MAXIMIZING AGRICULTURE EQUIPMENT CAPACITY USING PRECISION AGRICULTURE TECHNOLOGIES

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ABSTRACT

Guidance systems are one of the primary Precision Agriculture technologies adopted by US farmers. While most practitioners establish their initial AB lines for fields based on previous management patterns, a potential exists in conducting analyses to establish AB lines or traffic patterns which maximize field capacity. The objective of this study was to develop a simple methodology to determine the optimum traffic pattern for individual fields, at a particular farmstead. Several fields, varying in shape and size, were selected based on the farmer interest in improving field capacity. A major constraint was that all crop rows had to be straight. Field boundaries were established using a GPS mapping system with a geographic information system (GIS) and used for analysis. An optimization algorithm was developed which considered five parameters: number of turns, length of passes, total turning distance, variation in pass length, and ratio between actual planting distances to total distance travelled. Existing AB lines were also acquired from the autoguidance systems for inclusion into the analysis. Parallel lines were generated for each field then rotated at 5 degrees. For each rotation, lines were clipped to the field boundary and field parameters computed. The optimization algorithm then determined which angle maximized field capacity and results were compared to the existing AB line. Results indicated that the optimum degree for the AB line was a function of field shape. For more rectangular shaped fields, the optimum pass determined was the one intuitively established by the farmer whereas for less “regular” shaped fields, a slight modification of the original AB line angle produced a significant increase (up to about 17%) in machinery efficiency. However for some irrigated fields, the location of valves used for travelers had dictated the previous planting pattern greatly reducing field capacity. Automatic section control technology on the planter permitted implementation of an altered row pattern to reduce damaged crops while improving field capacity (increase of 62%). In return, this outreach effort provided the farmer optimum AB lines to ensure maximum field capacity for current equipment and adopted precision agriculture technologies.

Keywords: Extension, Guidance, Field Capacity, Efficiency, Row patterns

INTRODUCTION

Traditionally, agriculture equipment follows a systematic traffic pattern established by the farmer for individual fields. Many times, traffic or crop row patterns are determined by where machinery enters the field along with what the equipment operator perceives as the longest and straightest pass. Autoguidance technology continue to be a leading precision agriculture technology adopted by US farmers with most users establishing their initial AB lines based on previous management patterns. However, Srivastava et al. (2006) highlighted that agricultural machines are amortized only over hundreds of hours of annual use with time lost during these periods being costly. Therefore, a potential exists in analyzing field traffic patterns in order to optimize crop rows to maximize efficiency or field capacity of farm machinery.

Field capacity is defined as the amount of processing an agricultural machine can accomplish over a period of time (Renoll, 1981). It is mainly affected by row length, terracing, field size and field shape. Machine capacity determines the timeliness of field operations and is important information to take into consideration when making machinery management decisions (Grisso et al., 2002). Moreover, precision agriculture technologies such as autoguidance using real-time kinematic (RTK) level correction provides the ability to accurately drive the same equipment paths over time and affords the ability to alter crop management practices including row patterns to maximize production and machine usage.

The study presented here represents an extension activity with the primary goal of showcasing to farmers how the adoption of Precision Agriculture technologies can improve field capacity and provide benefit to their operations. Our hypothesis is that each individual field has an optimized crop pattern based on equipment size and a grower’s management strategy. The objective of this study was to develop a simple method to determine the optimum traffic pattern, maximizing field capacity, for individual fields at a particular farmstead. Results are then used as a case example to other farmers in the region to optimize their traffic and row patterns.

MATERIALS AND METHODS

Site Description

This study was conducted in 2011 for the Field Services Unit at the EV Smith Research Center (Shorter, Alabama). At this farm, RTK-autoguidance was adopted on several tractors in 2010 with the intent to improve crop row spacing and field capacity over time. Major production row crops grown include maize, cotton, and soybeans. Fields were selected based on the farm director's interest in improving field capacity and for their heterogeneity in shape and size. Some fields were regular and rather square while others were elongated or irregular shaped. Moreover, the Farm Services Unit at the EV Smith Research Center is fairly level, with no terraces and other in-field structures to be considered. Therefore, slope was not a considered parameter in this study. Field names were kept uniform as those defined at the farm unit.

The major constraint established by the farmer was that all crops rows or AB lines had to be straight. Curved passes generate excessive harvest loss for the towed forage chopper. Maize constitutes the most acreage since used to supply feed for the dairy and beef enterprises. Additionally, the optimum row pattern for each field was based on the planter since it established crop rows and thereby traffic lanes for all subsequent field operations. Once the row patterns are optimized for the planter, it will then be optimized for all other equipment at this farm. The farm director also provided prior knowledge about field access points. Calculations were conducted for a 6-row, 5.49-m wide, John Deere 1700 planter.

For each field, boundaries along with the existing AB lines were obtained. Field boundaries had been collected using a DGPS receiver and FarmWorks SiteMate software mounted on a vehicle. The AB lines had been initially established for the RTK autoguidance technology and were downloaded from the cab console. These initial AB lines were based on previous crop rows prior to the adoption of guidance systems. The farm currently is using Trimble AutoPilot systems on their tractors running Trimble's VRS correction.

Optimization Routine for Traffic Patterns

The optimization routine was based on the use of the field boundaries and current AB lines provided by the farmer. Each field boundary and AB line were loaded into ArcMap™ (v. 10) by ESRI. These spatial layers were projected into the UTM coordinate system using the WGS84 datum. For each field, a new straight AB line was generated in ArcMap™ with a bearing of 0.0 degrees. Copies of this AB line were created with each rotated at 5 degree increments providing thirty-six unique AB lines between 0 and 175 degrees. The 5 degrees of rotation was selected to provide suitable results without creating an excessive number of patterns and thereby minimizing processing time.

The next step included generating parallel lines at 5.49 m based on each 5 degree incremented AB lines. A sufficient amount of parallel lines were created to cover an entire field boundary. The lines were then clipped to the field boundary creating for each field different sets of row patterns (37 total including the original guidance AB line) to be compared by the optimization routine. ArcToolBox functions within ArcMap were used to calculate row length and ends coordinates for each pass. MS Excel was used to conduct the optimization routine and summarize results. Using the values calculated in ArcMap for every 5 degree row pattern, 5 indices were calculated using MS Excel for inclusion in the optimization routine: 1) length of passes (maximize), 2) total number of turns (minimize), 3) total turning distance (minimize), 4) variation or standard deviation in pass length (minimize), and 5) ratio between actual planting distance and total distance travelled (maximize). Time versus distance could have been used in the routine but preliminary comparisons determined both generated similar results but distance provided quicker processing and fewer assumptions. The optimization routine included ranking patterns for each index then computing which angle minimized the summed rankings. The bearing which maximized field capacity was noted for each field and compared to the original AB line rankings by field.

Based on the resulting analyses, additional steps were required to finalize the results of this study. Two steps were performed which included determining the bearing of the longest, straightest side of a field and making slight revisions of field boundaries. The bearing for the longest, straightest side of the field was determined within ArcMap. An additional AB line bearing was added into the optimization analysis for only three of the fields (4C, 5 and 7). These AB lines were considered since the optimum pattern determined through the 5 degrees of rotation did not exactly match the field edge. If this additional AB line was not included, difficulty in equipment maneuverability would exist along with excessive non-productive turn distances thereby decreasing field capacity. Therefore, in these three fields, a total of 38 row comparisons were conducted. The final step of this study included revision of the field boundaries to the equipment and precision agriculture technologies. This final step was completed after the optimum row pattern was selected. The amount of space around each field was considered in this process so not to impact fence or tree lines around several fields. A recommendation was made to the farmer providing the optimum AB line angle along with revised field boundaries to maximize field capacity.

RESULTS AND DISCUSSION

Optimum Pattern

The results obtained comparing both patterns were divided into 3 categories based on field shape. For more regular shaped fields, the pattern intuitively established and provided by the farmer already maximized field capacity. Indeed for regular shaped fields, the row orientation determined through the optimization routine provided results within about +/- 5 degrees (angle of rotation). Therefore, as presented in Table 1, the pattern intuitively established by the farmer provided higher field capacity than the one obtained through the optimization routine. For less regular shaped fields, a slight modification of the original AB line bearing (less than 5 degrees) produced a significant increase in field capacity. For instance, it is shown in Table 2 that such a modification decreased the number of turns by about 5% for field 8 and the total turn distance about -17% for field 1.

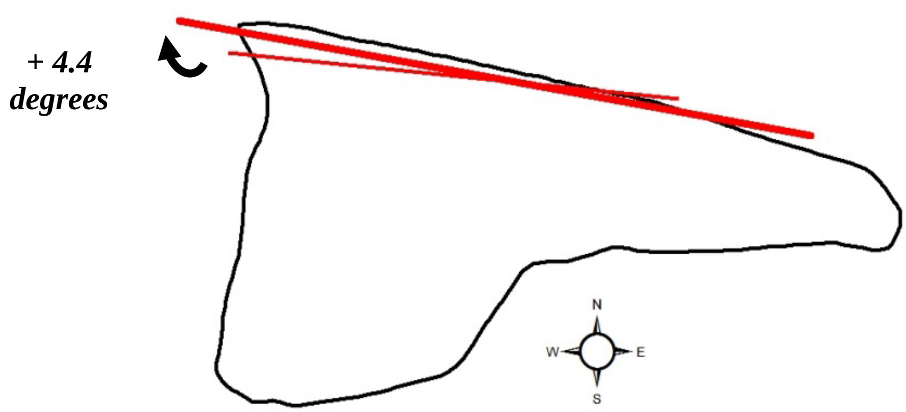
The patterns provided by the farmer were close to maximizing field capacity but the slight adjustment in bearing significantly improved it. Fig 1 is presented as an illustration of results provided to the farmer. For Field 1, Figure 1a presents the original AB lines versus the optimized, while Figure 1b presents the recommended pattern along with the new, revised field boundary.

Table 1. Effects on field capacity if using the optimized pattern for more regular shaped fields. In these two fields, the original AB line maximized field capacity.

Field	Original AB line	Optimized AB line	Length of passes	% of turn	Total turning distance
4A	96.8˚	95˚	-1.6%	+3.4%	+0.4%
4BW	104.2˚	105˚	0.0%	0.0%	+1.0%

Table 2. Savings provided by using the optimized pattern for irregular shaped fields

Field	Original AB line	Optimized AB line	Length of passes	% of turn	Total turning distance
1	95.6˚	100˚	0%	-2%	**-17%**
8	178.4˚	175˚	**+2.8%**	**-5%**	+7%



a.

b.

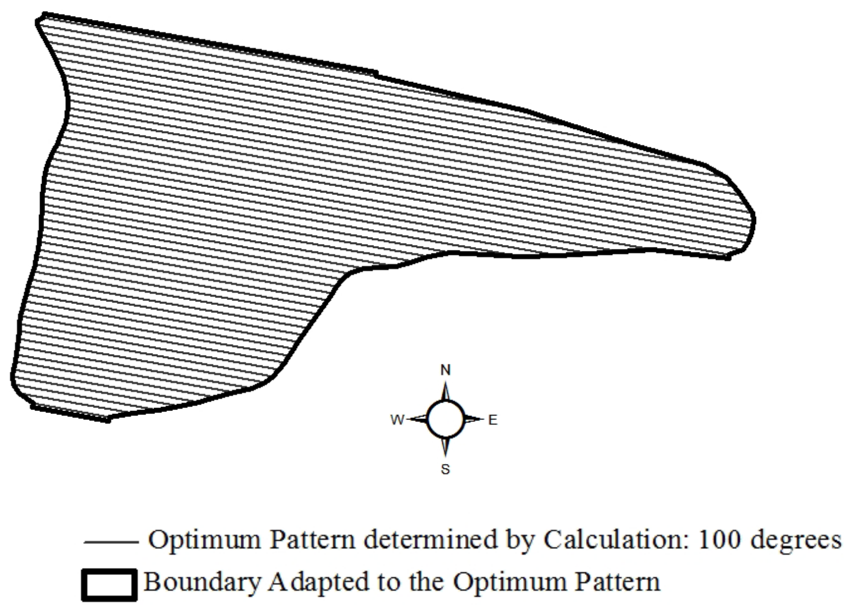


Fig 1. a. Original versus optimized AB lines and original field boundary for Field 1 with **b.** the recommended row pttern and revised field boundary. One should note that the revised boundary helped square field edges.

For the irrigated fields, the location of irrigation valves along the field exterior and the use of travelers had always guided the planting pattern. Essentially, rows were planted parallel to how the gun of the travel would be pulled across the field. By rotating the crop rows in the principal direction of field elongation, field capacity was greatly increased (Table 3). Using the optimum pattern determined through the optimization routine, enables the farmer to decrease the number of turns by more than 60% in Field 7 while having more than 2.5 times longer passes than the original ones. Significant increases were determined for fields 4C and 5 as well. In order to implement this strategy, row clutches (e.g. automatic section control) on the planter will be used to not plant the alleys used for the travel guns. The rate control system permits the farmer to define none planting areas allowing for easy implementation of the redefined row pattern. Fig 2 illustrates the type of pattern obtained in Field 7.

Table 3. Savings which could be provided by using the optimized pattern for the irrigated fields

Field	Original AB line	Optimized AB line	Length of passes	% of turn	Total turning distance
4C	90˚	0˚	+80%	**-45%**	**-27%**
5	170˚	80˚	+19%	**-16%**	+1.5%
7	170˚	80˚	**+154%**	**-62%**	-5.7%

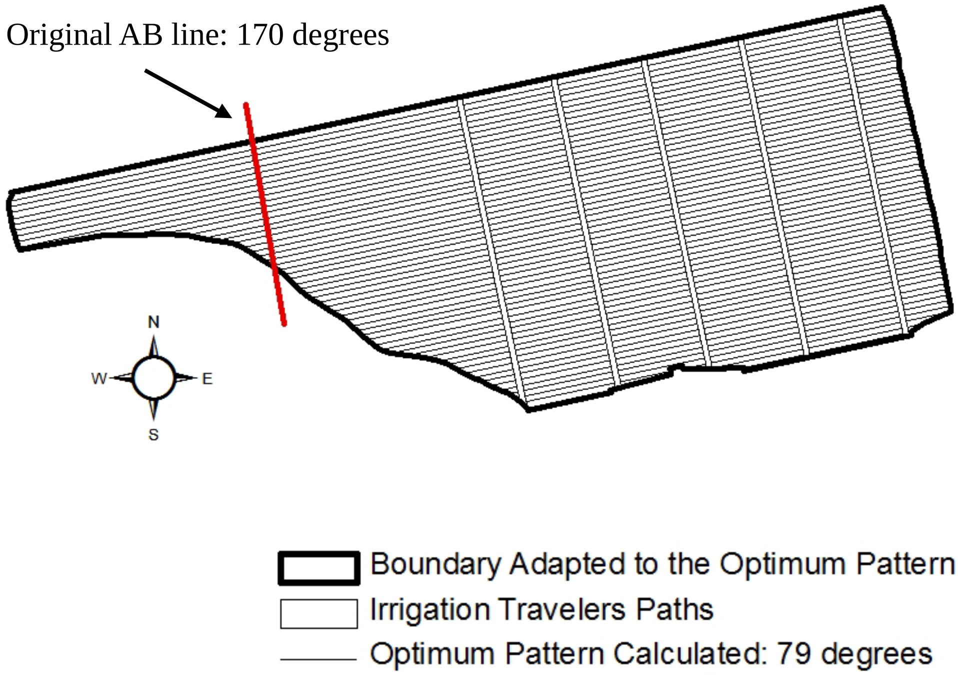


Fig 2. Example of alternate row pattern proposed with removed alleys for the irrigation travelers in Field 7. The optimum pattern along with revised boundary helped square off the field edges especially along the north side.

The methodology proposed was simple and initially designed to provide results for a specific farmstead and its management constraints. Table 4 summarizes the recommended AB lines by field presented to the farm director for use during the 2012 cropping season. These results provided the optimum AB lines for individual fields, maximizing field capacity for current equipment and precision agriculture technologies adopted. This method could be expanded to different row patterns such as curved paths and provide a step towards the adoption of controlled traffic. Indeed the method provides the optimum row direction to maximize efficiency while controlled-traffic prevents soil compaction while maintaining crop productivity (Gerik & Morrison, 1987). There might be interest in extending this method to other farmsteads in the US with similar field characteristics, in order to help farmers maximize benefits for their operation using Precision Agriculture technologies. At this farm, the recommended AB lines were used in 2012 with long term goals of implementing controlled traffic to further enhance production. It has been the adoption of precision agriculture technologies which has permitted the farm manager to realize to possibility of attaining this goal.

Table 4. Summary of AB line recommendations as proposed to the farmer.

	-------- AB Line --------	
Field	Original	Recommended
1	95.6˚	100˚
4A	97.0˚	97˚
4C	90.0	178˚
4BW	104.2˚	104˚
5	70.0˚	77˚
7	70.0˚	79˚
8	178.4˚	175˚

CONCLUSION

The results demonstrated through this study outlined the potential in conducting analysis to optimize field traffic patterns. Indeed, even if the pattern intuitively followed by the farmer already maximized field capacity for regular shape fields, a significant gain in field capacity could be potentially realized through slight adjustments in the AB line orientation for irregular shaped fields. Thereby, modifying the AB line orientation about 4˚ for field 1 produced a gain of 17% in turning distance. An alternate pattern was also proposed for irrigated fields, maximizing field capacity without impacting irrigation management; in reality it improves in-season management while minimizing crop loss. These results were presented to the farmer with the new AB lines and adopted for 2012, including making slight modifications to the field boundary. The developed methodology was simple in its optimization routine and easily understood by the farmer. The methodology could be expanded to include different row patterns (e.g. curved) and equipment sizes which considering various precision agriculture technologies. In summary, precision agriculture technology can provide benefits to farmers including maximizing field capacity based on equipment, cropping practices and field conditions.

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