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Economic cost of non-adoption of Bt-cotton in West Africa: with special reference to Mali

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Abstract: A major public policy issue in West Africa is whether or not and, how to introduce Bt-cotton in the region. The implications of non-adoption may be more significant than, for example, the issues often raised concerning cotton subsidies in advanced countries. This paper provides estimates of the potential benefits from Bt-cotton if introduced in West Africa. Our analysis shows significant farm-level benefits. Aggregate benefits depend on adoption rate and yield advantage of Bt-cotton. These range from a low of US$7 million to a high of US$67 million in Mali; US$4 million to US$41 million in Burkina Faso; US$5 million to US$52 million in Benin; US$4 million to US$38 million in Cote d'Ivoire; and, US$1 million to US$7 million in Senegal. The reduction in insecticide use is an added environmental benefit. Non-adoption of Bt-cotton in the region will ultimately result in non-competitiveness in the world market.

Keywords: Bt-cotton; West Africa; yield advantage; cost advantage; ex-ante analysis.

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1 Introduction

Bt-cotton, a genetically improved plant capable of protecting itself from lepidopterous insects, is a recent production technology now available to cotton producers around the world. Reports from a number of less developed countries where it has been

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commercially introduced, show encouraging results for adaptation and diffusion. Farmers get higher yields due to lower insect damage, and spend less on insecticides hence they obtain higher farm profits (James, 2002). In West African countries where cotton is a primary export crop, and, a major source of cash income among millions of resource-poor farmers, the economic benefits from Bt-cotton are expected to be high. The technology would enable these countries to be abreast with the rest of the world and remain competitive in the international market. At the micro level, it minimises the risk (e.g., from revenue losses due to insect damage) faced by farmers who are constantly subjected to harsh environmental conditions.

However, none of the cotton-producing countries in West Africa have taken concrete steps for adopting the technology. There continue to be apprehensions about the well-publicised potential negative environmental, health and social effects of biotechnology. Institutions essential for the adaptation and diffusion of biotechnology have not been put in place. The dearth of information on, and, lack of appreciation of the potential benefits from Bt-cotton may have contributed to the current state of affairs.

This paper provides an ex-ante analysis of the potential benefits (both at the farm and national levels) from Bt-cotton if introduced in West Africa with particular focus on Mali. Cost of adopting the technology is not explicitly tackled, but a qualitative analysis of this is provided in the next two sections where we briefly review the process of introducing Bt-cotton in three developing countries. It uses a linear programming model to determine the farm-level economic impact of Bt-cotton, and uses these results to estimate aggregate national benefits. The paper is divided into five main parts. Section II reviews adoption of the technology by a number of cotton-producing countries. Section III provides a framework for our analysis. The objective of this section is to establish a basis for determining whether it is technically and economically feasible to transfer/adapt Bt-cotton in West Africa. Section IV describes the empirical model, assumptions made, and data used in the analysis. Section V presents the results and Section VI, a set of conclusions.

2 Bt-cotton adoption

Bt-cotton was first introduced for commercial adoption in 1996. To date, seven developing countries (Mainland China, India, Indonesia, Mexico, Argentina, Colombia and South Africa) and, two industrialised countries (USA and Australia), have planted Bt-cotton on a commercial scale. Of the estimated 34 million hectares planted to cotton worldwide in 2001, 4.3 million hectares or 13% of the total, is Bt-cotton. Latest available information shows that this increased to 7.2 million hectares in 2003 (James, 2003) representing 21% of total cotton area.

Eighty four percent (3.6 million hectares) of the total Bt-cotton area worldwide in 2001 was located in the US and China with more than two-thirds of this in the USA. Based on available data from a number of countries, adoption rate is quite remarkable. Thirty four percent of the total cotton area in the US was planted to Bt-cotton in 2001, 31% in China, 30% in Australia and 35% in Mexico (Table 1). In South Africa, adoption rate by small farmers is reported to be 92%.[1]

A brief review of the adaptation of Bt-cotton in three developing countries shows a crucial role of Monsanto, the developer of the first variety (Bollgard^{TM}) commercially introduced in the market. In China, the commercial introduction of Bollgard^{TM} was done through a collaborative effort between Delta and Pineland, Monsanto's subsidiary, and the Chinese National Cotton Research Institute of the Chinese Academy of Agricultural Sciences (Huang and Pray, 2001).

Table 1 Adoption of Bt-cotton in selected countries, 1996–2001

Country / Year	*Bt-cotton Area (million hectares)*	*Percent of Total Cotton Area*
USA		
1996	0.73	14
2001	2.08	34
China		
1997	< 0.1	1
2001	1.5	31
Australia		
1996	0.03	8
2001	.146	30
Mexico		
1996	0.0009	7
2001	0.028	35
World		
1996	0.8	2
2001	4.3	13
2003*	7.2	21

Source: James (2002); * James (2003)

In South Africa, the locally available Bt-cotton NuCOTN37B, was developed by Delta and Pineland, and distributed by the cotton company Vunisa, a private enterprise that buys cotton from, and supplies seed, agrochemical, credit, and information to the farmers (Ismael, Bennett and Morse, 2001). In India, Monsanto formed a (50–50) joint venture with a local seed company, the Maharashtra Hybrid Seeds Co. Ltd. (MAHYCO), to produce locally adapted Bt-cotton varieties (GRAIN, 2001).

Among the three countries, only China invested a substantial amount of public funds in developing its own Bt-cotton. In 1999, the Chinese government allotted around US$112 million for crop biotechnology.[2] Development of the Chinese Bt gene was part of the country's biotechnology programme and the Biotechnology Centre of the Chinese Academy of Agricultural Sciences (CAAS), is in the forefront in this effort. The involvement of the Chinese government in developing its own Bt-cotton has enabled farmers to have a choice between varieties developed by the public and private sectors. However, economies of scale and other constraints, prevent many developing countries from following the Chinese example. For these countries, local adaptation of the available technology may be the most pragmatic approach to diffusion.

3 Framework for evaluating Bt-cotton potential in West Africa

In this section, the feasibility of introducing Bt-cotton in West Africa is established. Analysis is based on published reports, expert opinion, and farmer interviews. Reported benefits obtained in developing countries that have adopted Bt-cotton are also reviewed. This will serve as a guide in estimating the benefits from Bt-cotton in the region.

3.1 The insect problem and current control method

The insect problem in West Africa is similar to the other developing countries' where Bt-cotton has been introduced. Bollworms, leaf-eating caterpillars, and sucking insects are the three insect groups common in these countries (Table 2). The bollworms, (e.g., US bollworm, spotted and spiny bollworm) all belonging to the order lepidoptera, are noted to inflict the highest damage as they devour the critical plant parts – flowers, bolls and young buds. Among the bollworm complex, *Helicoverpa armigera,* also referred to colloquially as the US bollworm (*H. Zea*), is the most damaging.[3] Armigera has a relatively wide range of host plants that include corn, sorghum, groundnuts, and other wild plants (Greathead, 1989). The extent of damage inflicted on cotton, co-varies with other host plants.[4]

Table 2 Cotton Pests that are common in Senegal and Mali

Types of Pests	*Names of the Species*
Bollworms and other lepidopterous insects	Helicoverpa armigera
	Earias sp.
	Diparopsis watersi
Leaf-eating/caterpillars	Spodoptera littoralis
	Anomis flava
	Syllepte derogata
Sucking Insects	Aphis gossypii
	Bemisia tabaci

Source: Interviews with entomologists in Mali and Senegal

The insect group that inflicts the highest damage starts attacking the cotton plant in the seventh week of the plant cycle. Control method involves spraying broad-spectrum insecticides – usually a combination of organophosphates and pyrethroids – beginning in the sixth week. Depending on insect pressure, up to seven sprays are applied. Farmers interviewed in Mali, spray five times at one litre per spraying.

This method, however, does not provide complete protection against insect pests. Problems of timing and placement of application, and wash-off of insecticides often lead to less than optimal results. Eggs and/or larvae near the top of plant canopy are most vulnerable to insecticides. However, large larvae down in the canopy are very difficult to control (Pendergrass, 1989). Furthermore, the bollworm complex was reported to have developed resistance to organophosphates and pyrethroid sprays. This phenomenon has been reported in Cote d'Ivoire (Vassal and Vaissayre, 1997). In another report, it was noted that even if conventional sprays are applied, farmers in West Africa incur average yield losses of 23% depending upon the degree of insect incidence (Oerke, 2002). When compared to the reported potential loss of 34% with zero spraying[5], this implies that only 11% points of the loss from insect damage, are saved by chemical sprays.

In summary, Bt-cotton is a potentially viable alternative to the current insect control method in West Africa. The insects of greatest economic importance – US bollworm, spotted and spiny bollworm – are among the insects for which Bt-cotton is claimed to have high effective control (Table 3). Conventional sprays have become less effective due to increasing insect resistance to the chemicals currently used.

Table 3 Relative efficacy (percent Pest Mortality) of Bollgard and Bollgard II

Insect Pest	*Bollgard*	*Bollgard II*
Cotton Bollworm (Helicoverpa zea)	84.4	92.2
Fall armyworm (Spodoptera fungiperda)	16.1	100
Beet armyworm (Spodoptera exigua)	50.1	94.9
Soybean looper	1.2	97.4
Pink bollworm	99	NA
Tobacco budworm	95	NA

Source: James, 2002

3.2 Benefits from Bt-cotton

As an alternative to conventional sprays, Bt-cotton protects itself mainly from lepidopterous insects by producing a type of protein toxic to this group of insects.[6] Because the protein is expressed in all plant parts throughout the cropping season, Bt-cotton is claimed to be more effective than sprays in controlling lepidopterous insects.

Past studies in India (Naik, 2001), China (Pray *et al.*, 2001), and South Africa (Ismael, Bennett and Morse, 2001), show that Bt-cotton has an edge over non-Bt-cotton. Average yield is higher and cost per hectare is lower (Table 4). The Bt-cotton advantage is summarised as follows:

Yield advantage: In this paper, yield advantage is the magnitude in percent, by which Bt-cotton yield exceeds non-Bt-cotton. In India, Bt-cotton registered a 37% yield advantage over non-Bt-cotton in 1998–1999 and 38% in 2000–2001. In China, where average yields are notably higher than the other countries, the yield advantage reported was 8% in 1999 and 10% in 2001. On the other hand, in South Africa, farm surveys showed a yield advantage of 46% in small farms; 14% in large non-irrigated farms; and 19% in large irrigated farms. In the US, farms using Bt-cotton had 20% higher yield compared to non-Bt (Kerby, 1996).

Higher yield is attributed primarily to the more effective control of lepidopterous insects. With Bt-cotton, plant protection is active throughout the growing season, irrespective of the level of infestation. Thus, growers' overall yield is improved (Edge *et al.*, 2001).

Cost advantage: With Bt-cotton, the number of insecticide sprays is significantly reduced. In China (Huang *et al.*, 2002), it had been reported that in 2001, reduction of the number of insecticide sprays was 14 (28 reduced to 14), seven (from 11 down to 4) in South Africa[7] and five (from 7 to 2) in India.[8] The same sources reported that these reductions in number of sprays are translated into savings in variable costs. In India, pesticide cost on Bt field trials was $42/hectare lower than Non-Bt in 2000–2001 and $45/hectare in 1998–99. In South Africa, farm surveys showed reduction in insecticide costs of the following magnitude: Small farms, $3/hectare; large non-irrigated farms, $11/hectare; and large irrigated farms, $28/hectare.

Table 4 Yield and cost advantage of Bt over non-Bt-cotton in selected countries

	Yield Advantage				*Cost Advantage*			
	Bt Yield	*Non-Bt Yield*	*Difference*		*Number of Sprays*		*Reduction In*	
Country / year	Kg/ha		Kg/ha		Non-Bt	Bt	No. of Sprays	Cost (US$/ha)
India								
1998–1999	1,861	1,359	502	37	4	0	4	45
2000–2001	856	619	237	38	4	1	3	42
China (2001)	3,481	3,138	343	10	28	14	14	NA
South Africa					11	4	7	NA
(1998/99, 2000)								
Small Farms	576	395	181	46	NA	NA	NA	3
Large Non-irrigated farms	947	832	115	14	NA	NA	NA	11
Large, Irrigated Farms	4,046	3,413	633	19	NA	NA	NA	28
Indonesia (2001)	2,370	1,820	550	30	10	2	8	NA
Mexico								
1997	1,580	1,540	40	3	5	3	2	154
1998	1,710	1,420	290	20	5	2	3	139
Argentina (1999–01)	2,110	1,567	543	35	5	3	2	17
United States*	2,778	2,359	419	18	NA	NA	NA	NA

Notes: Average of two Bt (NuCOTN33B and NuCOTN35B) and two non-Bt varieties (DP5415 and DP5690). Yield was converted from lint to raw cotton in kg per hectare using 0.42 as conversion factor

Source: James, 2002

A review of global experience[9] showed that farmers using Bt varieties achieved an average reduction of 3.5 sprays per hectare.

3.2.1 Secondary benefits

Apart from yield and cost advantages, the following secondary benefits from Bt-cotton are reported:

- *Lower risk of insecticide-related accidents*: In China, the incidence of insecticide poisoning was much lower among farmers planting Bt-cotton compared to those planting non-Bt-cotton.[10]

- *Increased effectiveness of beneficial insects as pest control agents*: Non-target, beneficial insects are not harmed by the Bt protein (Benedict and Altman, 2001). With Bt-cotton, the use of broad-spectrum insecticides harmful to non-target insects is minimised. This allows the increase in the number of beneficial insects and enhances the effectiveness of the Bt technology in controlling pests.
- *Improved control of non-target pests*: Control of other pests of cotton not susceptible to the Bt protein (e.g., aphids, armyworms (Spodoptera), and cotton-stainer) is more effective with the use of Bt-cotton. The number of sprays for the control of these pests has been reported to be lower by one to two, on farms using Bt-cotton.[11] This is attributed to the increase in the population of beneficial predator and parasite insects due to the reduction in the application of broad-spectrum sprays.

4 Data and method of analysis

4.1 Farm level

Analysis at the farm-level was made on the assumption that Bt-cotton could provide both yield and cost advantage. Three possible levels of yield advantage were assumed – 10%, 30%, and 45%. Cost advantage was reflected by assuming a reduction in the number of sprays from five down to two, implying a saving of 3 litres of insecticide per hectare).

Table 5 shows the cost structure and, revenues of producing Bt and non-Bt-cotton, incorporating the above assumptions. Insecticide represents roughly 30% of the value of purchased inputs for non-Bt-cotton. Introducing Bt-cotton reduces insecticide cost from US$29 to US$12 per hectare. However, the additional Bt seed cost of US$15, and higher labour cost of harvesting due to higher yield, brings the net reduction in the cost of purchased inputs brought about by the introduction of Bt-cotton down to US$2 per hectare.

A linear programming model built upon earlier models used to analyse technology adoption in Mali (Vitale, 2001; Coulibaly, 1995), was used to determine the impact of Bt-cotton in a typical cotton farm. In Mali, a typical cotton farm grows four other crops – peanuts, maize, millet, and sorghum. Cotton and peanuts are grown as cash crops, while maize, millet, and sorghum (referred to as crop subset **c** in the model) are grown primarily as food crops. The model is algebraically written as:

$$\text{Max } E\Pi = \sum_{s=1}^{3} \sum_{i} \theta_s * (P_{si}Q_{si} - r_i x_{si}) \tag{1}$$

s.t.

$$AX \le B \tag{2}$$

$$\sum_{c} q_c \ge \overline{C} \tag{3}$$

where:

E = expectation operator

$E\,\Pi$ = expected profit

S = state of nature signifying degree of insect infestation (S_1 = high, S_2 = medium, S_3 = low)

i = crop activity (**i** = 1 . . . 5)

θ_s = probability of state of nature **s**, with $\sum_s \theta_s = 1$

P_{si} = price of crop activity **i** in state **s**

Q_{si} = total production of crop **i** in state **s** (area of crop **i** times yield per hectare)

r_{si} = per hectare production cost of crop **i**

x_i = area in hectares planted to crop **i**

$\bar{C}$ = quantity of cereals required for household subsistence

c = crop subset intended for food (i.e. cereal/food crops)

q_c = production of cereal/food crop **c**

A = matrix of technical coefficients

X = vector of all activities

B = vector of resource availability (briefly described in Annex A)

Food security requirement: Equation 3 takes care of the subsistence requirement of the household. A per capita cereal consumption of 200 kg (consisting of any combination of sorghum, millet and maize) is assumed. The model requires that at least 4000 kg of cereals be produced.

State of nature/degree of infestation: Three states of nature ($S1$ for high, $S2$ for medium, and $S3$ for low infestation) were assumed to reflect different degrees of lepidopterous insect infestation and account for the (potential) yield advantage of Bt over non-Bt-cotton. The degree of infestation and corresponding losses were based on interviews with farmers in Mali. $S1$ signifies a 40% reduction in yield, $S2$, 30% and $S3$, 15% yield reduction if non-Bt-cotton is planted. These three states of nature were assumed to have equal probabilities of occurring.

To validate the model, current farmers' practice was compared with our base model results. The base model assumes that only non-Bt-cotton is available for planting.

4.2 Aggregation at the national level

The results of the farm level analysis were used to aggregate national benefits. For this purpose, the estimated optimal profit per hectare from cotton was multiplied by total area planted to cotton. Three levels of adoption rate were assumed: 30%, 50%, and 100%. These are arbitrary numbers but nonetheless, closely reflecting the latest adoption rate in

China (31%), the US (34%), Australia (30%) and South Africa (60% in 2000–2001, and 92% in 2001–2002) as reported in James.[12] The 100% adoption rate is possible in Mali since under the current system, choice of variety to be planted is largely made by the cotton company, CMDT. Aggregation at the regional level was done by assuming that conditions observed in Mali also hold true in the other West African cotton growing countries.

Table 5 Farm costs and returns (US$/hectare) Bt and non-Bt-cotton

		Bt-cotton		
Items	*Non-Bt*	*10% Yield Advantage*	*30% Yield Advantage*	*45% Yield Advantage*
Cost				
• Purchased Inputs				
Seeds	–	15	15	15
Insecticide	29	12	12	12
Fertiliser and Others	69	69	69	69
• Labour				
Harvesting	31	32	35	39
Insecticide	4	1	1	1
Application	53	53	53	53
All other operations	31	31	31	31
• Depreciation	218	213	216	220
Total Cost				
Total Revenue	287	315	374	421
Net Returns	69	102	158	201

Note: US$1 = CFA600 Yield for non-Bt-cotton = 860 kg per hectare

Assumed yields at recommended fertiliser use: NPK = 150 kg, Urea = 50 kg

Source: IER, Mali

4.3 *Sensitivity analysis*

Sensitivity analysis was done to demonstrate the effects of varying the price of Bt-cotton seed, on the optimal solution. For this, we used as guide, data from other countries. In South Africa, the price of Bt-cotton seed was reported to be $15 per hectare for small farms, $19 for large non-irrigated, and $34 for large irrigated farms. In India, it is $56 per hectare.[13]

5 Results

Results from our analysis are organised in two main parts. The first presents the results of the farm-level analysis and, the second, an aggregation of benefits at the national level. Sensitivity analysis on the effects of varying technology fee, is shown at the end of this section.

5.1 Farm level: Bt-cotton compared with Non-Bt

Table 6 shows the farm-level effect of introducing Bt-cotton as an alternative to non-Bt variety. The first column summarises the land allocation as currently observed. The second column shows the results of running the model under the assumption that non-Bt-cotton is planted on the farm. The effects of making Bt-cotton as an alternative activity are shown in the succeeding columns.

Table 6 Land area allocation, output, and farm profit, non-Bt and Bt-cotton, Mali, 2003

Particulars	*Current Practice*	*Base Model*[i] *(Non-Bt Variety)*	*Bt-cotton Technology*[ii] *Under Alternative Yield Advantage*		
			45%	*30%*	*10%*
• Crop Area (ha)					
Cereals					
Sorghum	2.7 (18)	2.4 (16)	2.7 (18)	2.7 (18)	2.7 (18)
Millet	3.3 (22)	3.9 (26)	3.9 (26)	3.9 (26)	3.9 (26)
Maize	2.8 (19)	3.2 (21)	2.9 (19)	2.9 (19)	2.9 (19)
Cash Crops					
Groundnut	0.6 (4)	0.3 (2)	–	–	–
Cotton					
Non-Bt	5.5 (37)	5.2 (35)	–	–	–
Bt-Cotton	NA	NA	5.5 (37)	5.5 (37)	5.5 (37)
• Profit (US$)					
Whole Farm	NA	881	1,578	1,337	1,024
Cotton, Total	NA	348	1,114	873	560
Cotton, Per ha	NA	67	202	158	102

Notes: Number in parenthesis is percent of total area

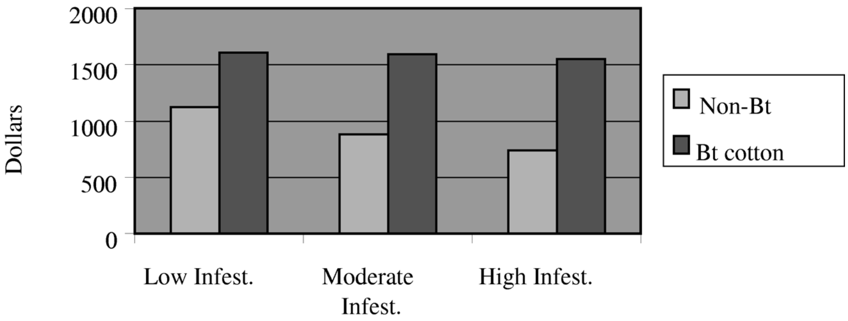
Assumed technology fee = $15/hectare. Exchange rate: CFA600/US$

[i] Bt-cotton not available in this run

[ii] Bt-cotton available to the farmer

Note first that the results of the base model closely resemble the current farm scenario (Table 5). By introducing Bt-cotton as an alternative activity, the model suggests significant observations. At the assumed price of Bt seed ($15 per hectare), there is a complete shift to Bt from non-Bt-cotton. Bt-cotton becomes the sole source of cash income for the household as groundnut drops out from the optimal solution. Contribution of Bt-cotton to total farm income increases from a little less than half (for non-Bt-cotton) to three-fourth. Income from cotton increases by as much as two to three times. Shifting to Bt-cotton also provides a more stable farm income. Only minor income variation is observed between extreme cases of insect infestation compared to that in non-Bt-cotton (Figure 1).

Figure 1 Profit ($/farm) under three levels of infestation



Source: Table 6 (Base model for Non-Bt and 45% yield advantage for Bt-cotton)

5.2 *Aggregate benefits*

Table 7 summarises the aggregate benefits both at the national and regional levels, from the introduction of Bt-cotton in three alternative adoption rates, and three yield advantage assumptions. Presenting the estimates of benefits from a low (lower right-hand corner) to a high (upper left-hand corner) level is an attempt to capture a wide range of possibilities.

As with other technologies that require ‘learning by doing’, it may take some time to achieve the higher yield associated with a better technology. In addition, some areas that are currently planted to non-Bt-cotton may not be conducive to Bt-cotton hence the high yield advantage (e.g. 45%) may not be achieved. Furthermore, rate of adoption is not certain at this point. Adaptation of Bt-cotton inevitably requires the involvement of the developer (i.e., Monsanto) of the technology, and this has important institutional ramifications that ultimately affect adoption rate.

The result will depend on how benefits of each interest group in the cotton sector who will play a key role in the process of adaptation and diffusion, are affected. It must be noted that our estimates of benefits are those that accrue directly to the farmers. Benefits to the cotton company (the sole supplier of production inputs, and the single buyer of cotton), and, the owner of the technology, have not been explicitly covered in the analysis.

Nonetheless, our estimates of benefits are fairly substantial, especially to the poor countries in West Africa. Our estimates range from a low of $7 million to a high of $67 million in Mali; $4 million to $41 million in Burkina Faso; $5 million to $52 million in Benin; $4 million to $38 million in Cote d’Ivoire; and, $1 million to $7 million in Senegal. The reduction in insecticide use is an added environmental benefit. Assuming a 100% adoption rate, and a 3-litre per hectare reduction in insecticide application, Mali would be applying 1,500 tons less insecticides, Burkina Faso 900 tons, Benin 1,100 tons, Cote d’Ivoire 843 tons and Senegal 165 tons.

5.3 *Effect of technology fee*

The effects of varying the price of Bt-cotton seed are shown in Table 8. Note that area allotted to cotton starts to decline at a fee of US$50 per hectare. At US$80 non-Bt-cotton re-enters the optimal solution and possibly replaces Bt-cotton at higher prices. These simple results provide important background for making decisions on the economics of introducing the technology to the region.

Table 7 Aggregate benefits from Bt-cotton at varying rates of adoption

Country	*Cotton Area*[i] *(000ha)*	*Total Benefits*[ii] *(million US$)*		
		100% Adoption	*50% Adoption*	*30% Adoption*
• *45% Yield Adv.*				
Mali	493	67	34	20
Burkina Faso	300	41	20	12
Benin	383	52	26	16
Cote d'Ivoire	281	38	19	11
Senegal	55	7	4	2
Total	1512	205	103	61
• *30% Yield Adv.*				
Mali		45	23	14
Burkina Faso		28	14	8
Benin		35	18	10
Cote d'Ivoire		26	13	8
Senegal		5	2	1
Total		139	70	41
• *10% Yield Adv.*				
Mali		23	11	7
Burkina Faso		14	7	4
Benin		18	9	5
Cote d'Ivoire		13	6	4
Senegal		3	1	1
Total		71	34	21

Note: [i] Two-year average area (1998–2000) data provided by IER

[ii] Derived by multiplying land area by the difference in per hectare profits from cotton between Bt and non-Bt shown in Table 6

6 Conclusions

This paper is an ex-ante analysis of benefits and costs of introducing Bt-cotton in West Africa. The analysis on cost of introducing the technology is qualitative and based on the experience of some developing countries (i.e., Mainland China, South Africa and India) that have now adopted Bt-cotton. Except for China, which has invested substantial amounts of budget for biotechnology research, these countries provided an environment that allowed the private sector to adopt and later market the technology for profit. This is a practical approach for West Africa as well. It effectively addresses both financial and human resource constraints in technology development.

Table 8 Effect of Technology fee for Bt-cotton on crop mix and farm profit

Particulars	*Alternative Technology Fee (US dollars per hectare)*				
	$15	*$50*	*$60*	*$70*	*$80*
• Area (hectares)					
Cereals					
Sorghum	2.7	2.4	2.3	2.2	2.4
Millet	3.9	4.2	4.6	4.9	3.9
Maize	2.9	3.2	3.3	3.4	3.2
Cash Crops					
Groundnut	–	0.3	0.3	0.3	0.3
Non-Bt	–	–	–	–	3.1
Bt-cotton.	5.5	4.9	4.6	4.2	2.1
• Farm Profit (US$)	1,593	1,213	1,080	967	890

Note: Yield advantage of 45% was used in the estimation procedure

Our review indicates that it is technically feasible to introduce Bt-cotton in West Africa. The insect problem is similar to those where the technology has already been adopted. Benefits to farmers are comparable to what have been reported in other countries. Results from a linear programming model indicate that farm income from Bt-cotton could be anywhere between two to three times higher per hectare, compared to non-Bt-cotton. Farm income is also more stable due to more effective control of insects.

Our analysis abstracts from the benefits obtained by other stakeholders who play a key role in the adoption of the technology. The rate of adaptation and diffusion will depend on how the influence of each of these interest groups figure out in the institutional arrangements that will ultimately emerge. Technical problems (e.g., regional adaptability) may also affect the yields obtainable from Bt-cotton.

Aggregate benefits to farmers could be as much as $67 million in Mali, $41 million in Burkina Faso, $52 million in Benin, $38 million in Cote de'Ivoire and $7 million in Senegal. These estimates would obviously vary according to the rate of adoption and, yield advantage realised. Nonetheless, this initial attempt on doing a benefit-cost analysis of introducing Bt-cotton in West Africa, should provide ample background for making public decisions on introducing the technology to the region. Failure to utilise this improved technology, jeopardises the future of an industry that provides export earnings and serves as source of income to millions of resource-poor farm households.

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Notes

1 op cit James (2002).

2 op cit James (2002).

3 Based on interviews with the following NARS entomologists: Mr. Djibril Badiani, ISRA, Senegal; Mr. Mamoubou Togola, IER, Sikasso, Mali; and Mr. Boubou Bagayoko, IER, Koutiala, Mali.

4 This was noted by the 39 farmers interviewed in Koutiala, Gouani, and Sikasso – three major cotton-growing areas in Mali.

5 op cit James (2002).

6 Ostlie, Hutchison and Hellmich provides ample explanation of how the insect succumbs to the toxin generated by the Bt crop. Cited in Hyde, J., Martin, M., Preckel, P. and Edwards, C. (1999) 'The Economics of Bt Corn: valuing protection for the European Corn Borer', *Review of Agricultural Economics*, Vol. 21, No. 2, pp.442–451.

7 op. cit. Ismael *et al.*, (2001).

8 op. cit. Naik, G. (2001).

9 op. cit. Edge, J. M. *et al.*, (2001).

10 op. cit. Huang, J. and C. Pray (2001).

11 op. cit. Benedict, J. and Altman, D. (2001).

12 op. cit. James, C. (2002).

13 op. cit. James, C. (2002).

Annex A: Description of a typical Mali cotton farm

A typical cotton farm is characterised to operate under the following condition:

- Family Labour: With an average of 20 members, a farm household has seven adults (5 male and 2 female) and one child available for farm work. A female adult's work-day is assumed equivalent to 0.75 and a child's is 0.5 of a male adult's work-day. Extra labour is hired during peak demand periods (e.g., weeding and harvesting).
- Land: Fifteen hectares allocated to the following crops:
  - cash crops: cotton (37% of total area) and groundnut (4%)
  - food crops: sorghum (18%), millet (22%) and maize (19%).
- Food Security Requirement: Land allocated to soybean, millet and maize is based on the household's cereal requirement for the whole year. Coulibaly (1995), estimates this to be 200 kg per capita per year. Land allocated to cash crops depends on their expected contribution to farm profits.
- Liquid Capital: For cotton, credit of up to CFA60,000 per hectare is available from the cotton company (CMDT) for the purchase of production inputs. For the other crops, CFA60,000 is available for the whole season.
- Inputs and Output Markets: Seeds, fertiliser, chemicals and technical information are provided by CMDT, the national cotton company and are repaid after harvest. CMDT is the sole buyer of cotton at a price set before planting.
- Work Animals and Farm Implements: Two oxen with a tandem plow, a donkey and a cart.
- Production Calendar: There are ten production periods spanning from May to November. Peak demand for labour occurs in periods 5 (July 15–30); 6 (Aug. 1–15) and 9 (Sept. 15–Oct. 15). July and August are peak weeding periods, and September and October are peak cotton harvest months.

Annex B: List of abbreviations

Bt	Bacillus Thuringensis
CFA	Communauté Financière Africaine
CMDT	Compagnie Malienne pour le Développement du Textile
IER	Institut d'Economie Rurale
ISAAA	International Service for the Acquisition of Agri-biotech Applications
MAHYCO	Maharashtra Hybrid Seeds Company, Ltd.