A STUDY OF MECHANIZATION OF COTTON HARVESTING IN INDIA: IMPLICATIONS FOR INTERNATIONAL MARKETS

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Abstract

Cotton is a very important commodity in Indian Agriculture. Recent technological advances and trade liberalization have made India a major player in international cotton markets. In the year 2010-11, India was the world's second largest producer and third largest exporter of cotton (FAOSTAT). The increasing role of the Indian cotton sector in international markets is a direct challenge to the US cotton exports, especially in markets like China which account for 40 percent of the total mill use of cotton in the world. Within this context, a better understanding of the Indian cotton sector and the impact of mechanization on cotton cultivation is needed to assess India's competitive position in international markets. The overall objective of this paper is to assess the competitiveness of Indian cotton producers and potential implications for India as a competitor in the world cotton market if it mechanizes some of the operations like harvesting. The results demonstrate that the net income of the cotton farmers will increase considerably with the mechanization of cotton harvesting. But, the adoption of mechanical cotton harvesting practice is possible only if efforts from many private and public agencies come together. In that scenario, the cotton production in India can increase considerably which can impact the international markets.

Introduction

Cotton is a very important commodity in Indian Agriculture and it has played a major role throughout India's history. Recent technological advances and trade liberalization have made India a major player in international cotton markets. In 2010-11, India was the world's second largest cotton producer, consumer and exporter (FAOSTAT). The increasing role of the Indian cotton sector in international markets is a direct challenge to the US cotton exports, especially in markets like China which accounts for 40 percent of the total mill use of cotton in the world. The importance of Chinese market is going to increase in future as China is expected to import cotton which is almost double to that of present level (FAPRI, 2010). A better understanding of the Indian cotton production system is necessary in order to comprehend its future role in international cotton markets. Though, India is the second most important producer of cotton in the world, the productivity in cotton production is very low compared to that of the world average. It is a major concern to its policy makers as cotton sector plays an important role in social and economic aspects of Indian society. Various reasons have been attributed to the existence of lower than world average yields in India like the inadequate inputs, lack of awareness about modern cultivation practices among Indian farmers, lack of irrigation facilities, lack of proper timing of field operations and too much dependence on labor to cultivate cotton (Majumdar, 2012). Along with the above reasons, the shortage of labor in some areas of India which are fast industrializing is impacting the profitability of cotton crop. Within this context, a better understanding of the Indian cotton sector and the impact of mechanization on cotton cultivation is needed to assess India's competitive position in international markets.

The overall objective of this paper is to assess the competitiveness of Indian cotton producers and potential implications for India as a competitor in the world cotton market if it mechanizes some of the operations like harvesting. The mechanization of cotton harvesting includes not only the availability of suitable harvesters, but also depends upon availability of appropriate cotton varieties, changing some of the agronomic practices like the seed rate, nutrient application, etc. and finally its economic feasibility in India. In this context, this paper analyses the economic feasibility of cotton harvesting by mechanical means in India as well as the practical feasibility of the adoption of the mechanical harvesting by Indian farmers. This paper utilizes the representative cotton farm models developed by the authors to analyze the impact of economic feasibility of cotton harvesters. The results are further used to understand their impact on India's competitiveness in the international markets.

In the following section, a brief description of the cotton production and its cultivation aspects in India are presented. The third section provides a discussion of the data collection and methodology for this study. The final section discusses results and provides conclusions.

Cotton in India

Cotton is an important cash crop for Indian farmers. It is third in total acreage planted among all crops in India behind rice and wheat. In the last decade, cotton acreage increased by almost four million hectares from 2003 to 2013 (See Table 1). In 2011-12, it was cultivated on about 12.19 million hectares producing 35.3 million bales (1 bale = 170 Kilograms). In the last ten years, cotton acreage has been growing at an average annual rate of around 3 percent. However, the average cotton yield in India is only 0.49 tons per hectare compared to a world average of 0.73 tons per hectare (ICAC, 2010). The low yields of cotton in India are attributed to inadequate inputs usage, rainfed cultivation, untimely operations on field and inefficient crop production technologies (Majumdar, 2012). In many parts of India, the farmers still use human labor for many of the operations like planting, weeding and picking and use inefficient farm implements/machinery for those operations. The adoption of machinery in farm operations is lagging because of various factors like unavailability of credit to purchase expensive machinery, small size holdings of farmers and lack of technical knowledge and skills to operate complex farm machinery. The low yields persistent in Indian cotton production are also attributed to the lack of disease resistant and high yielding varieties. Another factor affecting the yields is the rainfall pattern in India. About 65 percent of the cotton acreage in India is dependent on rain; the annual variation in monsoon rainfall plays an important role in production and yield for any particular year (Aggarwal, et al., 2008). The planting period for cotton in India is from March to September while harvesting takes place from October to February. The monsoons occur between June and September. Any mismatch in timing of planting operations and occurrence of monsoons impact the yield and hence production of cotton. Along with the above problems in cotton cultivation, various states in India especially industrialized ones like Gujarat, Maharashtra, Punjab, Andhra Pradesh, etc., are experiencing labor shortages due to migration of labor to urban areas and due to various employment generation schemes due to infrastructure projects sponsored by government (Singh, 2002, The Hindu, 2012).

Cotton yields have increased on an average by almost 7 percent in the last ten years, but are still considerably lower than world average. The major reasons for this improvement is the increasing usage of high yielding varieties including Bt cotton, improved pest management practices and improved irrigation facilities in some parts of India. The acreage of Bt cotton in India was almost 65 percent of the total cotton acreage in 2007-08 (Qaim and Sadashivappa, 2009), a major reason for increased yields.

Table 1. Area, Production and Yield of Cotton in India 2001-13

Year	Area (million ha)	Production (million metric tons)	Yield (tons/ha)
2000-01	8.58	2.38	0.28
2001-02	8.73	2.69	0.31
2002-03	7.67	2.31	0.30
2003-04	7.63	3.04	0.40
2004-05	8.79	4.13	0.47
2005-06	8.68	4.15	0.48
2006-07	9.14	4.76	0.52
2007-08	9.41	5.22	0.55
2008-09	9.41	4.93	0.52
2009-10	10.31	5.19	0.50
2010-11	11.14	5.53	0.50
2011-12	12.19	6.00	0.49
2012-13*	11.61	5.68	0.49

*Projected Source: Cotton Corporation of India

Cotton is produced in three zones in India. The Northern zone comprising the states of Punjab, Haryana and Rajasthan, the Central zone comprising the states of Maharashtra, Madhya Pradesh and Gujarat and the Southern zone comprising the states of Andhra Pradesh, Karnataka and Tamil Nadu (Chakraborthy, et al 1999). The states of Gujarat, Maharashtra and Andhra Pradesh contribute about three quarters of the total production. Even though the acreage in Maharashtra is 50 percent more than the state of Gujarat in 2010-11, the production is almost 20 percent less than in Gujarat as the yield is almost double that of Maharashtra (See Table 2). Historically, the low yields in the state of Maharashtra are due to irregular rainfall pattern and use of low yielding varieties (Chakraborthy et al, 1999). But, the productivity in the state of Maharashtra is also increasing considerably fast as the adoption rate of Bt cotton is one of the highest compared to many other states even Gujarat in some years. The proportion of Bt cotton as percentage of total area of cotton increased by almost 10 times more than that of Gujarat between 2003-05 (Gandhi and Namboodiri, 2006). It was estimated that if India's cotton yield reached the world average by 2016/17, its cotton production would dramatically increase by almost 27 percent more than that of a lower yield scenario (Pan, et al., 2007).

Figure1. Map of India

Table 2: Top Five States in India in Terms of Area, Production and Yield.

	2010-11			2011-12		
State	Area	Production	Yield	Area	Production	Yield
Gujarat	2.63	10.62	0.69	2.96	12.00	0.69
Maharashtra	3.93	8.78	0.38	4.13	7.40	0.31
Andhra Pradesh	1.78	5.95	0.57	1.88	5.60	0.51
Madhya Pradesh	0.65	1.77	0.46	0.71	1.80	0.43
Haryana	0.49	1.70	0.59	0.64	2.50	0.66

Notes: Area in million hectares, Production in million bales, Yield in tons per hectare
Source: Cotton Corporation of India

Data Collection and Methodology

Data Collection

Data was collected in two cotton producing states of India namely Gujarat and Maharashtra in 2012. These are the top two states in terms of production and acreage in India contributing about 73 percent and 75 percent of the total production and total acreage in India respectively. Rapid Rural Appraisal (RRA) methodology has been adopted to collect information, where in a multidisciplinary team conducted focus group discussions in various villages to get information and develop hypotheses. In each state, information was collected from focus groups in different villages and the information was aggregated. There were a total of six focus group discussions conducted with three each in Gujarat and Maharashtra in summer of 2012. Each focus group constituted about 7-12 farmers and a survey instrument was used to provide structure to the discussion. Table 3 provides summary information on the cost of cultivation collected in these two states. The cost of production of cotton in Gujarat is 21 percent more than that of Maharashtra due to more usage of fertilizers and micronutrients and greater irrigation costs. In focus group discussions, the average yield of seed cotton that was reported in Gujarat was 1100 kg per acre compared to only 900 kg per acre in Maharashtra. The gross profit in Gujarat is considerably higher than in the Maharashtra demonstrating the importance of higher yields prevalent in Gujarat. The gross profit excludes returns to family labor and managerial compensation. The cost of production in the above table does not include transportation expenses from farm to processor. In all the locations, the buyer/broker who buys cotton from the farmers is responsible for the transportation and he also performs quality checking at the time of transaction. Almost all the transactions of the farmers are with private dealers who in turn may represent cotton ginners. The data gathered from the two states is aggregated by giving appropriate weights according to their share in the total cotton acreage in India to obtain an India wide representative cotton model. The results can be seen in the last column of table 3.

Table 3. Cost of Cultivation and Gross Profit in Maharashtra and Gujarat in India ($ per Acre)

	Maharashtra	Gujarat	India
Seeds	28.79	25.36	26.73
Fertlizers	96.97	80.45	87.06
Herbicides	-	15.45	9.27
Irrigation	66.67	70	68.67
Pest Control	93.94	62.27	74.94
Total Materials	**286.37**	**253.53**	**266.67**
Labor and Machinery Costs			
Land Preparation	48.48	42.73	45.03
Seed Sowing	12.12	6.36	8.66
Fertlizer application	24.24	8.18	14.60
Pesticide application	28.79	27.27	27.88
Manual Weeding	87.88	59.09	70.61
Harvesting costs	97.36	110	104.94
Total Labor	**298.87**	**253.63**	**271.73**
Total Expenses	**585.24**	**507.16**	**538.39**
Yield(kgs/acre)	900	1100	1020.00
Price ($/kg)	0.7061	0.6545	0.68
Revenue	**635.49**	**719.95**	**686.17**
Profit	**50.25**	**212.79**	**147.77**

The cost of production and profitability estimates by various studies sponsored by government of India and the respective state governments are much lower than estimated by our study. The differences may be due to the limited coverage area of this study compared to other studies and also the higher knowledge and skill levels of the farmers who participated in our focus group discussions. Most of the participants in our focus group discussions are progressive farmers who have higher knowledge and skills in farming than their peers in that area.

This study also included an analysis of mechanical harvesting of cotton in India. The researchers have met representatives from agricultural equipment, seed and chemical firms to discuss about and understand the various initiatives adopted by them to promote cotton pickers among Indian cotton farmers. Data about various trials in which cotton pickers were tested in Indian conditions were made available for this study. Information about additional inputs that are required and additional revenues due to higher yields possible due to adoption of new cultivation practices are obtained during discussions with industry representatives.

Methodology

Stochastic simulation models are used to generate a large random sample of outcomes for a dependent variable where that dependent variable is a function of some selected set of explanatory variables. A unique feature of these types of models is that there is an explicit recognition that the independent variables have some probability distribution around their mean values.

The forecast of the dependent variable is thus a function of the probability distributions of the explanatory variables as well as their mean value. The simulated distribution of the dependent variables thus captures the variability or risk associated with forecasting the dependent variable that cannot be obtained by using simply the mean value of the explanatory variables. If the explanatory variables are uncorrelated an appropriate univariate probability distribution is chosen (e.g. normal, Poisson, empirical, etc).

It is also possible to capture the joint variability of two or more correlated explanatory variables on the dependent variable. The joint variability can be captured by determining the multivariate probability distribution (e.g. multivariate normal, multivariate empirical, etc.) for the two or more correlated explanatory variables. The multivariate probability distribution is developed much the same as the univariate probability distribution but includes information in the correlation matrix to account for the correlation between the independent variables. The determination of the appropriate probability distributions and the construction of stochastic models are followed from Richardson (2010).

The simulated forecast of dependent variables using either univariate or multivariate probability distributions of the explanatory variables is very useful in informing decision makers of the variability or risk in the dependent variable forecast, the skewness of the forecast, and the probability of a specific outcome for the dependent variable. Most stochastic simulation models have more than one dependent variable. The dependent variables in a stochastic simulation models are often referred to as Key Output Variables (KOV's).

From the sample of farms in the rapid assessment study, the impact of fertilizer subsidies and minimum support prices (MSP) on the profitability of Indian cotton farms can be analyzed. Two Indian cotton representative farm simulation models have been developed for the states of Gujarat and Maharashtra using information collected through focus groups. Representative farm models are stochastic simulation models that are used to analyze the impacts of current and changing market conditions and government policies on a number of KOV's. Examples of KOV's in a representative farm models are yearly net income, cash flow position, financial ratios such as debt to equity or liquidity, and net present values of net income.

These models can be used for several purposes. They simulate the producer's income statement, statement of cash flows, and balance sheet as well as any financial indicator calculated from those three statements. From there we can analyze the impact a new policy may have on a producer's net income or net present value prior to implementation. They can also determine the impact a change in production practices may have on the producer's financial statements prior to actually changing practices. In other words, these models act as a decision making tools. The models are constructed in a way that allows for easy analysis of several variables.

By using a stoplight chart, one of the graphical capabilities of the model, we can compare probabilities for one or more alternatives for the target values of net present values of net income. In order to generate the stoplight chart, two value targets, lower and upper, are chosen from observed returns. The stoplight function calculates the probabilities of: (a) exceeding the upper target (green), (b) being less than the lower target (red), and (c) observing values between the targets (yellow). In this study, the stochastic simulation models are used to analyze the impact of mechanical harvesting of cotton on the net income of the representative cotton farm in India. The analysis forecasts the net income for a period of two years from 2013-14.

Results and Conclusion

In order to adopt cotton pickers for harvesting, lot of changes in agronomic practices of cotton cultivation needs to be adopted as well. The seed rate adopted for mechanical harvesting of cotton is three times the seed rate adopted for conventional cotton picking by manual labor. As the height of the plants need to be uniform and much lower than in the conventional way, the plant population needs to be much higher in order to achieve sufficient yields. In the conventional way, the cotton plant will have much more branches and more number of bolls per plant than in the cotton field cultivated for mechanical harvesting. The inter-row and inter-plant spacing for mechanical harvesting is also much less to accommodate more number of plants. The cotton plants that are going to be mechanically harvested also need to be sprayed with defoliant chemicals in order to make the harvesting process clean and efficient. The harvested cotton also needs to be pre-cleaned before sending it to the cotton gin as cotton pickers gather more debris than by manual picking. All the above changes in cultivation practices are going to increase the expenditure, but it is expected that the yields under this process will be up to 35 percent more than the conventional method of cotton cultivation. The additional expenditure incurred due to the above practices in order to mechanically harvest cotton using cotton pickers is given in the table below.

Table 4: Additional Expenditure and Additional Revenue to Mechanical Harvesting of Cotton ($ per acre).

Seed Cost and Labor	110
Defoliant Spray	50
Mechanized Harvesting (including pre-cleaning)	45
Total Additional Expenditure	**205**
Additional Revenue due to Higher Yields	**244**

This paper analyses the impact of mechanical harvesting of cotton on the profitability of Indian cotton farm by creating a counterfactual scenario in which the additional expenditure and additional revenue is taken into consideration. The additional expenditure of $205 per acre and additional revenue of $244 per acre creates an additional profit of $39 per acre. These are incorporated into the representative farm model of cotton to get the results of the counterfactual scenario.

The results of the simulations of baseline model and counterfactual model are analyzed for any differences in the cost of production, net income and net present value of sum of income streams of both years 2013 and 2014. The two year forecast shown in Table 5 estimates that the present value of the net income of the farmers decreases by about 28 percent where as the production cost increases by 4 percent in both the years. Charts 1A and 1B in Figure 2 provide a comparison of the simulated probability distributions of net present value of sum of net income after taxes per acre in years 2013 and 2014 without and with mechanization. The harvesting by cotton picker increases the probability of earning a net income of more than $419 per acre by 19 percent and the probability of earning a net income less than $419 decreases by 20 percent.

Table 5. Comparison of Results with Baseline Forecast.

($ Per Acre)	**Baseline**		**Under Mechanization**	
	2013	**2014**	**2013**	**2014**
Net Income	220	244	281	312
Production Cost	541	561	746	774
Net Present Value (Sum of Income Stream 2013-2014)	419		536	

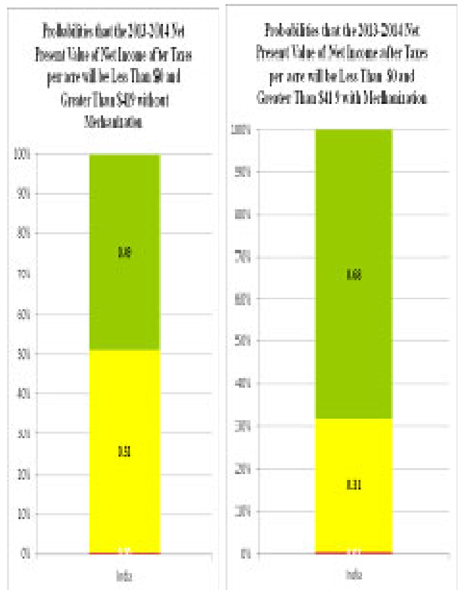

Chart 1A Chart 1B

Figure 2. Stop-light Charts ‘Without’ and ‘With’ Mechanization

Conclusion

In this paper we have analyzed the impact of mechanical harvesting of cotton by pickers on the net income of Indian cotton farmers. We have used information collected from focus group discussions of farmers in top two cotton growing states of India and the information about trials on mechanized harvesting from representatives of equipment and input manufacturers. The results demonstrate that the net income of the cotton farmers represented from this study group will increase considerably with the mechanization of cotton harvesting. The results also show that the probability of earning a lower net income decreases, whereas the probability of earning a higher net income increases when harvesting is done by cotton pickers. But adoption of mechanical harvesting through cotton pickers by Indian farmers is not dependent upon just the availability of suitable harvesters, but also depends upon availability of appropriate cotton varieties, changing some of the agronomic practices like the seed rate, nutrient and defoliant application, pre-cleaning of cotton before sending it to cotton gins, and finally its economic feasibility in India. In order for the change in agronomic practices adopted by Indian farmers, the government extension agencies should play an active role in educating the farmers. The equipment manufacturers should come out with suitable equipment for Indian conditions like small land holdings and pre-cleaners suitable for cleaning cotton before sending them to cotton gins. Efforts also should be made by credit agencies to offer suitable credit facilities for farmers wanted to adopt mechanical harvesting and support should be also offered for establishing custom service providers. With the help of all the above public and private agencies, the adoption of mechanical harvesting of cotton by Indian cotton farmers can be successfully achieved. The mechanized harvesting of cotton in India may lead to increase in yields in Indian cotton farms and thereby the total cotton production in India. In this scenario, the international cotton markets may see more of cotton from India which may impact the prices of cotton. But, further research needs to be done in order to understand the time line of adoption of mechanized harvesting in India.

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