ADVANCES IN COTTON GINNING SIMULATION: TRANSPORTATION RESOURCE MANAGEMENT

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Abstract

In recent years, cotton production in Texas has increased significantly from a three decade historic average of around 3 million bales per year to more than 8 million bales per year in 2006 and 2007. The number of cotton gins in Texas has decreased from 1400 in 1960, to less than 260 in 2007. The increasing production of seed cotton along with the decreasing number of cotton gins in Texas was the justification for more research with the goal of more efficient cotton handling and ginning systems. Specifically, fewer gins and increased production will likely result in transporting seed cotton longer distances. Application of management science tools to minimize costs associated with seed cotton transport and cotton ginning has been the goal of this project for a number of years. This paper details the progress made in a systems analysis project focused on minimizing costs of ginning and seed cotton transport using module trucks. An example is provided to illustrate how a consultant could determine the appropriate schedule and the minimum number of trucks needed to manage seed cotton required for the gin, such that the gin was never idle waiting for cotton. The findings of this research illustrate how a large gin could conceivably travel 45 miles away, to obtain sufficient seed cotton to reduce ginning costs by increasing its percent utilization (%U). The reduced cost could result in decreased ginning costs for local producers while offering reasonable ginning costs for producers in an area 45 miles away. This paper is an example of how management science can be utilized to manage costs and resources in the cotton industry

Introduction

For many years, cotton production was a localized discipline in which growers in an area always had a gin available in close proximity. With the development of the module builder, the module truck became the primary tool for transporting cotton from field to gin. Since cotton gins were numerous, and fuel was affordable, transportation costs were manageable. The number of cotton gins in Texas has decreased from over 1400 in the early 1960's, to less than 280 in 2007. In recent years, cotton production in Texas has increased significantly from a three decade historic average of around 3 million bales per year to more than 8 million bales per year by 2007. The typical gin has grown in size, and the average ginning season has increased in length. Also, some areas of the state have grown more isolated from cotton gins. As gins continue to close, distance from the turn-row to the nearest operating gin has increased. The corresponding costs associated with transporting seed cotton modules to an operating gin has also increased.

Seed cotton is typically stored in 8 ft. by 32 ft. by 8 ft. cotton modules that are transported by a live bottom, chain operated module truck. A loaded module truck typically weighs at least 50,000 pounds. Loaded module trucks may exceed the allowable load limit in Texas of 34,000 pounds. Over-weight module trucks are not allowed to use the interstate highway system. Routing these loaded trucks can be a problem for many gins. Current research is exploring the possibility of implementing semi-tractor trailers that can haul two modules for traveling long distances with seed cotton and utilize the interstate highway system (Hamann et al., 2009).

Emsoff et al., (2007) published research findings including models and algorithms for determining optimal season length, in terms of percent utilization (%U) and minimal ginning cost for four different ginning rate categories. Fuller et al., (1993) developed and published the %U model for cotton gin operations. The concept of the %U model is that a cotton gin operating at 100%U would normally process seed cotton at 80% of its rated capacity (GR) for 1000 hours per season. Equation 1 defines the number of bales ginned (BG) per season for a gin processing cotton at 100%U with zero downtime:

$$BG = GR \times 0.8 \times 1000 \tag{1}$$

Utilizing the percent utilization model, Emsoff developed the following equation to determine ginning season length (L) in hours:

$$L = BG / (GR \times 0.8) \quad (2)$$

To illustrate the use of this %U model consider the following model: Given a gin rated at 20 bales per hour (bph) operating for 1250 hours per season will gin 20,000 bales at 125% utilization. The gin will process cotton at an average rate of 20 * 0.8 = 16 bales per hour for 1250 hours per season = 20,000 bales per season (with no down time). For a gin rated at 50 bph processing 60,000 bales in a season, the length of the gin season (L) would be 1500 hours. [L=60,000/(0.8*50)] = 1500 hours. This gin would be operating at 150%U (1500/1000*100). The Emsoff model included cost per bale of fixed and variable costs as a function of %U. The variable cost data for these algorithms were obtained from gin cost surveys (Valco et al., 2002 and 2004). The gins participating in the surveys reported their annual variable costs for electric power, drying fuel, bale packaging, repair and maintenance, and seasonal labor. These costs per bale along with calculated percent utilizations were used by Emsoff to form the model of costs per bale as a function of %U used in this research.

This paper includes an example of a particular gin which has the opportunity to travel outside of its normal service area to retrieve more seed cotton for processing with the result of increasing its %U. A decision support package combining the Simpson et al., (2007) and Emsoff models (Parnell et al., 2006) was developed to illustrate how decisions to acquire additional cotton could reduce ginning cost and allow for long range transport of seed cotton using module trucks.

Cotton producers in areas that have lost their local gin must find a gin to process their cotton. It is assumed that they will seek a gin that can provide this service at a reasonable cost. The following example illustrates the calculations used to support management decisions for an example 60 bph (rated) gin expecting to process 55,000 bales in a season at 115%U. In this particular year, they have the opportunity to attain 17,000 additional bales of cotton outside of their normal service area. By ginning this extra cotton, they will increase their %U from 115% to 150%, which would result in lowering their ginning cost per bale.

Procedures and Results

Ginning Cost versus %U Analysis

When deciding whether or not to attain additional cotton for ginning, a gin manager must first determine if acquiring the additional seed cotton would be economically feasible for their operation. Obviously seed cotton transportation costs for the additional cotton outside the normal service area would be a factor to be considered. The service provided could be essential to the potentially stranded producers and may actually be monetarily advantageous for the gin when looking at the ginning costs per bale. Previous research findings reported by Parnell et al., (2006), which will be referred to as the Emsoff model, utilized years of survey data from gins all across the cotton belt and historical data from cooperating gins in the state of Texas, to formulate mathematical models of fixed, variable and total costs per bale for gins with processing rates of 0-15, 15-25, 25-40, and >40 bph. (The survey data were provided by Valco et al., (2002 and 2004). Emsoff's findings suggested that as a gin increases its %U, ginning costs per bale decreased as long as the gin is operating at less than optimum %U. Figure 1 depicts the ginning cost model for the greater than 40 bph category for fixed cost per bale (Emsoff model). The variable cost per bale as a function of %U, was relatively constant at $25 for gins in this category. Hence, any change in fixed cost per bale would in affect be equal to the change in the total cost per bale for ginning.

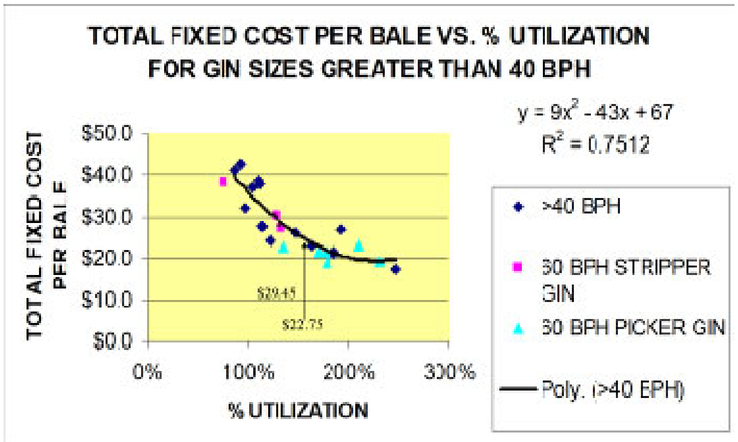

Figure 1. Total Fixed Cost per Bale (Emsoff et al., 2007)

This management science example utilizes a hypothetical ginning situation to portray the possibility of a gin retrieving extra cotton, and the decisions a gin manager may face. The example gin is a 60 bale per hour (rated) plant that has a truck fleet of six module trucks, and a local supply of 55,000 bales. According to the Emsoff model, this plant would have a fixed ginning cost per bale of $29.45. It was determined that an additional 17,000 bales of cotton are available in an area outside of the normal service area without access to a local gin. With the additional cotton, the 60 bph plant could process 72,000 bales and potentially lower its fixed ginning cost per bale to $22.75. If the gin could acquire this cotton and increase its %U to 150%, it would result in a decrease in fixed cost per bale for all producers in both areas of $6.70 per bale.

Transportation Cost Analysis

Simpson et al., (2007) developed the following model for calculating transportation costs associated with module trucks:

$$TC = \$60 + (D-15) * \$3.35 \qquad (3)$$

where: TC = Transportation cost per module, and
D = One-way distance from the gin site to the module.

The model was based upon the assumptions listed below

- A used module truck will cost $50,000 @ 6% interest for a 5 year period
- Straight line depreciation of the module truck over 10 years
- Fuel mileage of 5 mpg
- Diesel cost @ $2.50/gal
- Module truck average speed 40 mph
- Maintenance costs $1000/yr
- Insurance costs $1000/yr
- License cost $500
- Driver can work a 12 hour day and is paid $15 per hour including benefits
- 1 shift per day, 10 hours per shift
- 15 bales per module
- 20 minute loading & unloading time per module

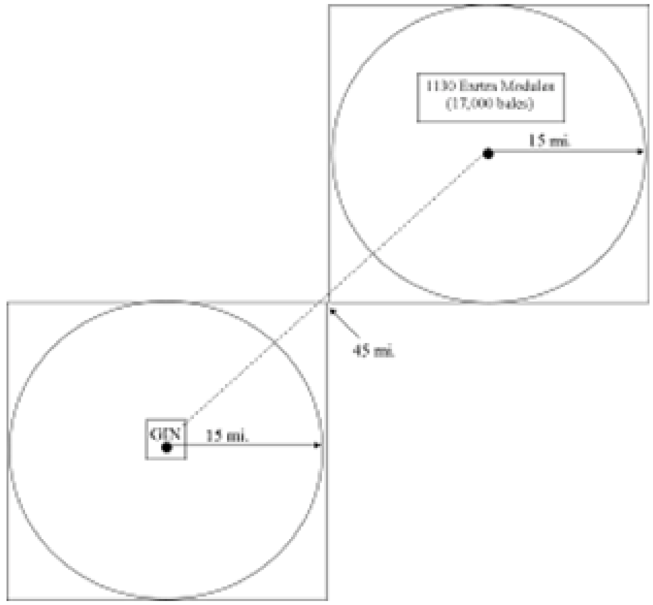

Figure 2. Schematic of the relative location of local and remote seed cotton supply areas relative to the gin

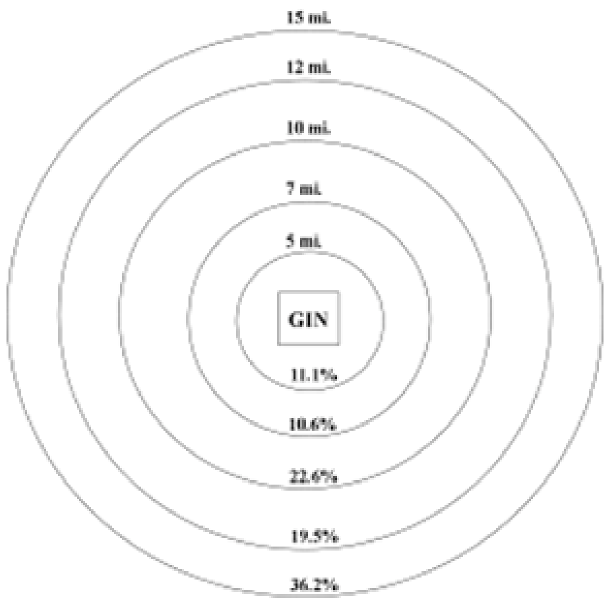

Figure 3. Concentric rings with distributions of areas directly proportional to seed cotton.

The management science example used in this paper includes the following assumptions:

1. All modules contained 15 bales of seed cotton.
2. The 60 bph gin had an average processing rate of 48 bph for all cotton processed. This is equivalent to 77 modules per day.
3. Local producers provided 55,000 bales (3,670 modules) located within a 15 mile radius (one way).
4. The additional 17,000 bales (1,130 modules) were located in an area 45 miles from the gin module storage area.
5. The 17,000 bales are within a 15 miles radius of a remote module yard that can be used as a central

gathering and loading site for modules to be transported to the gin 45 miles away. (See Figure 1.)

6. Using the Simpson model, all cotton within the 15 mile radius of the gin will pay a flat fee of $60 per module or $4 per bale. Likewise, all cotton within 15 miles from the remote module yard will pay a flat fee of $60 per module or $4 per bale.
7. The cost of transporting modules from the remote module yard 45 miles from the gin module yard will be an additional $3.35 per mile for every mile over 15 miles = $100 per module or $6.70 per bale.
8. The remote and local module yards for this example may contain unlimited number of modules in order to simplify the example.
9. The goal of the transportation systems analysis was to gather and deliver all seed cotton to the gin yard that would allow the gin to operate 24-hours per day without interruption
10. The average speed of a module truck used to gather and deliver seed cotton to the gin storage yard was 40 mile per hour (mph). Likewise, the average speed of a module truck used to gather and deliver seed cotton to the remote storage yard was 40 mile per hour (mph).
11. The distribution of seed cotton in each concentric ring shown in Figure 3 was directly proportional to the area in each ring and uniform.
12. The time required to deliver modules located in a ring 12 to 15 miles from the storage yards was calculated using equation 3. This time would include the time to travel from the storage yard to the module and return and include 10 minutes for loading and 10 minutes for unloading the module or 0.33 hours. The mid-point distance from the storage yard was used for all modules in each ring.
13. The module truck fleet consisted of 6 trucks. These trucks were operated 8, 10, and 12 hours per day, 7 days per week in the tables provided below.
14. The travel to and from the remote storage yard was assumed to be at an average speed of 45 mph rather than 40 mph. The module truck would likely travel on the interstate at a faster rate when unloaded. Hence, the travel time to and from the remote yard including the same 10 minutes for loading and unloading would be 2.33 hours per module.
15. A fleet of 6 module trucks would be contracted to move the remote cotton to the remote seed cotton storage yard and transport this cotton to the gin yard with a goal of not delaying the ginning of all 72,000 bales.

Module Truck Transportation Analysis Results in the Local Area:

Table 1 contains the analysis of the number of bales of seed cotton and 15 bale modules in each concentric ring shown in Figure 2. The time in hours per module (HPM) required to retrieve a module from the 12 (d_1) to 15 (d_2) mile ring (Figure 2) can be calculated using equation 3.

$$HPM = \frac{2\times\left(d_1 + \frac{d_2 - d_1}{2}\right)}{40} + 0.33 \qquad (3)$$

Where, HPM =hours required to pickup and deliver a module in this ring to the gin;
d_1=inside radius, miles;
d_2= iutside radius, miles; and
0.33 = hours required for loading and unloading.

Table 1. Transportation analysis results for the local area within a 15 mile radius. Distribution of the 55,000 bales contained in each concentric ring from the source, hours per module needed to move it to the gin and number of modules per truck per hour.

Concentric Rings miles	% Seed Cotton	Bales	Modules	Hours per module	Modules per hr per truck
0-5	11.1	6105	407	0.458	2.18
5-7	10.6	5830	389	0.633	1.58
7-10	22.6	12430	829	0.758	1.32
10-12	19.5	10725	715	0.883	1.13
12-15	36.2	19910	1327	1.008	0.99
total	100	55000	3667		

Table 2 shows the calculated number of 15-bale modules moved in 8, 10 and 12 hour shifts for the fleet of 6 module trucks. It also shows the number of 8, 10, and 12 hour days required to move all of the modules from each concentric ring. For example, there are 715 modules in the concentric ring defined by 10 to 12 mile ring. The total time required to move the modules to the gin would be 715 * 0.883 hours per module = 631 hours. For a 10 hour shift, 63 days would be required to deliver all of the seed cotton in this ring to the gin.

Table 2. Number of modules transported from the field to the gin from each concentric ring in an 8, 10 and 12-hour day; hours required to move all modules in each ring to the gin yard; 8-hour, 10-hour and 12-hour days required to move the modules from each ring.

Concentric Rings miles	Modules per 8-hour with 6 trucks	Modules per 10-hour with 6 trucks	Modules per 12-hour with 6 trucks	Total hours required to move modules	Total 8-hour days required	Total 10-hour days required	Total 12-hour days required
0-5	105	131	157	186	23	19	16
5-7	76	95	114	246	31	25	21
7-10	63	79	95	628	79	63	52
10-12	54	68	82	631	79	63	53
12-15	48	60	71	1338	167	134	111
total				3030			

Table 3 shows the analysis used to determine if there are a sufficient number of trucks available to meet the requirement to deliver all of the seed cotton to the gin (in the local area) such that the gin is not idle. % Utilization for trucks is calculated by dividing the number of 8, 10, and 12 hour days by the number of days that the gin will require to gin 55,000 bales at 48 bph using 24 hour shifts for ginning. This number is 48 days. The results of these analyses suggest that 8 and 10 hour shifts will not meet this requirement. 7.9 and 6.3 trucks will be required for the 8 and 10 hour shifts, respectively, to get all the cotton to the gin.

Table 3. Percent utilization for a fleet of 6 trucks for 8, 10, and 12 hour work shifts per day in the local area.

Concentric Rings miles	% Utilization 8-hour per day	% Utilization 10-hour per day	% Utilization 12-hour per day
0-5	49%	39%	32%
5-7	64%	51%	43%
7-10	164%	131%	109%
10-12	164%	132%	110%
12-15	348%	279%	232%
total	789%	631%	526%

Module Truck Transportation Analysis Results in the Remote Area:

Table 4 contains the analysis of the number of bales of seed cotton and 15 bale modules in each concentric ring shown in Figure 2 for the remote area that totals 17,000 bales. The time in hours per module (HPM) required to retrieve a module from the 12 (d_1) to 15 (d_2) mile ring (Figure 2) can be calculated using equation 3. In this remote area, we merely need to move the 1133 modules to the remote storage location in preparation for being transferred to the gin.

Table 4. Transportation analysis results for the remote area located 45 miles from the gin yard. Distribution of the 17,000 bales (modules) contained in each concentric ring assumed to have a 15 mile radius from the remote yard location. Hours per module needed to move it to the remote yard and calculated number of modules per truck per hour.

Concentric Rings miles	% Seed Cotton	Bales	Modules	Hours per module	Modules per hour per truck
0-5	11.1	1887	126	0.458	2.18
5-7	10.6	1802	120	0.633	1.58
7-10	22.6	3842	256	0.758	1.32
10-12	19.5	3315	221	0.883	1.13
10-15	36.2	6154	410	1.008	0.99
total		17000	1133		

Table 5 shows the calculated number of 15-bale modules moved in 8, 10 and 12 hour shifts for the fleet of 6 module trucks. These module trucks are a different from the 6 truck fleet used in the local area. It also shows the number of 8, 10, and 12 hour days required to move all of the 1133 modules from each concentric ring. For example, there are 221 modules in the concentric ring defined by 10 to 12 mile ring. The total time required to move the modules to the remote storage yard would be 221 * 0.883 hours per module = 195 hours. For a 10 hour shift, 20 days would be required to deliver all of the seed cotton in this ring to the remote storage yard.

Table 5. Number of modules transported from the field to the remote yard from each concentric ring in an 8, 10 and 12-hour day; hours required to move all modules in each ring to the gin yard; 8, 10, and 12-hour days required to move the modules from each ring.

Concentric Rings miles	Modules per 8-hour with 6 trucks	Modules per 10-hour with 6 trucks	Modules per 12-hour with 6 trucks	Total hours required to move modules	Total 8-hour days required	Total 10-hour days required	Total 12-hour days required
0-5	105	131	157	58	7	6	5
5-7	76	95	114	76	10	8	6
7-10	63	79	95	194	24	19	16
10-12	54	68	82	195	24	20	16
12-15	48	60	71	414	52	41	34
total				937			

Table 6 shows the analysis used to determine if there are a sufficient number of trucks available to meet the requirement to deliver all of the seed cotton in the remote area to the remote storage yard. The objective of this analysis is different than that of the local area. The goal in the remote area is to accumulate the 17,000 bales (1133 modules) in the remote storage and loading area so that this cotton can be delivered to the gin such that the gin is not idle waiting for this cotton. The gin will operate for an additional 14.5 days to gin the remote area cotton. The total ginning time needed to gin the entire 72,000 bales would be 62.5 days at 24 hours per day. It will take 2.33 hours to pick up and deliver a module from the remote yard to the gin 45 miles away. An 8, 10, and 12 hour shift will allow one module truck to pickup and deliver 3, 4, and 5 modules to the gin, respectively. It is assumed that the ginner would want to gin all of his local cotton before ginning the remote cotton. The %U calculations for the trucks in the remote area were calculated differently. The %U calculations shown in Table 6 were 24 days. The results suggest that in 24 days, the entire 1133 modules can be moved to the remote site. Back-calculating using 14.5 24-hour days to gin the remote cotton, we know that we can only deliver 24 modules per day with 6 trucks per 10 hour day and the gin will be processing 77 modules per day. The total number of modules we can deliver in this 14.5 day period is 348 modules. (We have 1133 modules that must be moved to the gin yard to be ginned before 62.5 days.) Hence, we have to start delivering modules to the gin from the remote area. In 24 10-hour days, 4 trucks can move the entire 1133 modules to the remote storage and loading area. Using 2 of the 6 truck fleet to start moving cotton to the gin site for 20 of the 24 days that the remaining four trucks are simultaneously moving cotton from the field to the remote site, 160 modules can be moved. We still must move 933 modules to the gin. Using all 6 trucks to move 24 modules per 10-hour day, it will take an additional 39 days to get the rest of the remote cotton to the gin. A total of 59 days will be needed to move the cotton from the remote area to the gin site

Table 6. %U for a fleet of 6 trucks for 8, 10, and 12- hour work shifts per day in the remote area. It is assumed that each truck has 24 days to transport cotton to the remote yard and up to 62.5 days to complete transport to the gin.

Concentric Rings miles	% utilization 8-hour per day	% Utilization 10-hour per day	% Utilization 12-hour per day
0-5	30%	24%	20%
5-7	40%	32%	26%
7-10	101%	81%	67%
10-12	102%	81%	68%
12-15	215%	172%	144%
total	488%	390%	325%

Summary

Producers in the gin's local service area would see a reduction in fixed ginning cost of $6.70 per bale as a result of processing at 150%U rather than 115%U. The producers of the extra 17,000 bales of cotton would also see the reduction in ginning costs, but would incur transport costs of $6.70 per bale which would be equivalent to the reduced ginning costs. The increase in gin's %U from 115% to 150% benefitted the local producers by reducing ginning costs. A reduction of $6.70 per bale would potentially result in over $350,000 for the local customers. In addition, producers of the additional 1,133 modules would be able to continue growing cotton and get it ginned at a reasonable cost. This example is a hypothetical situation of only one possible ginning scenario. There are many and each gin should carefully examine all assumptions before proceeding with acquiring additional cotton for their specific gin. The findings outlined in this paper demonstrates that gin managers should consider the costs/benefits of ginning additional cotton from remote areas before the gin season, using a management science approach. The resulting costs could potentially be more than the rewards from reduced ginning costs as a consequence of increasing %U.

It was determined that the best way to transport the additional cotton from the central loading site to the gin was to contract an additional fleet of six module trucks to gather and deliver the modules. At 45 mph with 20 minutes loading/unloading time, each of the six contracted module trucks could deliver 4 modules per 10-hour day, or 24 modules per day for the entire fleet. The management science calculations used in this paper with the Emsoff and Simpson models can be used to evaluate the merits of increasing %U by acquiring additional cotton.

A decision support model was developed to assist gin managers (Hamann et al., 2008; Emsoff et al., 2007; Parnell et al., 2005a and 2005b; Simpson at al., 2006 and 2007). The question addressed in this paper was, is it possible that an increase in %U by acquiring additional seed cotton from a remote area and have the result that both the local cotton producers and producers in remote areas would like? The model can be used to generate information that ginners and producers can both evaluate. It is meant to be used as decision support. The example and assumptions used in this paper should be carefully evaluated before proceeding with a decision to acquire cotton from remote areas. Care must be taken to develop an optimal scheduling of module trucks. Obviously, traveling further distances for cotton modules will increasingly raise transportation costs, but by moving closer to their optimal %U, the gin could see savings in ginning costs that may offset the additional cost of transport. Gin management must decide if those savings or a combination of the savings and extra fees will make increasing %U cost effective. A remote storage and loading area was assumed to be the best approach. There is considerable variability in these types of decisions. The research team portrayed one hypothetical example to illustrate the calculations needed for decisions support. The strength of this model is that its simplicity and flexibility allows for it to be tailored to any ginning situation.

Future Research

There are a number of management science tools that can be incorporated in this decision support model. It is anticipated that Monte Carlo simulation will be incorporated that will include variations in ginning rates, transport times and speeds of module trucks. Queuing theory will play a role when the allowable number of modules in the yard is limited. Linear programming can be used to optimize the number of number of trucks assigned to local and remote areas. The assumption that all cotton produced in local and remote areas was uniform should be evaluated closely.

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