MINIMIZING FARM-TO-MILL CLEANING COST FOR IRRIGATED AND DRYLAND COTTON

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Abstract

By employing survey and simulation techniques, this research identifies the least cost cleaning configurations across the harvesting, ginning, and textile mill stages of cotton processing. Given the standard textile mill technology, the least cost cleaning configurations were found to include the use of low trash producing cultivars in the harvesting stage and one lint cleaning in the ginning stage for the best quality of yarn for both irrigated and dryland cotton. For the second and third best quality of yarn, the least cost cleaning configuration was found to include the use of medium trash producing cultivars in the harvesting stage and one lint cleaning in the ginning stage again for both irrigated and dryland cotton. It was determined that if the recommended cleaning configurations are employed, the cotton industry could save between $7.78 and $7.40 per bale of irrigated cotton and $7.30 and $7.26 per bale for dryland cotton, depending on the desired yarn quality.

Problem and Objectives

Cotton cleaning is a multi-stage operation that involves stages of production, harvesting, ginning, and textile processing. Further, management and cleaning practices can vary significantly within each of these stages. At the production stage, cultivars, soil type, the use of irrigation, and weather-related factors may have a significant impact on the cleanliness and quality of harvested cotton. Variation in management and cleaning activities may include the use of irrigation and type of cotton used in the harvesting stage and a combination of one to three stages of lint cleaning at the gin plant. At the textile mill, variation in opening, carding and drawing practices can also affect the degree to which cotton is cleaned.

Production practices employed and the mix of cotton cleaning activities during harvesting, at the gin plant, and at the textile mill determine not only cotton cleanliness, but also lint weight and fiber qualities. Therefore, the cost of cleaning cotton should include the cost of various management practices used (the cost of owning and operating the cleaning equipments across the stages), effects of these management practices and cleaning activities on cotton quality factors, and the loss of lint during the various cleaning stages. The debate surrounding cotton cleaning, however, has been limited to operational efficiency at the typical gin plant processing stage and market prices (bale value). For example, the USDA (United States Department of Agriculture) recommended combination of cotton ginning machinery, regardless of the cleaning practices used in the production stage and desired yarn quality, includes two lint cleanings. This processing procedure achieves satisfactory bale value and reduces damage to the inherent quality of the fiber, but it may not maximize the net cash value for each individual bale (Anthony, 1985).

From the overall industry perspective, it is important to know the most efficient (least cost) mix of cotton cleaning activities across the entire system of cotton handling. Market prices do not seem to guarantee implementation of the most efficient cleaning configuration in a system framework. Haskel (1973) suggests that price should not be considered because the segmentation and division of responsibility within the cotton industry contributes to excessive farm-to-mill costs. Excessive farm-to-mill costs are demonstrated by the fact that additional lint cleanings usually result in higher prices (Ethridge et al., 1994). This may be profitable for producers, but may not be efficient across the entire system if the objective is to minimize farm-to-mill cleaning costs.

The availability of alternative management practices and cleaning configurations raises the question of identifying the optimal approach to clean cotton. The optimal cotton cleaning configuration for the overall industry, would include various management practices in the production stage and a sequence of cleaning processes at the gin and at the textile mill which can be accomplished at a minimum cost. If it is assumed that textile mills are usually targeting a desired quality of yarn, the issue is one of selecting least cost cleaning configurations across the ginning and textile mill stages given various management practices in the production stage to achieve the desired yarn quality. Bennett and Misra (1996) addressed the issue of minimizing costs across the three stages and found that one lint cleaning in the gin plant was the best general rule. However, a problem with this study is that it ignored lint loss resulting from the sequential stages of lint cleaning in the gin plant.

This study revisits the economic consequences of alternative cotton cleaning configurations for a given yarn quality at the least cost. This criteria used differs from the Bennett and Misra (1996) study in that it considers costs associated with lint loss in the gin plant due to successive lint cleanings and only considers non-field cleaned cotton.

Methods and Procedures

Given that there are alternative methods of cleaning cotton from the ginning stage through the textile mill stage, conceptually the problem becomes one of cost minimization (identifying the cleaning process across the three stages that delivers a certain degree of cotton cleanliness and quality at

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the least cost). The analysis was based on both irrigated and dryland, stripper harvested cotton produced on an average farm size of 1,000 acres in the Southern High Plains.

Harvesting Stage

For the purpose of this analysis, secondary data for average yield per acre for high trash producing cultivars (Lankart LX-571 and Cencot), medium trash producing cultivars (Tamcot CAB-CS, Deltapine SR-383, and Deltapine 50), and low trash producing cultivars (Paymaster HS-26, Paymaster 145, and All-Tex Atlas) of irrigated and dryland cotton were calculated by averaging agronomic yield data for 1988 through 1992 reported by Gannaway et al. (1992). The purpose of this exercise was to categorize cotton cultivars into six groups (irrigated and dryland cotton each with high, medium, and low trash) representing irrigated and dryland cultivars with different trash content and lint turnout. The low trash category represents low trash cultivars of cotton with high turnout ratios (1.56 bales/acre for irrigated cotton and 0.70 bales/acre for dryland cotton), the medium trash category represents cotton cultivars with medium trash content and turnout ratios (1.26 bales/acre for irrigated cotton and 0.55 bales/acre for dryland cotton), and the high trash category represents cultivars with low turnout ratios (0.81 bales/acre for irrigated cotton and 0.31 bales/acre for dryland cotton) and high trash content. Since it was assumed that no alterations would be made in the harvesting stage between cultivars, no cleaning costs were assigned to the harvesting stage.

Ginning Stage

Impacts of the cleaning configurations in the gin on the cleanliness and quality of cotton were determined by employing a simulation model, GINQUAL (Barker et al., 1990). The cultivars of cotton were ginned using the simulation model separately. The ginning rate and number of ginstands were set constant for the three cultivars at 18.67 bales per hour and three ginstands. A single stream cleaning system with the standard machine sequence for gins was employed for the three cultivars. The moisture content of the seed cotton was also set constant at fourteen percent for the three cultivars. The three cultivars were subjected to one to three lint cleanings each with three parallel lint cleaners in each stage.

The total cleaning cost in the gin plant was determined by surveying three ginners who operate gins in the Lubbock, Texas area. A survey pertaining to the costs associated with the gin operation was completed. The results from the survey were used in the GINMODEL, ginning cost simulator (Roy Childers, 1995). Output from GINMODEL consists of total and per bale ginning costs separated into fixed and variable components. The ginning cost simulator did not, however, account for the disposal cost of waste produced by the gin plant or the cost of lint loss due to ginning. Because gins pay a fixed amount per bale of cotton lint to dispose of the waste, waste disposal cost per bale was estimated and added to the estimated ginning cost per bale from the GINMODEL. The lint loss in the gin plant due to precleaning and successive levels of lint cleaning were estimated from the GINQUAL output for the different cultivars at various levels of lint cleaning. Lint loss at each level of lint cleaning was calculated by subtracting the current level of turnout from the previous stage lint turnout. The resulting lint turnout difference was multiplied by 2,300 lbs. of initial seed cotton entering the gin plant and was further adjusted to a lint loss weight per bale.

Producer level market prices and premiums and discounts were then obtained from the DPES. The price equation (Hudson and Ethridge, 1995, pg. 5) used was:

$$\begin{aligned} \ln P = {} & 2.7847 - 0.00082\,LF^2 - 0.00109\,C1^2 - 0.00705\,DUM1 \\ & - 0.03206\,DUM2 - 0.05592\,DUM3 + 0.056945\,STA \\ & - 0.00076\,STA^2 + 0.001088\,STR + 0.211416\,M - 0.0255\,M^2 \\ & - 0.00036\,LB - 0.01335\,HB - 0.02346\,LO - 0.07774\,HO \\ & - 0.07323\,R \end{aligned} \qquad (1)$$

where

ln	= natural logarithm,
LF	= leaf grade (1 - 7),
C1	= first digit of the color grade (1 - 7),
DUM1	= binary indicator for the second digit of the color grade (If the second digit = 2, DUM1 = 1; DUM1 = 0 otherwise),
DUM2	= binary indicator for the second digit of the color grade (If the second digit = 3, DUM2 = 1; DUM2 = 0 otherwise),
DUM3	= binary indicator for the second digit of the color grade (If the second digit = 4, DUM3 = 1; DUM3 = 0 otherwise),
STA	= staple length in 32nds of an inch,
STR	= strength of the cotton in grams/tex,
M	= micronaire reading,
LB	= percentage of bales in a lot classed as Level 1 bark,
HB	= percentage of bales in a lot classed as Level 2 bark,
LO	= percentage of bales in a lot classed as Level 1 other extraneous matter,
HO	= percentage of bales in a lot classed as Level 2 other extraneous matter,
R	= binary indicator for the region (R = 0 if the market is West Texas, R = 1 for East Texas/Oklahoma).

The price associated with the various levels of grade, staple length, fiber strength, micronaire, and percent barky bales was assumed to account for all price changes as quality varied with each discrete level of lint cleaning (one, two, and three). More specifically, prices were assigned to simulated cotton attributes generated by GINQUAL at the three levels of lint cleaning as cotton quality changed with successive lint cleaning. These two additional costs (waste disposal cost and lint loss cost) were added to the cost per bale estimates provided by GINMODEL to obtain a total ginning cost for one, two, and three lint cleanings in the gin plant.

Textile Mill Stage

Given the assumption that cotton is cleaned at the textile mill to obtain a desired quality yarn, the amount of cleaning that is done in the textile mill will depend on the cleanliness and quality of cotton that is delivered to the mill. Given the desired quality of yarn, some cotton may have to be cleaned more aggressively in the mill than others. Further, it is also possible that some cotton will not achieve the desired quality of yarn regardless of the cleaning process that is undertaken at the textile mill.

The desired level of cleanliness and quality for spinning was established with the aid of Trutzschler GMBH & Co., Germany and the International Textile Center at Texas Tech University. The data produced for each configuration from the GINQUAL model were analyzed and it was determined that no alteration in the cleaning process is needed at the textile mill. Therefore, a single cleaning configuration (Bennett 1995) in the textile mill was identified. The suggested method of spinning the cotton into yarn involved open-end spinning with the use of an opening roller which also removes some fine dust from the cotton lint.

Yarn qualities that can be obtained for the alternative cotton cleaning configurations were predicted with the aid of the International Textile Center, Lubbock, Texas to classify the cleaning configurations according to yarn qualities. This relationship can be expressed as:

$$CSP = C - (m * N_{ec}), \qquad (2)$$

where CSP is yarn strength prediction, C is 382.5 + (52.26*HVI Strength) + (792.2*Length), m is 44.47 - [(23.96*Length) + (1.918*Mic)], and N_{ec} is the Yarn size and was held constant at 16.

By obtaining the HVI strength, length, and micronaire for each configuration from the GINQUAL model, the yarn strength was predicted for each configuration using equation (2) and grouped into three different quality categories based on strength. These yarn qualities ranged from: 2350 and above for the best quality yarn; 2200 and above for the second best quality yarn; and 2000 and above for the third best quality of yarn.

Finally, the total cleaning cost in the textile mill was determined. Because a single cleaning configuration was chosen for the textile mill to clean cotton coming out of alternative configurations, the only difference in cleaning cost in the textile mill was revenue loss due to lint loss and the disposal cost of waste produced at the textile mill. To obtain the revenue loss per bale, an econometric relationship reported by Chen, 1995 was used to determine prices paid by textile mills for cotton from each configuration. The pricing equation is given by:

$$Price = 8.5640(9\text{-}G1)^{0.1726}(8\text{-}G2)^{0.2444}(L)^{0.1674}e^{0.3706M-0.522MM}, \qquad (3)$$

where Price is the price paid per pound for cotton lint, G1 is the first digit of the color grade, G2 is the second digit of the color grade, L is the length measurement of the cotton lint, M is the micronaire measurement, and MM is the micronaire measurement squared.

The price received by the textile mill for lint waste was obtained by surveying several textile mills in the United States and an average price per pound received for lint waste. The prices for each configuration were then subtracted from the estimated prices to determine the revenue loss per pound of cotton for each configuration. It was assumed that five percent of the cotton would be lost per bale in the textile mill (Smith, 1995). Revenue loss per bale for each configuration was determined by the product of the revenue loss per pound and twenty-four pounds (five percent of 480 pounds).

Trash generated at the textile mill for each configuration was estimated with the help of Trutzschler GMBH & Co., Germany. Trutzschler suggested that about ninety-nine percent of the trash is extracted from the cotton lint in pre-cleaning and carding at the textile mill. During open-end spinning using a rotor machine, eighty percent of the remaining trash in the cotton lint is removed (Smith, 1995). Therefore, the amount of trash extracted from the cotton lint before the rotor machine was determined by taking ninety-nine percent of the initial trash levels entering the textile mill (obtained from the GINQUAL simulation runs). The remaining trash levels were then multiplied by 0.8 (eighty percent) to determine the amount of trash removed during the rotor machine. These two trash levels were added to give the total amount of trash removed in the textile mill. The mills surveyed indicated that they discard the non-lint waste by using their own trucks to haul the waste to landfills. The average cost of using the landfill for these six textile mills was calculated to be $0.015/lbs. of waste material. The waste disposal cost was computed by multiplying the number of pounds of trash extracted in the textile mill from each configuration by the waste disposal cost ($0.015) per pound at the textile mill.

Determination of the Least Cost Cleaning Configuration

The determination of the least-cost cleaning configuration was accomplished by combining the total costs of each alternative cleaning configuration which met the yarn quality specifications. This involved examining the different total costs associated with each possible configuration and identifying of the optimal configuration which provided the desired degree of cotton yarn quality at the least cost. It should be noted that various cost components were excluded from this analysis (e.g., owning and operating costs of a stripper, textile mill costs following the rotor machine, etc.) because they did not differ among configurations.

Results

Ginning Stage

Results on the impacts of the cleaning configurations in the gin on the cleanliness and quality parameters (table 1) determined by GINQUAL indicated no significant difference in cotton quality between dryland and irrigated cotton. The low and medium trash cultivars possessed the highest strength, length, micronaire, +b, and uniformity ratio. Non-lint percent in the ginned cotton was found to be highest in cotton subjected to one lint cleaning and lowest with three lint cleanings in the gin plant. There was no significant difference in other quality characteristics among the three cultivars.

Estimated lint turnout varied by cultivar for both dryland and irrigated cotton. The lint loss at various stages of lint cleaning demonstrates that successive stages of lint cleaning consistently increase lint loss, but that lint loss increases at a decreasing rate as the amount of lint cleaning increases. Average lint weight loss across all cultivars associated with precleaning and one lint cleaning amounted to 57.19 lbs./bale and 58.04 lbs./bale for irrigated and dryland cotton, respectively. The second and third lint cleanings increased lint losses across all cultivars and production practices. The average weight of lint loss across all cultivars was estimated at 66.39 lbs./bale for precleaning and two lint cleanings of irrigated cotton, 66.96 lbs./bale for precleaning and two lint cleanings of dryland cotton, 69.99 lbs./bale for precleaning and three lint cleanings of irrigated cotton, and 70.39 lbs./bale for precleaning and three lint cleanings of dryland cotton. Thus, irrigated cotton lost an additional 9.2 lbs./bale and 3.60 lbs./bale with the second and third lint cleaning, respectively, and dryland cotton lost an additional 8.89 lbs./bale and 3.45 lbs./bale for the second and third lint cleaning, respectively.

The cost of lint losses in the gin plant increased with successive stages of lint cleaning (table 2). Across irrigated cotton cultivars, the average cost of lint losses was $37.98/bale, $44.52/bale, and $47.19/bale for one, two, and three lint cleanings, respectively. Likewise, the average cost of lint losses associated with dryland cotton cultivars were $38.57/bale, $44.91/bale, and $47.57/bale for one, two, and three lint cleanings, respectively. These losses represent an additional loss of about $6.54/bale and $6.33/bale for the second lint cleaning and about $2.68/bale and $2.67/bale for the third lint cleaning for irrigated and dryland cotton, respectively.

Estimated ginning costs plus waste disposal and lint loss costs per bale increased with each additional lint cleaning (table 2). Specifically, the total cost of ginning increased on average by $6.92/bale and $6.71/bale between one and two lint cleanings of irrigated and dryland cotton, respectively. Likewise, the total cost of ginning increased on average by $3.00/bale and $2.89/bale between two and three lint cleanings of irrigated and dryland cotton, respectively.

Textile Mill Stage

Results on the effects production practices, cultivar, and number of lint cleanings on the yarn quality in the textile mill, determined with the aid of yarn strength relationships obtained from the International Textile Center and the results of the GINQUAL model, indicated that the low trash cultivars met the requirement of having the highest yarn quality by possessing a yarn strength of 2350 and above. Second, the medium trash and low trash cultivars met the second best yarn quality with a yarn strength of 2200 and above. Finally, all three cultivars (low, medium, and high trash cultivars) were found to meet requirements for the third best quality of yarn with a yarn strength of 2000 and above.

Results of the cleaning costs in the textile mill (table 3), determined by estimating the revenue loss due to lint loss and non-lint waste disposal cost, indicated that textile mills had lower costs associated with non-lint disposal as the number of lint cleanings in the gin plant increased regardless of whether the cotton was irrigated or dryland. This can be seen by examining configuration 1, with a non-lint disposal cost of $0.50/bale, and configuration 2, with a non-lint disposal cost of $0.42/bale. It was also observed that in most cases textile mills had lower revenue losses when cotton is cleaned more in the gin plant (subjected to more lint cleaning). Again from table 3, revenue loss associated with configuration 1 is $10.37/bale, while configuration 2 is $10.36/bale. Whether the cotton was irrigated or dryland was found to not have a significant impact on the revenue loss in the textile mill with the exception of the low trash producing cultivars. Generally, low trash producing irrigated cultivars had a higher associated revenue loss than did dryland, low trash producing cultivars. The total cleaning costs in the textile mill for each configuration, on the other hand, was generally observed to be less for irrigated cotton cultivars.

Determination of the Least Cost Cleaning Configuration

Results for cotton cleaning cost for the overall industry, for one hundred percent utilization in the gin plant are presented in table 4 (Ninety and eighty percent utilization rates were not reported in this study because no differences were observed from the results found with one-hundred percent utilization). These results indicated that, if cotton is irrigated (dryland), for the best quality of yarn with a strength of at least 2350, the low trash producing cultivar should be cleaned in the gin plant using only one lint cleaner, and sent to the textile mill for further processing at an estimated total cleaning cost of $90.75/bale ($91.39/bale). For the second and third best quality of yarn with a strength of 2200 and above and 2000 and above, respectively, using irrigated (dryland) cotton cultivars, the medium trash producing cultivar of cotton should be subjected to one lint cleaning in the gin plant, and further processed in the textile mill at a total estimated cost of $89.40/bale ($91.31/bale). When the production practices (irrigated versus dryland) are analyzed, the use of irrigated cotton and one lint cleaning was found to produce cotton at the least cleaning cost to the industry regardless of the desired yarn quality.

Results of this study clearly suggest that, given the standard cleaning and processing practices in the textile mill, the least cost cleaning configuration for achieving high yarn quality is the use of irrigated cotton cultivars that produce low trash and one lint cleaning in the ginning stage. However, if a medium or low qualities of yarn are desired, results indicated that the medium trash cultivars of irrigated cotton should be used, but still be lint cleaned only once in the gin plant.

Conclusions

It is currently a standard practice to employ two lint cleanings in the gin plant. Results from table 4 indicate that if the existing cleaning practices are employed for irrigated cotton: the best quality of yarn can be produced by using configuration 14 at a total cleaning cost of $98.53/bale, and the second and third best qualities of yarn can be produced by using configuration 8 at a total cleaning cost of $96.80/bale. Results from this study, however, suggest that the least cost configuration using irrigated cotton to obtain the best quality of yarn is given by configuration 13 and for the second and third best qualities of yarn is given by configuration 8. The least cost cleaning configurations are distinctly different from the currently used cleaning practices as configuration 13 and 7 include one lint cleaning in the ginning stage. If these least cost cleaning configurations are employed, the cotton industry could save about $7.78/bale for producing the best quality of yarn, and $7.40/bale for producing the second best and third best qualities of yarn for irrigated cotton. Considering dryland cotton, the least cost cleaning configuration could save the industry about $7.30/ bale for producing the best quality of yarn, about $7.26/bale for producing the second best quality of yarn, and about $5.57/bale for producing the third best quality of yarn. It was further observed that the recommended optimal cleaning configurations can save, on average, about $7.69/bale in the ginning stage for irrigated cotton and $7.38/bale for dryland cotton. Cleaning costs at the textile mill, however, on average go up by about $0.10/bale for both irrigated and dryland cotton.

Caution should be used in generalizing the results of this study. The conclusions and implications to be drawn from this study are limited to the simulated conditions and the Texas-Oklahoma market since the estimated prices reflect market premiums and discounts for only this market. Further, this study did not consider the effects of prep on the price. In addition, it is recognized that the results of this study are based on the market price structure that existed in 1994/1995 crop year and the prices paid for cotton by textile mills from Chen, 1995. Any further change in the pricing structure may alter the findings of this study.

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Table 1. Effects of one, two, and three lint cleanings on quality parameters of irrigated and dryland cotton exiting the gin plant.

Cultivar	Config. Number	Irrigated or Dryland	# of LC	Str.	Mic	Length	Unif. Ratio	Refl.	+b	Color Grade	Comp. Grade	Trash Grade	Moisture % (Wet Basis)	Non-lint %
High Trash	1	Irrigated	1	21.89	2.44	30.7	80.99	69.05	7.47	51	61	7	6.64	6.99
	2	Irrigated	2	22.22	2.44	30.5	80.20	69.95	7.64	51	60	6	6.53	5.81
	3	Irrigated	3	22.54	2.44	30.3	80.00	70.58	7.68	51	60	6	6.24	5.59
	4	Dryland	1	21.89	2.44	30.7	80.96	69.12	7.52	51	61	7	6.63	6.98
	5	Dryland	2	22.22	2.44	30.5	80.17	70.02	7.70	51	60	6	6.52	5.80
	6	Dryland	3	22.54	2.44	30.3	79.97	70.66	7.73	51	60	6	6.23	5.58
Medium Trash	7	Irrigated	1	25.10	3.39	32.5	81.76	69.37	7.75	51	60	6	6.53	5.75
	8	Irrigated	2	25.63	3.39	32.3	81.07	70.28	7.93	51	51	5	6.41	4.57
	9	Irrigated	3	26.16	3.39	32.1	80.86	70.91	7.96	41	50	5	6.14	4.36
	10	Dryland	1	25.10	3.39	32.5	81.82	69.41	7.70	51	60	6	6.55	6.00
	11	Dryland	2	25.63	3.39	32.3	81.12	70.31	7.87	51	51	5	6.43	4.82
	12	Dryland	3	26.16	3.39	32.1	80.91	70.94	7.91	41	50	5	6.16	4.60
Low Trash	13	Irrigated	1	25.03	3.49	32.8	82.33	69.37	7.75	51	60	6	6.51	5.65
	14	Irrigated	2	25.57	3.49	32.6	81.64	70.27	7.93	51	51	5	6.40	4.48
	15	Irrigated	3	26.12	3.49	32.3	81.43	70.91	7.96	41	50	5	6.12	4.26
	16	Dryland	1	25.03	3.48	32.8	82.37	69.41	7.69	51	60	6	6.54	5.93
	17	Dryland	2	25.57	3.48	32.6	81.66	70.31	7.86	51	51	5	6.43	4.75
	18	Dryland	3	26.12	3.48	32.3	81.46	70.94	7.90	41	50	5	6.15	4.53

Table 2. Pounds of lint loss, estimated price, ginning cost, cost of lint loss, and total ginning cost per bale of irrigated and dryland cotton.

Cultivar	Config. Number	Irrigated or Dryland	# of LC	Lint Loss (lbs./bale)	Price ($/lbs.)	Ginning Cost ($/bale)	Lint Loss Cost From Ginning ($/bale)	Gin Cost and Lint Loss Cost ($/bale)
High Trash	1	Irrigated	1	64.17	0.6259	41.38	40.1671	81.5471
	2	Irrigated	2	71.53	0.6316	41.76	45.1759	86.9359
	3	Irrigated	3	74.29	0.6304	42.08	46.8346	88.9146
	4	Dryland	1	63.02	0.6259	41.38	39.4473	80.8273
	5	Dryland	2	70.38	0.6316	41.76	44.4496	86.2096
	6	Dryland	3	73.37	0.6304	42.08	46.2546	88.3346
Medium Trash	7	Irrigated	1	52.90	0.6848	41.38	36.2242	77.6042
	8	Irrigated	2	62.79	0.6903	41.76	43.3443	85.1043
	9	Irrigated	3	66.70	0.6964	42.08	46.4498	88.5298
	10	Dryland	1	55.66	0.6848	41.38	38.1141	79.4941
	11	Dryland	2	65.32	0.6903	41.76	45.0908	86.8508
	12	Dryland	3	69.00	0.6964	42.08	48.0515	90.1315
Low Trash	13	Irrigated	1	54.51	0.6887	41.38	37.5406	78.9206
	14	Irrigated	2	64.86	0.6943	41.76	45.0345	86.7945
	15	Irrigated	3	69.00	0.7000	42.08	48.3012	90.3812
	16	Dryland	1	55.43	0.6885	41.38	38.1614	79.5414
	17	Dryland	2	65.09	0.6941	41.76	45.1790	86.9390
	18	Dryland	3	68.77	0.6998	42.08	48.1226	90.2026

Table 3. Revenue loss, non-lint disposal cost, and total cleaning cost in textile processing for irrigated and dryland cotton.

Cultivar	Config. Number	Irrigated or Dryland	# of LC	Revenue Loss	Cost of Non-Lint Disposal	Textile Mill Total Cleaning Cost
High Trash	1	Irrigated	1	10.3709	0.5023	10.8731
	2	Irrigated	2	10.3561	0.4175	10.7736
	3	Irrigated	3	10.3413	0.4017	10.7430
	4	Dryland	1	10.3709	0.5016	10.8724
	5	Dryland	2	10.3561	0.4168	10.7729
	6	Dryland	3	10.3413	0.4010	10.7422
Medium Trash	7	Irrigated	1	11.3853	0.4132	11.7984
	8	Irrigated	2	11.3703	0.3284	11.6987
	9	Irrigated	3	11.9236	0.3133	12.2369
	10	Dryland	1	11.3853	0.4311	11.8164
	11	Dryland	2	11.3703	0.3463	11.7166
	12	Dryland	3	11.9236	0.3305	12.2541
Low Trash	13	Irrigated	1	11.4243	0.4060	11.8302
	14	Irrigated	2	11.4094	0.3219	11.7313
	15	Irrigated	3	11.9565	0.3061	12.2626
	16	Dryland	1	11.4233	0.4261	11.8494
	17	Dryland	2	11.4084	0.3413	11.7497
	18	Dryland	3	11.9555	0.3255	12.2810

Table 4. Total cleaning cost for the harvesting, ginning, and textile mill stages and for the industry.

				Total Cleaning Cost			
Cultivar	Config. Number	Irrigated or Dryland	# of LC	Ginning Stage	Textile Mill Stage	Industry	Yarn Strength Prediction
High Trash	1	Irrigated	1	81.5471	10.8731	92.4202	2009
	2	Irrigated	2	86.9359	10.7736	97.7095	2024
	3	Irrigated	3	88.9146	10.7430	99.6576	2030
	4	Dryland	1	80.8273	10.8724	91.6997	2009
	5	Dryland	2	86.2096	10.7729	96.9825	2024
	6	Dryland	3	88.3346	10.7422	99.0768	2030
Medium Trash	7	Irrigated	1	77.6042	11.7984	89.4026	2281
	8	Irrigated	2	85.1043	11.6987	96.8030	2299
	9	Irrigated	3	88.5298	12.2369	100.7667	2317
	10	Dryland	1	79.4941	11.8164	91.3105	2281
	11	Dryland	2	86.8508	11.7166	98.5674	2299
	12	Dryland	3	90.1315	12.2541	102.3856	2317
Low Trash	13	Irrigated	1	78.9206	11.8302	90.7508	2378
	14	Irrigated	2	86.7945	11.7313	98.5258	2410
	15	Irrigated	3	90.3812	12.2626	102.6438	2431
	16	Dryland	1	79.5414	11.8494	91.3908	2378
	17	Dryland	2	86.9390	11.7497	98.6887	2410
	18	Dryland	3	90.2026	12.2810	102.4836	2431