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A Study of Mechanization of Cotton Harvesting in India and Its Implications

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Abstract: Cotton is one of the most important crops throughout the history of India and it also plays an important role in social and economic aspects of the Indian society in the present age. Recent technological advances and trade liberalization have made India a major player in international cotton markets. In the year 2011-2012, India was the world's second largest producer, consumer and exporter of cotton. The increasing role of the Indian cotton sector in international markets is a direct challenge to other major players like the US. Within this context, a better understanding of the Indian cotton sector and the impact of mechanization on cotton cultivation are needed. 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 harvesting of cotton. The results demonstrate that the net income of the Indian cotton farmers will increase considerably with the mechanization of cotton harvesting. But the adoption of the practice of harvesting cotton by mechanical means 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.

Key words: Cotton, India, mechanization, harvesting.

1. Introduction

Cotton is one of the most important crops throughout the history of India and it also plays an important social and economic role in the Indian society in the present age. India has made tremendous gains in the cotton sector in recent times, as it stood second in the world in terms of production, consumption and exporting in 2011-2012 [1]. The increasing role of the Indian cotton sector in international markets is a direct challenge to major cotton exporters like the United States especially in fast growing markets like China. In this context, a better understanding of the Indian cotton production system is necessary in order to comprehend its future role in international cotton markets.

Like most of the other crops grown in India, cotton production is also associated with low productivity compared to world average. The average cotton yield in India is only 0.49 t/ha compared to a world average of 0.73 t/ha [2]. The strategies that were used to achieve the gains in productivities during the green revolution of 1970s and 1980s like introduction of high yielding varieties, usage of synthetic fertilizers and pesticides, etc., are not able to meet the growing needs of the country in the present day. Various reasons have been attributed to the existence of low yields of cotton in India: 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 [3]. Along with the above reasons, the shortage of labor along with the associated rise in wages in some fast industrializing areas of India is impacting the profitability of the cotton crop. Within this context, a better understanding of the Indian cotton sector and

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the impact of mechanization on cotton cultivation are 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 success of mechanization of cotton harvesting depends not only on the availability of suitable harvesters, but also depends upon various other factors. So this paper analyses the impact of mechanical harvesting of cotton on the profitability of Indian cotton farmer 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 mechanical harvesters by stochastically simulating and forecasting into the future. The results are further used to understand their impacts on India's competitiveness in the international markets. In the following section, a brief description of the cotton production and its cultivation aspects, the status of mechanization of farm operations and the status of mechanization of cotton harvesting in India are presented. The third section provides a discussion of the data collection and methodology for this study. The final section discusses the results and provides conclusions.

2. Cotton Production and Mechanization in India

2.1 Cotton Production in India

Cotton is an important cash crop for Indian farmers. It takes the third place 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 (Table 1). Cotton is produced in three zones in India, namely 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 [4]. The states of Gujarat, Maharashtra and Andhra Pradesh contribute about three quarters of the total production. Even though the acreage in Maharashtra is 50% more than the state of Gujarat in 2010-2011, the production is almost 20% less than in Gujarat as the yield is almost double that of Maharashtra (Table 2).

Table 1 Area, production and yield of cotton in India 2001-2013.

Year	Area (million ha)	Production (million metric tons)	yield (t/ha)
2000-2001	8.58	2.38	0.28
2001-2002	8.73	2.69	0.31
2002-2003	7.67	2.31	0.30
2003-2004	7.63	3.04	0.40
2004-2005	8.79	4.13	0.47
2005-2006	8.68	4.15	0.48
2006-2007	9.14	4.76	0.52
2007-2008	9.41	5.22	0.55
2008-2009	9.41	4.93	0.52
2009-2010	10.31	5.19	0.50
2010-2011	11.14	5.53	0.50
2011-2012	12.19	6.00	0.49
2012-2013*	11.61	5.68	0.49

*Projected source: Cotton Corporation of India, accessed Jan. 2013.

About 65% of the cotton acreage in India is dependent on rain and so the annual variation in monsoon rainfall plays an important role in production and yield for any particular year [5]. 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 can impact the yield and hence production of cotton. The cotton production in India is also plagued by inefficient labor operations and labor shortages. 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. Along with the inefficiencies in cotton

Table 2 Top five states in India in terms of area, production and yield.

State	2010-2011			2011-2012		
	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

Area in million hectares, production in million bales, yield in t/ha; Cotton Corporation of India, accessed Jan. 2013.

cultivation, various states in India especially industrialized ones like Gujarat, Maharashtra, Punjab and 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.

In spite of all the above problems, cotton yields have increased on an average by almost 7% in the last 10 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% of the total cotton acreage in 2007-2008 [6], a major reason for increased yields and its adoption is growing fast even in states like Maharashtra, whose cotton productivity is very low [7, 8]. It was estimated that if India's cotton yield reached the world average by 2016/2017, its cotton production would dramatically increase by almost 27% more than that of a lower yield scenario [9].

2.2 Status of Mechanization of Farm Operations in India

Farm mechanization is defined as essentially a judicious mix of resources, implements, machines and power sources [3]. In this context, the farm mechanization in India is undergoing changes in all the above-mentioned components at different paces in different field operations and in different geographic areas. Though the usage of mechanical power in Indian agricultural fields is on an increasing trend, it is mostly restricted to usage of improved hand tools, animal drawn equipment and to some extent tractor drawn equipment. The most common types of mechanization that are seen on Indian farms are tractors and irrigation equipment [10]. At present, tractors are being used for tillage of 23% of total area and for 21% of sowing operations and the tractor ownership is restricted to only about 5% of the total agricultural households in India [11, 12]. The cumulative annual growth rate of domestic tractor volumes has increased by about 5% over the past decade, and about half a million tractors have been sold in 2012 [13].

The mechanization of various agricultural operations in India can be categorized on the basis of size of the farms, geographic location and type of crop. Mechanization in terms of ownership of tractors is mostly seen in larger farms than in smaller farms. According to a survey done in 242 villages in 17 of the major states of India, only less than 5% of the farms below two acres own any equipment, whereas about 30% of the farms with more than 10 acres own a tractor and 20% own a mechanized thresher [14]. The mechanization is also seen mostly in the states of Punjab, Haryana and Uttar Pradesh though it is increasing in other states as well [13], thereby, giving a geographic variability to its adoption. Though the usage of tractors for tillage and other operations is increasing, recently the usage of combine harvesters is also increasing in wheat and paddy crops [15]. It is expected that with the increasing purchasing power of Indian farmers and increasing cost of manual labor, the farm equipment industry is bound to grow rapidly

in the coming years. Various international farm equipment manufacturers are also setting up their facilities to capture the growing Indian market, which is expected to grow at a cumulative annual growth rate of 5% [15].

2.3 Status of Mechanization of Cotton Harvesting in India

A similar rate of mechanization also prevails in cotton sector as in other crops for land preparation and application of fertilizers and chemicals. But regarding the harvesting operation, almost the entire cotton production in India is hand-picked by human labor spending about 0.9 man-h/kg of cotton and costing almost 10 times than irrigation and two times the weeding costs [16]. India is lagging behind many other large producers of cotton in mechanization of harvesting. In the USA, machines harvest the entire cotton crop, whereas in some regions of China, it is estimated that by 2020, about 60% of cotton will be mechanically picked [17]. It is expected that India will soon have to mechanize its cotton harvesting operations as it is facing labor shortages and rising farm wages. It is reported that the labor availability has dropped from 70.3% of the population in 1961 to 48.9% in 2010 and cost of picking cotton from the farm has increased to Rs 10-12 a kg now from Rs 4 in 2007 [17].

Cotton harvesters are of two types, pickers and strippers. The pickers are selective that they only harvest the open bolls of seed cotton, whereas strippers are non-selective, as they strip the entire plant of both opened and unopened bolls. This study takes into consideration only the pickers into the analysis and not strippers. Some Indian government agencies have come out with animal drawn and tractor drawn cotton pickers, but they have not been successful. Studies have been done on the feasibility of introducing mechanical pickers in India, and most of them have concluded that in order to have a successful introduction of cotton pickers, many other aspects have to come together [16]. The first aspect is about the spacing between the plants in the field. In our visits to the cotton farms in India, we observed that the spacing ranged from 3 feet (inter-row) by 3 feet (inter-plant) to 5 feet (inter-row) by 2 feet (inter-plant), which is much higher than what is needed for cotton plants to be harvested by mechanical picker. With the above-mentioned range of spacing, the plant population comes to around four to five thousand plants per acre, whereas, from our discussion with industry personnel, it was recommended to have a population of more than 50,000 plants per acre, if mechanical picking is to be done. Secondly, the cotton plant should not be too tall and having many branches, as it will be difficult for the picker to pick all the bolls. Also, the bolls should be well of the ground so that the amount of soil and dirt collected during the picking may be reduced [16]. Studies have shown that the trash content in hand-picked cotton is much less than in the mechanically picked cotton, thereby, creating a need for pre-cleaning of mechanically picked cotton before sending it to ginning mills. Another important aspect is that all the bolls should come to maturity at the same time, as mechanical picking is expensive to be done multiple times. The plants also need to be treated with defoliants as it is necessary that green leaves should not be present on the plant when cotton bolls are picked up by the machine [17]. The expenditure incurred for mechanical picking also includes the cost of defoliators and their application costs. So in order to have a successful introduction of cotton pickers, farmers need to be educated about the new agronomic practices and awareness has to be created about the costs and benefits involved in the mechanical picking of cotton. The mechanical picking of cotton on a large scale is possible if suitable cotton varieties are introduced along with adequate educational and awareness programs for cotton farmers in India.

In this background, this study throws light on the impact of mechanical picking of cotton on the

profitability of Indian cotton farm. The results would be useful in creating awareness among the cotton farmers about the costs and benefits of mechanical picking of cotton.

3. Methods

3.1 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% and 75% 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 15% lower than that of Maharashtra due to less usage of fertilizers, chemicals and lower labor costs. In focus group discussions, the average yield of seed cotton that was reported in Gujarat was 1,100 kg/acre compared to only 900 kg/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 also responsible for the transportation and quality checking at the time of transaction.

Table 3 Cost of cultivation and gross profit in Maharashtra and Gujarat in India ($/acre).

	Maharashtra	Gujarat	India
Seeds	28.79	25.36	26.73
Fertilizers	96.97	80.45	87.06
Herbicides	-	15.45	9.27
Irrigation	66.67	70.00	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
Fertilizer 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	110.00	104.94
Total labor	298.87	253.63	271.73
Total expenses	585.24	507.16	538.39
Yield (kg/acre)	900	1,100	1,020
Price ($/kg)	0.7061	0.65	0.68
Revenue	635.49	719.95	686.17
Gross profit	50.25	212.79	147.77

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.

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 picking of cotton in India. The researchers have met representatives from agricultural equipment, seed and chemical firms to discuss 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.

3.2 Simulation Model

This study utilizes stochastic simulation models, which are used to generate a large random sample of outcomes for a dependent variable that is a function of some selected set of explanatory variables. Many studies have utilized these simulation models to understand the impact of various policy factors on profitability of farmers [18]. 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. These models help as decision-making tools and are utilized to determine the impact a change in production practice may have on the net income prior to actually changing practices.

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 can not 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 determination of the appropriate probability distributions and the construction of stochastic models are followed [19, 20].

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.

The simulation model also produces stoplight charts, which can be used to 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: (1) exceeding the upper target (green); (2) being less than the lower target (red); (3) observing values between the targets (yellow). The representative cotton farm model of India is used as a stochastic simulation model to analyze the impact of mechanization of cotton picking on the net present value of net income. The analysis forecasts the net income for a period of two years from 2013-2014.

4. Results and Discussion

To analyze the impact of mechanical picking 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 information collected from focus group discussions showed that the profitability of cotton farmers is not similar in the top two cotton producing states of India due to the difference in yields, input and labor expenses. But this study aggregated the values obtained from these two states to obtain India wide representative model.

In order to adopt cotton pickers for harvesting, a lot of changes in agronomic practices of cotton cultivation need to be implemented as well. The first major change is to increase in the seed rate. The seed rate adopted for mechanical harvesting of cotton is

three times the seed rate adopted for conventional cotton picking by manual labor. This will lead to an increase in the input expenditure as well as the labor expenses for planting the seeds. Secondly, 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 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. Thirdly, 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, which leads to an increase in input expenditure again as well as increase in the labor expenses. Lastly, 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 also expected that the yields under this process will be up to 35% 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 and the additional revenue obtained due to higher yields are given in Table 4.

The above information is utilized to analyze 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/acre and additional revenue of $244/acre creates an additional profit of $39/acre. These are incorporated into the representative farm model of cotton to get the results of the counterfactual scenario.

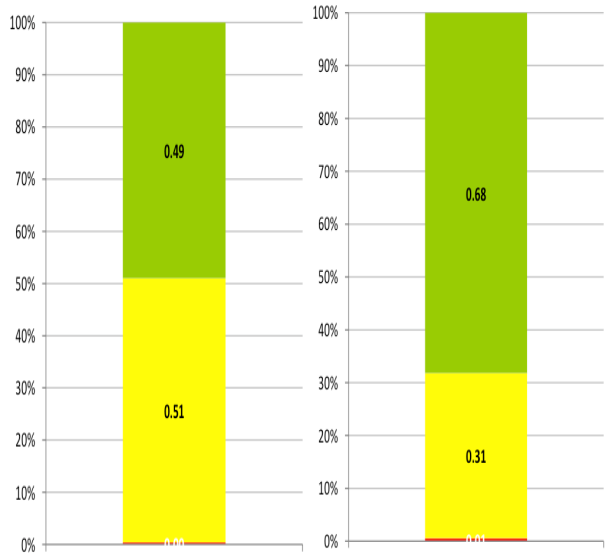
The results of the simulations of baseline model and counterfactual model are analyzed for any differences in the cost of production, net income and net present value of sum of income streams of both years 2013 and 2014. The two-year forecast shown in Table 5 estimates that the present value of the net income of the farmers increases by about 28% where as the production cost increases by 4% in both the years. Fig. 1 provides 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/acre by 19% and the probability of earning a net income less than $419 decreases by 20%. The probability of having a zero net income is nil in both the scenarios. The results show that it is advantageous for the Indian cotton farmers to adopt mechanical picking of cotton in spite of increase in the input and labor expenditure. The probability of earning more net income significantly increases due to the adoption of mechanical pickers. The mechanical 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 cotton exports from India, which may put a downward pressure on international cotton prices [9].

Table 4 Additional expenditure and additional revenue due to mechanization of cotton harvesting.

	$/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

Table 5 Comparison of results with baseline forecast.

	Baseline ($/acre)		Under mechanization ($/acre)	
	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	



(a) without mechanization (b) with mechanization

Fig. 1 Stop-light charts showing the probabilities that the present value of net income per acre will be more than $419 (a) without and (b) with mechanization.

But adoption of mechanical harvesting through cotton pickers by Indian farmers is not dependent upon just the availability of suitable cotton pickers, but it also depends upon availability of appropriate cotton varieties, changing some of the agronomic practices as described above, pre-cleaning of cotton before sending it to cotton gins, and finally the adequate availability of repair and maintenance services for cotton pickers in India. It is expected that the practice of cotton harvesting by mechanical means will take a long time to get established in India, expected to be up to a decade by some experts [17]. In order for the change in agronomic practices adopted by Indian farmers, both the public and private extension agencies should play an active role in educating and training the farmers [10]. The equipment manufacturers should come out with equipment suitable for Indian conditions like small land holdings and pre-cleaners suitable for cleaning cotton before sending them to cotton gins. Some international farm equipment manufacturers have already developed cotton pickers suitable for Indian conditions and trials are taking place [21]. Efforts also should be made by credit agencies to offer suitable credit facilities for farmers wanting to adopt mechanical harvesting and support should be also offered for establishing custom service providers. As most farmers in India have small land holdings, it is essential that cotton pickers may be rented more than they are owned, which creates the need for custom service providers and farm equipment rental agencies. With the support of the public and private agencies, the adoption of mechanical harvesting of cotton by Indian cotton farmers can be successfully achieved.

5. Conclusions

This paper analyzed the impact of mechanical harvesting of cotton on the profitability of Indian cotton farmers as well as its implications on cotton supply in the international markets. 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 cotton pickers are used. The more usage of cotton pickers may lead to increase in yields and thereby increased cotton production in India, which may put a downward pressure on international cotton prices. But our observation of the conditions that are necessary for adoption of mechanical means of harvesting showed that it would take considerable period of time before Indian farmers adopt it.

The findings of this study will be important for policy makers involved in improvement of Indian cotton sector as well as the livelihoods of farmers involved in cotton cultivation. Further research needs to be done to understand the efforts already put on by various public and private agencies to improve the pace of development and adoption of mechanical harvesting in India. Because when it happens, it is sure to create a major impact on international cotton markets.

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