Economics of Swarm Bot Profitability for Cotton Harvest

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Abstract. Improved equipment management is one way which producers can increase profits. For cotton, this is especially true due to specialized equipment used for the sole purpose of harvest. Questions are raised regarding a way to either reduce or replace traditional cotton pickers. The main alternative being discussed is an investment in autonomous "swarm bots" to replace traditional equipment. Swarm bots are fully automated robots tasked with the responsibility of picking cotton one row at a time. Small robots make multiple passes through the field and remove the cotton from the bolls as matures therefore increasing fiber quality and minimizing risk. A set of simulations were conducted to assess break points that autonomous robotics are physically feasible and economically sound. Results are pertinent to cotton producers and equipment manufacturers as this may reduce one of their largest expenses in cotton production.

Keywords. *autonomous vehicles, nanobots, swarm bots, cost of operation, robots.*

Introduction

As input costs continue to increase to produce a crop, improved equipment management is one way that producers can increase profit margins. For cotton, this is especially true due to the use of specialized equipment for the sole purpose of harvest - which could potentially lead to them only being used for as little as one month out of the year. When specifically discussing the task of harvesting cotton, this raises the question of whether there is a way to either reduce or completely replace the use of traditional cotton pickers because of the following reasons: traditional cotton harvest machinery is expensive, the machinery is limited to a single harvest pass, and it is limited in the ability to perform more than one task. The main alternative already being discussed by other researchers is for a producer to invest in autonomous “swarm bots” to replace their traditional cotton equipment.

Background and Literature Review

Autonomous vehicles have become a household phrase in last several years. In popular culture, driverless cars have been available from Google and Tesla. In agriculture, the beginning of autonomy was automated guidance around 2000 followed by true autonomy in last three years. Currently, autonomous tractors are the same size as the status quo. The next generation of autonomous farm machinery may remain that size, become larger, or may become much smaller similar to the ‘swarm bots’ imagined by examples in popular culture. As an example of relative interest by society, the proportion of Google searches for the search terms “nanobot”, “swarm bot”, and “autonomous vehicles” are presented in Figure 1. The phrase “nanobot” has been searched for almost steadily over the last decade while “autonomous vehicles” have been searched for relatively more frequently since 2013. “Swarm bots” were relatively steady however much less interest than the other two search terms.

The first step in evaluating the feasibility of swarm bot technologies toward the adoption of robotics was a review of how automated guidance technologies impacted row crop production. With the adoption of automated guidance tractors, cotton picker harvesters, human interaction was still required although to lesser extent than before the utilization of the technology. Not only was there less reliance on humans, i.e. labor resources, but increased efficiencies due to reduced overlap (Griffin et al. 2005; Shockley et al. 2011).

Closely related to current issues regarding autonomous vehicles within the automobile industry, safety is a large concern. According to Pedersen et al., for these systems to efficiently operate autonomously, robots must be reliable and trusted to operate without human interaction 24 hours per day. If these systems require human interaction or oversight, productivity and feasibility of the “fully autonomous” robots are diminished (Pederson et. al. 2008). Liability insurance must be considered when analyzing economics related to autonomous systems.

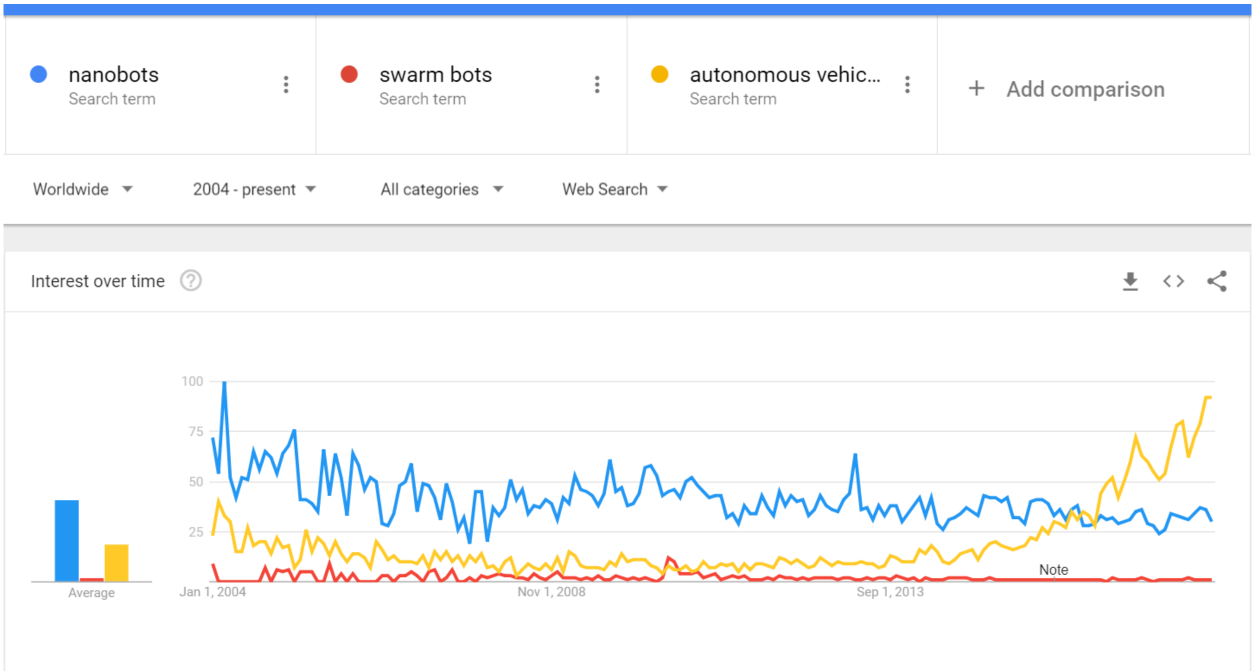

Figure 1. Proportion of Google searches on robot related topics over time

Swarm bots used as cotton harvesters are fully automated robots that are tasked with the responsibility of picking cotton one row at a time. The robots move in-between the rows and pick cotton on either side of the machine. Even though individual bots are only able to pick cotton one row at a time, when producers are equipped with multiple bots, they may be able to perform just as much if not more work as a traditional picker at a fraction of the cost. A main concern for current cotton producers when discussing the functionality of swarm bots within their operation is around the issue of downtime. The question was asked, what happens when my machine is out of service and unable to perform its task? The response many researchers have is that when one robot fails, it has less of an impact on the take being performed when compared to a single machine breaking down which is supposed to cover 80 acres per day.

Typical cotton harvesting takes place when all of the cotton in the field is mature and ready to be picked. This is typically 60-90 days after the first boll is mature and ready to be picked (approximately 100 days after planting, Snider and Oosterhuis, 2015). A positive feature of these machines is that they could make multiple passes through the field and remove the cotton from the bolls as they mature. This should increase the operations overall crop/fiber quality as the cotton can be picked at the ideal time for which the producer sees fit for their operation's demands. By being able to pick the cotton that is ready to be picked right after maturation, the risk can be minimized that the cotton could be lost in large wind or rain events.

Contamination within cotton fields is an issue many producers are fighting today. Plastic bags, twigs, leaves, and other foreign material currently make their way into the cotton modules and on into the cotton processing facilities. Much effort has taken place to help contain this issue within the cotton processing facilities to gather the debris and prevent it from ruining the end product. There has been discussion in being able to gin the cotton on the robot itself. This would be an additional step toward zero contamination which could be a legitimate goal for the industry. Dr. Alex Thompson at Texas A&M is evaluating the feasibility of this process of ginning the cotton on the robot itself as well as the leading a project with Dr. Gaylon Morgan at Texas A&M where cotton is being hand-picked right at maturation to better understand how this impacts fiber quality.

Multi-purpose usability would allow producers to use the bots more time out of the year as they could change attachments to perform other tasks necessary for cotton production. The main stages we need to consider when discussing cotton production would be tillage, planting, weed control/chemical application, and harvest. The current hypothesis is that for these machines to be feasible in today's cotton operations, they will need to be multi-purpose built.

Another issue regarding the functionality of swarm bots is the space/carrying capacity of the cotton that is picked by the bot. One solution being discussed is for the bot to return to a "mother ship" to drop off the cotton. This is seen as a positive to many researchers as soil compaction is a large concern when discussing the way current harvesting equipment harvest the crop. Cotton modules being produced by harvesting operations can weigh over 20,000 lbs.

Other than the projects already explained, other researchers are focusing on the remaining major aspects of swarm bot usage within cotton fields. Dr. Joe Maya at Clemson University is examining the different ways to adapt robots current readily available for purchase for use within a cotton operation, specifically the Husky from Clearpath Robotics. At the University of Georgia in Tifton, Dr. Glen Rains is focusing on the harvesting process itself. He has developed an imaging system which helps the robot identify the cotton bolls as well researching a vacuum system used for harvesting the bolls. Dr. Brian Ayres at the University of North Texas has a similar project where plant and boll conformation by the robot is being evaluated.

Shockley et al. (2011) performed a study similar to this research regarding planting corn/soybean by examining the feasibility of the adoption of autonomous planting machinery. Through a whole-farm LP, the research showed a 2% increase in net returns by implementing autonomous machinery. Machinery Ownership costs were decreased by 24% and machinery operating costs were decreased by 17%. Not only were costs reduced, yields were increased through the study as the crop was able to be planted at the optimal time (Shockley 2011).

Data and Methods

Building upon the four engineers' work and the assumptions made by the principal investigators (PI's), within this research we perform a set of simulations using mathematical programming methodologies to assess break points that autonomous robotics are physically feasible and economically sound. The model developed by Shockley will potentially be used as a baseline model for this research (Shockley 2011).

A brief understanding of how the cotton harvesting process has changed over time will be imperative for this research. The percentage of cotton acres harvested by mechanical pickers grew from just over 0% to almost 100% within a few decades (Figure 1). Technological innovation has gone full circle by potentially reverting back to individual row picking, with robots now, not people.

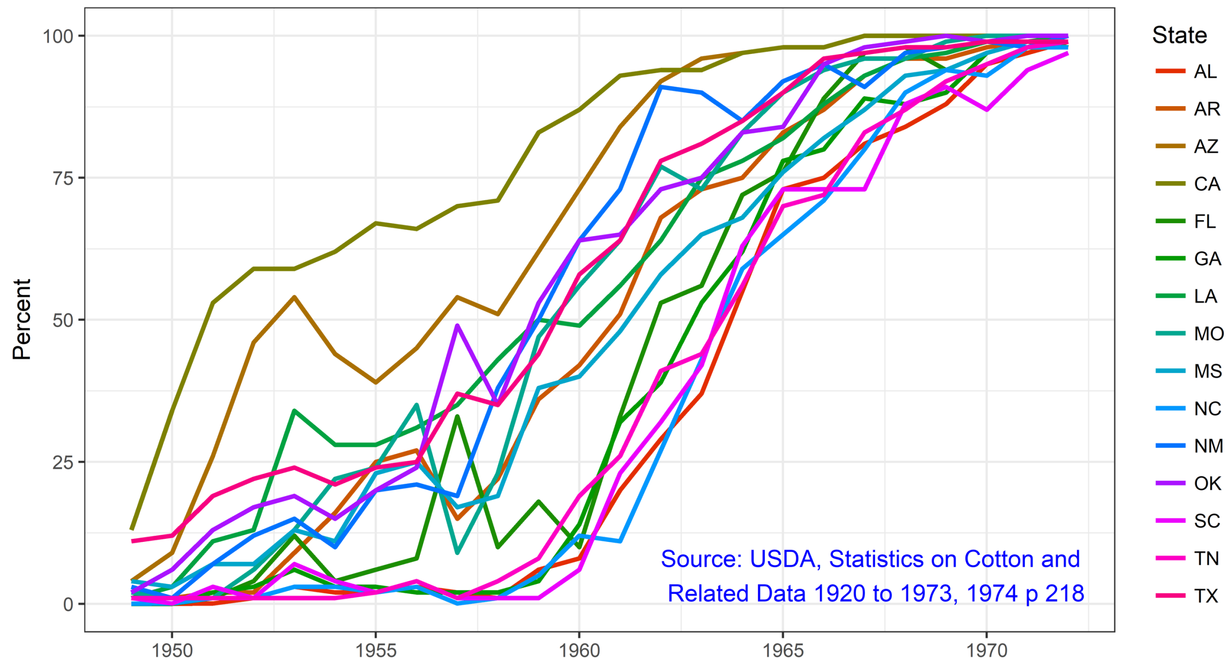

Figure 2 - Percentage Change of Cotton Acres Harvested through Mechanization in the Top Cotton Producing States

As the proportion of machinery harvest cotton acreage approached 100% (Figure 2), the total harvested acreage of cotton was declining to near levels of current production (Figure 3). In the United States, harvested cotton acreage peaked in the 1920s and reached the current levels during the 1960s (Figure 3).

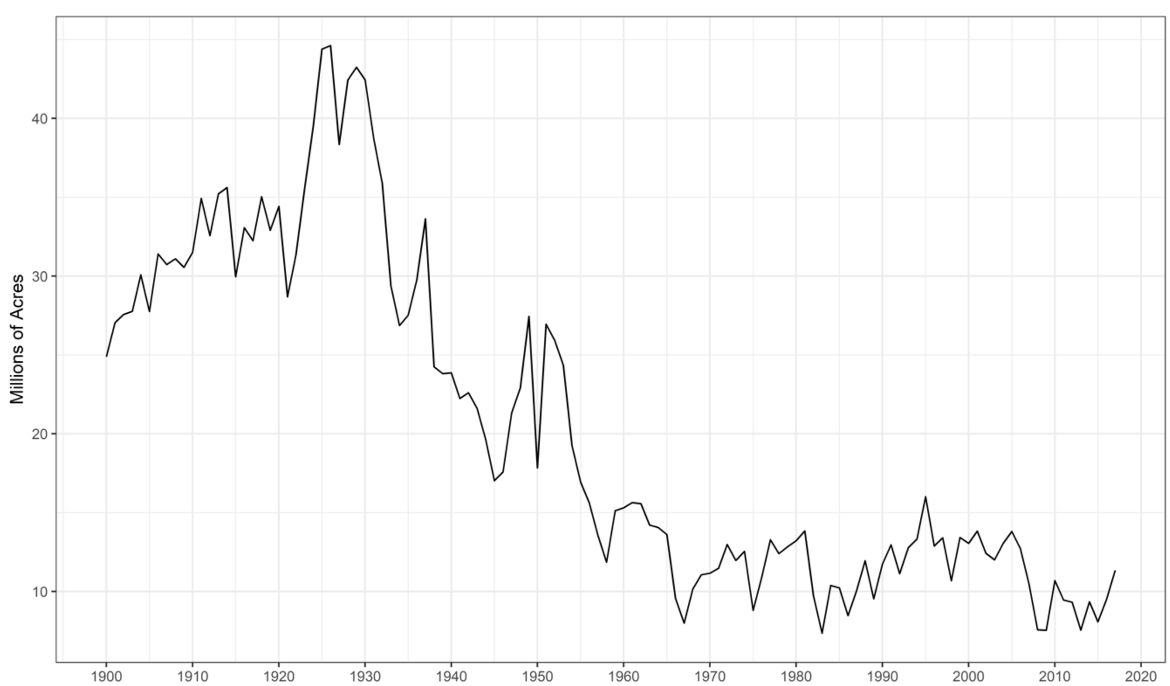

Figure 3. Harvest cotton acreage in the United States, 1900 to present

By examining Figure 3 and Figure 4, there is a shift that can be seen where the number of cotton producing counties within the U.S. has dropped over time. Even some of the top producing counties in 1974 have completely stopped producing cotton. This shift is due to the addition of mechanization, specifically the cost related to the harvest equipment. Producers found other crops to grow and to substitute in for cotton.

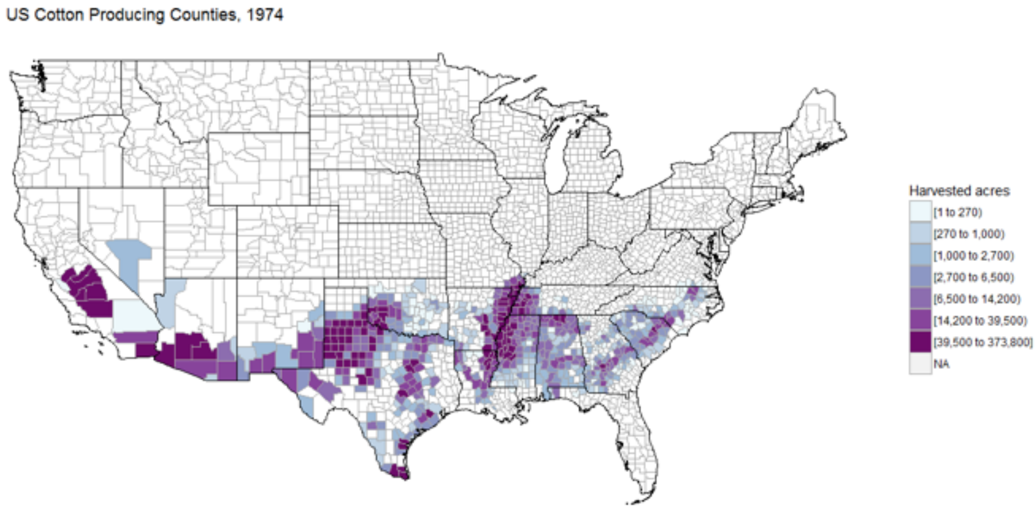

Figure 3 - U.S. Cotton Production within U.S. Counties in 1974

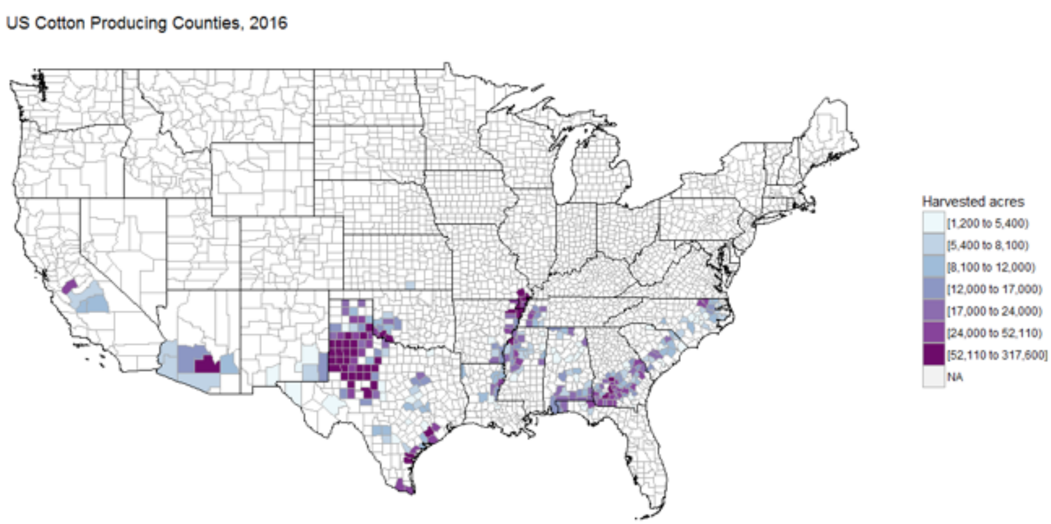

Figure 4 - U.S. Cotton Production within U.S. Counties in 2016

Results & Discussion

Results are predicted to give us information regarding the feasibility of the varying systems discussed within the analysis. In the end, the overall goal of the research is to challenge the current practices within cotton production and to examine the multiple new routes that could be followed to improve cotton production efficiency. Results are pertinent to cotton producers and equipment manufacturers as this may reduce one of their largest expenses in cotton production. To be able to use these machines for multiple different uses through the season increases the feasibility and practicality of these machines. Producers of other crops may be interested in this information as well - if the results show significant cost reductions within cotton production, then this system could very easily be transitioned into other regions as well as other high-valued cropping systems.

In this analysis, a spectrum of cotton equipment is considered with primary focus on harvest and secondary examination on planting and in-season activities. The *status quo* field equipment serves as a baseline for comparison. This equipment likely to have automated guidance systems that utilize global navigation satellite systems (GNSS) (Griffin et al 2017). The next iteration is autonomous vehicles, which have become commercially available in the last two years (Table 1). Autonomous vehicles are similar sizes as the status quo and can conduct the same field operations. The remaining iterations are also autonomous but incrementally become much smaller in size both in terms of horsepower and dimension. Large robots greater than or equal to 2-row equipment up to the size of the status quo machinery. Small robots are essentially 1-row equipment and somewhat analogous to human labor. The final iteration in this analysis are small swarms of autonomous robots, i.e. nanobots or swarm bots. Swarm bots may be up to the size of 1-row equipment or as small as baseballs. Swarm bots and small robots both likely to have a 'mother-ship' where docking occurs for repairs and maintenance (R&M), reloading supplies, or unloading (such as harvested seed cotton or samples such as soils or tissue).

Table 1. pro's and con's of each iteration of automation/rotation about here

Technology	Pro's	Con's
Status quo (8-row to 24-row)	Some farmers enjoy operating machinery Human locally in case of malfunction Carries enough seed to plant many acres per pass	Requires human labor Requires cotton acreage to be concentrated in geographic region Harvest field in single-pass ST yield & quality compromised
Autonomous (8-row to 24-row)	Maintain only few units Mechanically similar as status quo, such that repairs & maintenance available Carries enough seed to plant many acres per pass	Liability insurance Harvest field in single-pass ST yield & quality compromised
Large robots (>= 2-row)	Maintain only few units Mechanically similar as status quo, such that repairs & maintenance available	Liability insurance Harvest field in single-pass ST yield & quality compromised
Small robots (1-row), similar to single human laborer (may include a 'mother-ship')	Pick cotton by the boll, higher yield and quality Many passes possible	Liability insurance Requires skilled-laborers to maintain robots R&M dissimilar to current services
Swarms of nanobots (may include a 'mother-ship')	Pick cotton by the boll, higher yield and quality Allows cotton acreage to be spread over larger geographic regions, potentially in non-traditional areas Many passes possible	Must maintain many units Requires skilled-laborers to maintain swarm R&M dissimilar to current services

Conclusion or Summary

In conclusion, there are many different routes that can be taken when discussing the integration of swarm bot technology into current cotton production practices. Mainly due to the high cost of existing cotton harvest machinery, swarm bots could have a great advantage if proven to be multi-functional for their usage. A spectrum of technology has been defined. Advantages and disadvantages of each iteration of the spectrum have been presented. No clear winner or loser has been identified.

Future Work

Whole-farm linear programming model evaluates land, labor, and equipment resources for limiting constraints. Breakeven economic analysis of per area cost to own, maintain, and operate machinery from the spectrum identified in this study.

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