
	MAR	Typical	7-May	140,000	1.4	No	0
		Yield	7-May	240,000	1.4	Yes	50
		Profit	7-May	160,000	1.4	Yes	0
	SPO	Typical	15-May	140,000	1.0	No	0
		Yield	20-Apr	200,000	1.0	Yes	50
		Profit	20-Apr	160,000	1.0	No	0
2022	ARL	Typical	9-May	140,000	2.4	No	0
		Yield	9-May	200,000	2.4	Yes	75
		Profit	9-May	170,000	2.4	No	0
	PLT	Typical	10-May	140,000	2.4	No	0
		Yield	10-May	190,000	2.4	Yes	75
		Profit	10-May	160,000	2.4	No	0
	HAN	Typical	4-May	140,000	2.0	No	0
		Yield	4-May	200,000	2.0	Yes	75
		Profit	4-May	160,000	2.0	No	0
	MAR	Typical	13-May	140,000	1.4	No	0
		Yield	13-May	200,000	1.4	Yes	75
		Profit	13-May	180,000	1.4	No	0
	SPO	Typical	24-May	140,000	1.1	No	0
		Yield	5-May	200,000	1.1	Yes	50
		Profit	5-May	160,000	1.1	No	0
	LANES	Typical	27-Apr	140,000	1.2	No	0
		Yield	27-Apr	200,000	1.2	Yes	50
		Profit	27-Apr	170,000	1.2	No	0

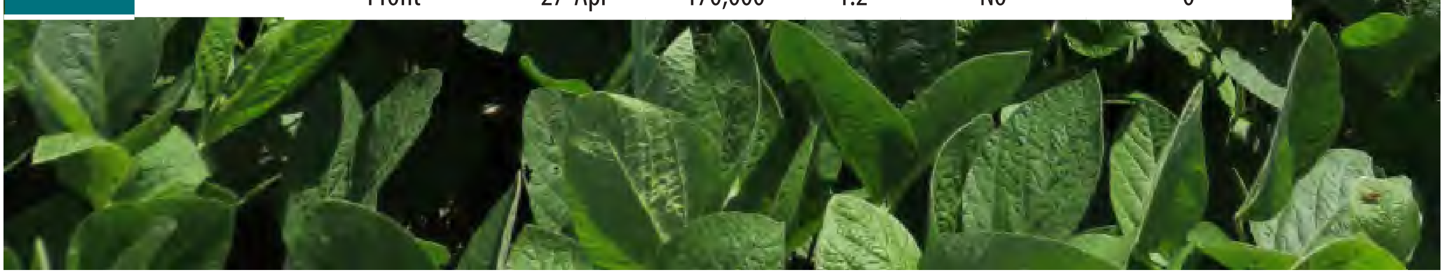


Figure 2. Soybean yield comparison between algorithm-recommended (Agroptimizer) cropping systems for maximum yield and UW-recommended systems (Typical) within each site-year. Stars (*) above bars indicate significantly different yield at alpha=0.05. Errors represent standard error of the mean.

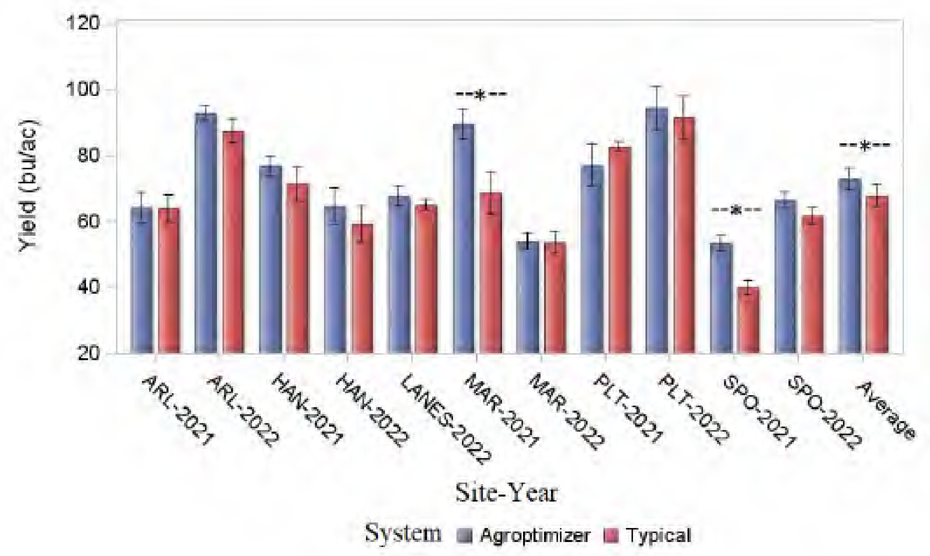


Figure 3. Soybean revenue comparison between algorithm-recommended (Agroptimizer) cropping systems for maximum revenue and UW-recommended systems (Typical) within each site-year. Stars (*) above bars indicate significantly different revenue at alpha=0.05. Errors represent standard error of the mean.

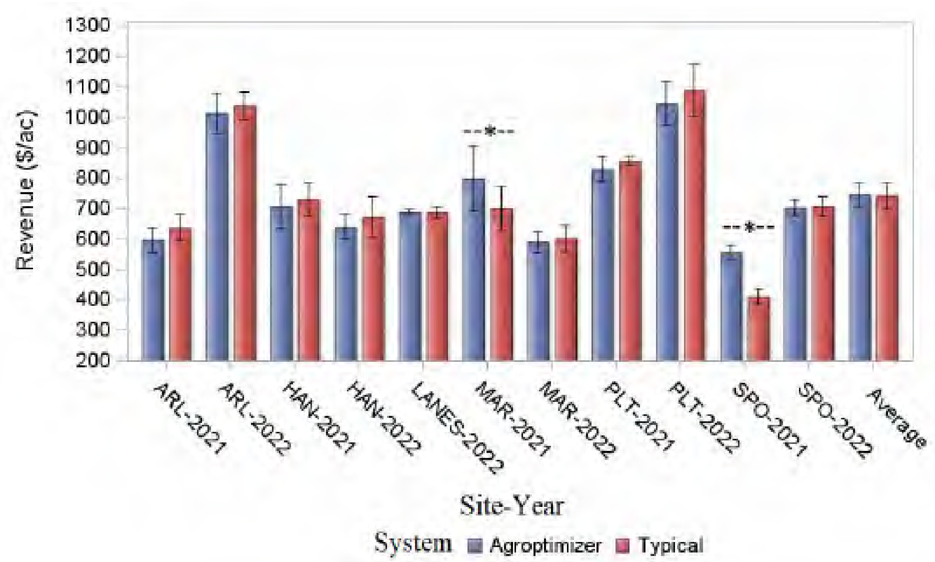
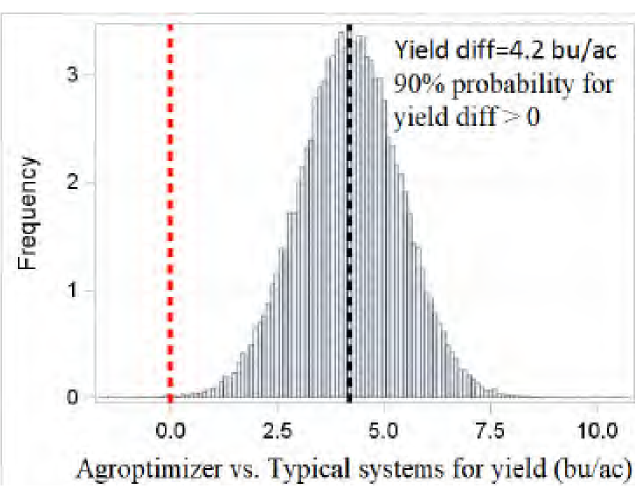


Figure 4. Distribution of the soybean yield differen algorithm-recommended (Agroptimizer) cropping syst maximum yield and UW-recommended systems (Typical) and probabilities for yield difference > 0 across site-years using Bayesian analysis (see Methods for explanation). Red dashed line shows zero yield difference and black dashed line shows the mean yield difference.



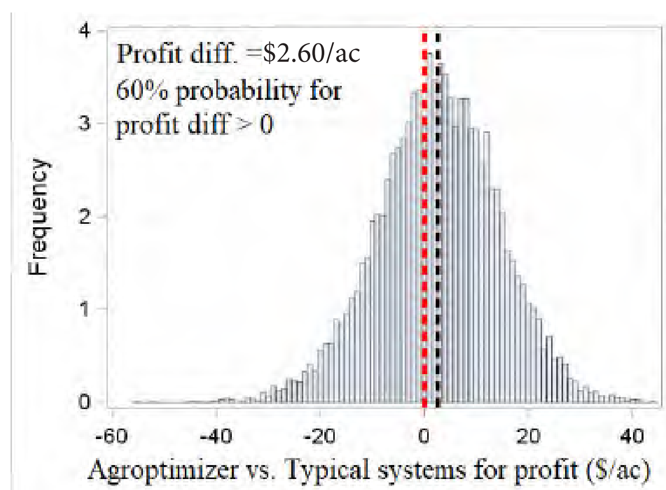


Figure 5. Distribution of the soybean revenue difference between algorithm-recommended (Agroptimizer) cropping systems for maximum revenue and UW-recommended systems (Typical) and probabilities for profit difference > 0 across site-years using Bayesian analysis (see Methods for explanation). Red dashed line shows zero revenue difference and black dashed line shows the mean revenue difference.

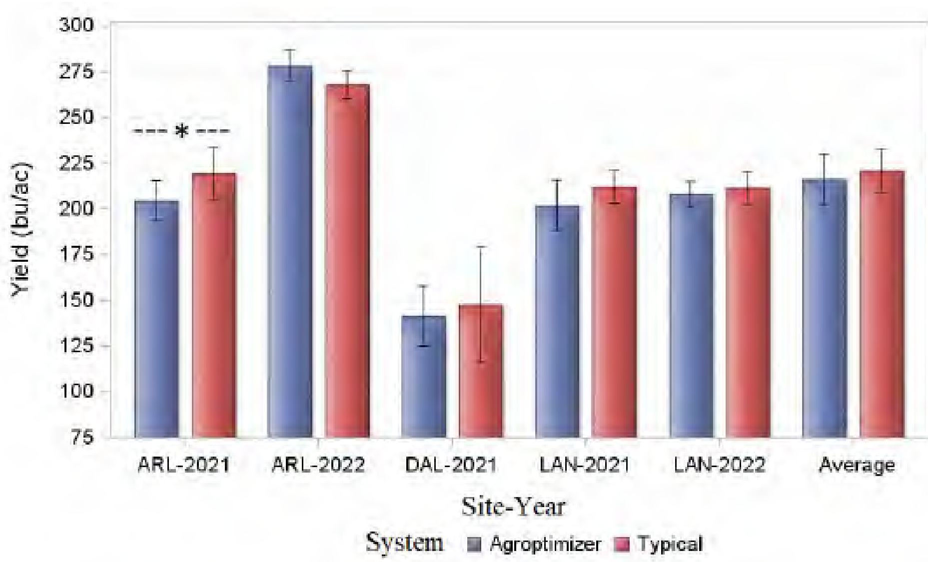
Corn

Three experiments were conducted in 2021 and two in 2022 across WI (5 site-years) to evaluate the effectiveness of Agroptimizer-recommended corn cropping systems to increase yield and profit compared to UW-recommended systems ("Typical"). Agroptimizer provided maximum yield ("Yield") or maximum profit ("Profit") cropping system depending on the objective (Table 2).

Table 2. Agroptimizer-recommended and typical corn cropping systems used in each location. Note: GM= Genetically modified, RW=rootworm, F=fungicide, I=insecticide.

Year	Location	Cropping system name	Planting date	Seeding rate (seeds/ac)	RM	Seed traits	Starter fertilzer (N-P-K-S-Zn lbs/a)	Pre N (lbs/a)	Post N (lbs/a)
2021	ARL	Typical	29-Apr	36,000	107	GM+RW+F+I	30-76-60-0-0	0	207
		Yield	29-Apr	38,000	105	GM+F+I	30-76-60-0-0	37	55
		Profit	29-Apr	34,000	99	GM+F+I	30-76-60-0-0	64	0
	LAN	Typical	26-Apr	35,000	105	GM+F+I	14-35-45-0-0	120	0
		Yield	26-Apr	40,000	105	GM+F+I	14-35-45-0-0	101	0
		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
		Yield	8-May	39,000	104	GM+RW+F+I	39-80-60-0-0	0	176
		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
		Yield	12-May	40,000	102	GM+RW+F+I	18-22-60-12-10	125	70
		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
		Yield	11-May	40,000	105	GM+F+I	14-35-45-0-0	115	0
		Profit	11-May	35,000	105	GM+F+I	14-35-45-0-0	115	0

Figure 6. Corn yield comparison between algorithm-recommended (Agroptimizer) cropping systems for maximum yield and UW-recommended systems (Typical) within each site-year. Stars (*) above bars indicate significantly different yield at alpha=0.05. Errors represent standard error of the mean.



Among the five site-years, Agroptimizer resulted in lower yield in one site-year (Fig. 6) and in increased profit in one site-year (Fig. 7), whereas no other differences were observed. Across all five site-years, Agroptimizer-based corn recommended systems resulted in 3.9 bu/ac lower yield than UW-recommended cropping systems (Fig. 8) but in increased profit (97% probability) with an average difference of $26.30 /ac (Fig. 9) compared to typical cropping systems by applying substantially less nitrogen fertilizer.

Figure 7. Corn revenue comparison between algorithm-recommended (Agroptimizer) cropping systems for maximum revenue and UW-recommended systems (Typical) within each site-year. Stars (*) above bars indicate significantly different revenue at alpha=0.05. Errors represent standard error of the mean.

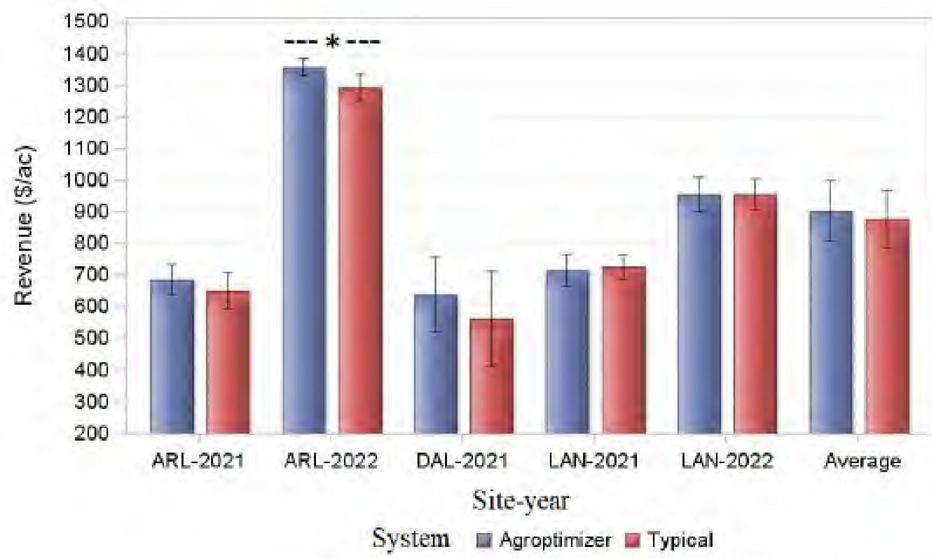


Figure 8. Distribution of the corn yield difference between algorithm-recommended (Agroptimizer) cropping systems for maximum yield and UW-recommended systems (Typical) and probabilities for yield difference > 0 across site-years using Bayesian analysis (see Methods for explanation). Red dashed line shows zero yield difference and black dashed line shows the mean yield difference.

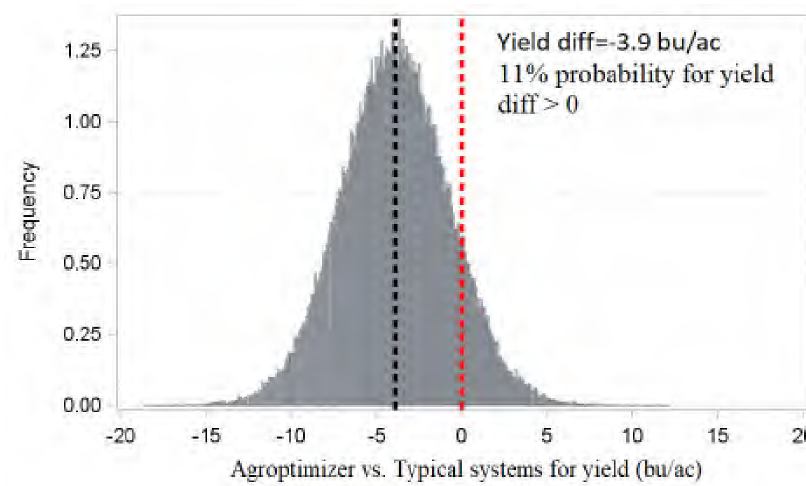
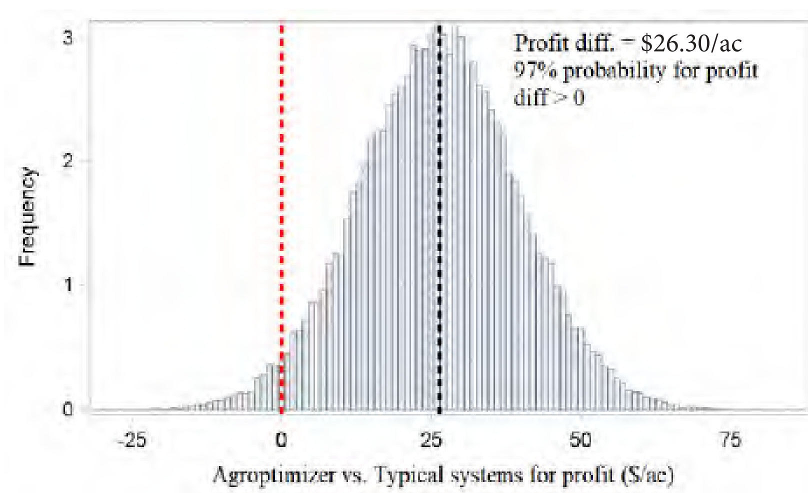


Figure 9. Distribution of the corn revenue difference between algorithm-recommended (Agroptimizer) cropping systems for maximum revenue and UW-recommended systems (Typical) and probabilities for profit difference > 0 across site-years using Bayesian analysis (see Methods for explanation). Red dashed line shows zero revenue difference and black dashed line shows the mean revenue difference.



DISCUSSION

Algorithm-based decision making will likely play an important role in grower management decisions in the future. Algorithms can capture and quantify complex relationships that can result in more informative decisions with greater probability of success (i.e., increase profit) compared to current approaches. Evaluation of algorithm-based decision support systems (here Agroptimizer) in field conditions, which involve unexpected and unmanageable yield adversities, is important. Across all site-years, soybean Agroptimizer-based cropping systems exhibited potential to increase yield (probability=99%) and profit (probability=60%) compared to typical systems. Corn Agroptimizer-based cropping systems resulted in 3.9 bu/ac lower yield but in increased profit (probability=97%) compared with UW-recommended systems.

It is interesting to observe the profit comparison between Agroptimizer profit and typical systems for corn. Agroptimizer-recommended systems either increased (in ARL-2022) or resulted in similar profit with typical systems by applying similar or substantially lower nitrogen fertilizer rate (e.g., in ARL and DAL in 2021). These results show the potential of Agroptimizer to identify and recommend more profitable corn cropping systems. We note that Tar Spot was found in 2021 and 2022 at all locations. At ARL-2022, the entire trial was treated with a fungicide. This may have impacted the overall results of the experiment and suggest that Agroptimizer alone cannot account for in-season IPM decisions and should be paired with scouting or other management tools such as TarSpotter.

Overall results suggest that Agroptimizer can identify profitable corn and soybean cropping systems across WI. The probabilities at which Agroptimizer was able to identify more profitable cropping systems than UW-recommended suggest that typical UW corn systems may be optimized mainly for maximum yield which allows further optimization for increased profit whereas soybean typical UW cropping systems are more balanced between high yield and increased profitability. However, 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. Therefore, identification of even more improved cropping systems is very challenging. 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 profit. Agroptimizer algorithms are being constantly updated and will be evaluated in additional locations in subsequent years.

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