



EXECUTIVE BRIEF

Environmental Benefits of Biotechnology in Brazil "The Bollgard Cotton case"

Agriculture is the oldest and most important economic activity in the planet, occupying, at present, approximately 40% of the global area (COAG, 2007), generating 1.3 billion jobs and annually producing circa US\$ 1.3 trillion in raw materials and merchandise (EL FEKY, 2000).

According to the United Nations Population Fund – FUNFPA, the increase in population, and, consequently, in consumption, are aggravating the stress on the environment worldwide, increasing global heating, deforestation, and water shortage, and decreasing areas of harvestable land.

Even in face of intransigent disputes, the harvest of genetically modified crops has expanded throughout the world, and has become the fastest adopted technology in the history of agriculture, being singled out as vital to breakthrough the barrier of productivity (MANN, 1999) and as providing a solution for the restrictions imposed by biotic and abiotic stress, particularly in areas in which low productivity, malnutrition and hunger are constant threats (HERRERA-ESTRELLA, 2000).

The responsible management of biotechnology has enabled the first twelve years of GM crops to be conducted without any of the terrifying results predicted by the technology's opponents. In 2007, 114.3 million hectares of GM crops were planted by 12 million farmers in 23 countries, in comparison to the 102 million hectares planted by 10.3 million farmers in 22 countries in 2006.

According to Peter Raven, it is evident that global climate changes require fast adaptations to be made in crops for food production, which can only be sustained by using the most efficient tools available, including those that allow for greater water conservation. However, these changes will not be achieved if the paradigm of the negative effects caused by GM crops is not overcome. A great contradiction lies in the fact genetically engineered medications are approved in industrialized countries because they need them, while the production of food by a similar method is not approved for undernourished Africans.

In this sense, the most promising option in terms of technology to increase the supply of food, animal feed, and fibers, is to combine the advantages of the old and new, integrating the best of conventional technology (adapted germplasm) with biotechnological applications (new traits) (JAMES, 2006).

In 2007, Brazil continued ranking third in areas planted with GM crops, planting in 15 million hectares, despite the fact that estimates show that the country has reached its greatest absolute growth this year, with a variation of 3.5 million hectares with GM plantations, followed by the United States, with 3.1 million hectares, and India, with 2.4 million hectares (JAMES, 2007).

Millions of producers are already employing GM varieties in their farms worldwide (JAMES, 2007). Thus, the implementation of genetically modified crops may be considered one of the pillars of the global strategy for the fight against poverty and hunger, which needs to include a sufficient distribution of improved foods (JAMES, 2006).

The planting of Bollgard cotton brings, among other benefits, a potential increase in productivity without necessarily having to expand farming borders; a decrease in water and soil contamination; a drop in the emission of greenhouse gases; the guarantee of better health and life standards for producers (VILLALOBOS, 2007), and the drop in costs that has already been observed (the accrued global net benefits of GM crops from 1996 to 2005 amounted to US\$ 27 billion) (JAMES, 2006).

The overall purpose of this study is to analyze the environmental impacts generated by the adherence to Bollgard cotton in Brazil by reviewing the scientific literature on the environmental impacts resulting from growing it in Brazil and, as a world reference, to establish and explain

the social-environmental benefits achieved and observed by the producer as a result of adopting the genetically modified cotton technology.

Secondly, through this study it was also possible to analyze the user's expectation (rural producer's) related to the social-environmental aspects inherent to the Bollgard technology.

Methodology

The methodology used in this study included conducting local interviews with farmers chosen from conventional and GM cotton producing regions. The states sampled were Mato Grosso, Goiás, Mato Grosso do Sul, Bahia, and Minas Gerais, which account for 90% of the cotton planted in 2007/08 cotton crop year.

In view of the areas planted in the 2007/08 crop year (1,086 thousand hectares), the interviews with producers were planned based on a ratio of one interview for every 12.1 thousand hectares of planted area, amounting to 90 interviews (statistically rounding off numbers).

With a view at developing a better understanding of the issue of the adoption of Bollgard cotton, comparing the results observed on a large scale with the potential results of the adoption of this technology, the research was divided into two phases:

- ✦ Phase I: Detailed review of the scientific literature and interviews with consulting companies in the visited areas;
- ✦ Phase II: Field survey with farmers in the chosen states.

Phase I

In this phase I, technical visits were made to regions that are reference in the production of cotton in Brazil. In this visits, interviews were made with agricultural consulting companies responsible for the technical accompaniment of properties in the region.

As a reference, the agronomic production models adopted in Mato Grosso and Western Bahia were studied, as these two are the main cotton producing regions in Brazil. The production models for the conventional cotton and Bollgard cotton were taken as reference. Also, the impacts and benefits of adopting Bollgard II cotton, Bollgard II + RR and Bollgard II + Flex were simulated. With the information obtained in visits in loco, it was also possible to estimate:

- ✦ The reduced use of water;
- ✦ The reduced use of fossil fuel;
- ✦ The reduced emission of carbon dioxide.

Still in the first stage study, by means of the agronomic model of handling and production, it was possible to estimate the use of active ingredient (a.i.) and assess the toxicological profile of the main agrochemicals used in the cotton crop, having the conventional and transgenic (Bollgard) crops as reference. To do so, the methodology was based on the survey of the following production item for both production systems:

- ✦ Number of agrochemical sprays;
- ✦ Survey on the average consumption of fuel;
- ✦ Survey on the average consumption of water used in the preparation and application of the agrochemical solution;
- ✦ Survey on the typical package of inputs used

For these variables, the units used were: hectare (10,000 m²) for area, kilogram (kg) for mass, and liters or m³ for volume.

Phase II

The phase II was essentially aimed at assessing the socio-environmental benefits observed by a wider sampling of producers, and thereby, identifying their perception of general socio-environmental themes, and

themes that are specific to the Bollgard technology.

In the first part of the questionnaire, with general themes, was intended to obtain the opinion of farmers regarding themes like genetics and biology of the Bollgard Cotton, the influence of transgenics in the physical environment (soil, air, and water) and in biodiversity, aspects of food safety, health, and safety of rural workers, quality of life, and agricultural production.

The second part of the questionnaire was intended to identify the level of attractiveness and environmental risk experienced by the rural producer through the adoption of the Bollgard Cotton. With the purpose of providing information to assist the studies on the environmental impact of the Bollgard Cotton in Brazil, adaptations of the SWOT analysis methodology and the Porter strategic positioning analysis were developed. Both methodologies were used to elaborate prospective scenarios, defining environmental indicators and evaluating strong points, weak points, opportunities, and threats that influence the environment.

In this study, the strong points and opportunities were referred to as environmental attractiveness, while the weak points and threats were referred to as environmental risk, so as to demonstrate the advantages and disadvantages of the adoption of genetically modified products.

Therefore, relevance (weight) and efficacy (response) values were assigned to each indicator in a relative way (considering the importance of each indicator compared with all others), in order to obtain indexes for the intended evaluations. These indexes result from the multiplication of the values assigned to the relevance (between 0 and 100%) by the efficacy values (between 0: poor response, and 10: superior response) of each impact. Below is the mathematic reasoning used to define the analysis of attractiveness and environmental risk.

$$At = \sum_1^{n!} (N \times W) \qquad Ri = \sum_1^{n!} (N \times W)$$

Where:

At : socio-environmental attractiveness

Ri : socio-environmental risk

n! : total number of interviews made with producers

N : Grade assigned to each variable defined to attractiveness and socio-environmental risk, as the relevance indicator

W : weight assigned to each variable

Provided that, N for the attractiveness (minimum: 0 and maximum: 10) and N for the risk (minimum: 10 and maximum: 0), reminding that at least one variable must be graded 10.

Provided that, W is the weight assigned to each variable, ranging from 0.0 to 1.0, with total equal 1.0.

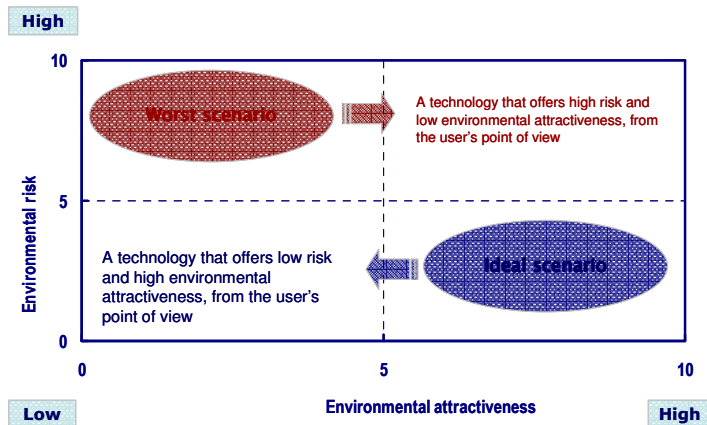
The sum of the indexes related to the environmental attractiveness and environmental risk, when compared, shows if the advantages overcome the disadvantages, in order to assess the validity of a continuation in the adoption of the technology, considering the impacts involved (PESSÔA; CARVALHO; PEREIRA JR., 2005).

The values considered for weights (W) were based in the fundamentals of the technology developed, from evaluations of the transgenic agriculture and conventional agriculture available in the scientific literature. Differently, the values for the relevance indicator (N) were obtained from field surveys in the states selected in the study.

By means of the analysis of matrixes elaborated for the Bollgard Cotton, it was possible to build the matrix that demonstrate what the ideal scenario would be to continue the adoption of transgenics, and the worst scenario, which would result in the discontinuation of the adhesion

to the technology.

Figure 1. Projection of the ideal scenario and worst scenario to evaluate the continuation of the adoption of transgenics.



Source: Céleres

Phase I results

Water is an indispensable natural resource, since it is a vital input for production and a strategic resource for economic growth. Water is also crucial for maintaining the biological, geological, and chemical cycles that hold together the balance of ecosystems, being thus considered essential for agricultural production.

Hydric resources are most commonly and frequently used in connection to the agricultural sector (irrigation), industry and urban supply. As economic activities become more diversified, the need for water increases and levels of sustainability need to be achieved to counterbalance the pressures of the consumer society, and industrial and agricultural production.

Biotechnology is a strategic tool in environmental conservation as it allows for the rationalization of the employment of natural resources. The adoption of biotechnology, in the case of Bollgard cotton, decreases the number of insecticide sprayings, which results in many environmental gains, such as a substantial decrease in the volume of water used in the mixture sprayed over the cotton fields, a decrease in volume of diesel oil used as fuel in the sprayers, and, consequently, a drop in greenhouse gas emissions released into the atmosphere.

Using the western region of Bahia and the central region of Mato Grosso as references, considering an average consumption of 120 liters of water used to prepare the mixture sprayed per hectare, it is possible to obtain an annual reduction of 360 liters of water per hectare, assuming a reduction of 3 applications of insecticides over Bollgard cotton fields, considering a self-propelled sprayer with a 2,000-liter tank capacity.

Environmental problems are caused by an intensified use of natural resources, particularly of fossil fuels (Kaya & Yokobori, 1997), nonetheless, in many urban centers around the world, the emissions from vehicles are increasingly contributing towards the deterioration of air quality and environmental damages (Kojima & Lovei, 2000).

One of the social-environmental benefits from the adoption of Biotechnology is the saving in fossil fuels, in this case, diesel oil.

Examining the same regions (west of Bahia and the central region of Mato Grosso), estimates indicate that the drop in diesel oil consumption is 3 liters per hectare, per year, reducing by three the spraying of insecticides over Bollgard cotton fields. In view of some variables observed in the different cotton producing regions in Brazil, the drop in diesel oil consumption, if the same premises are maintained, can reach up to 7.2 liters per hectare, per year, in a scenario of minus six applications and a lower operating yield of the self-propelled sprayer,

which runs on an average of 12 liters of diesel per hour.

Considering a drop in the insecticide sprayings over Bollgard cotton fields, and, consequently, savings in diesel oil, it was possible to quantify the emission of Greenhouse Gases – GEE in Portuguese, which decreased as a result of the drop in use of the fossil fuel. This assessment was based on the IPCC (Intergovernmental Panel on Climate Change) methodology, which analyses the emissions of greenhouse gases from moving sources, considering the quantity of burnt fuel, carbon content and the corresponding CO₂ emissions.

The saving of 3 insecticide sprayings over Bollgard cotton fields implies a CO₂ decrease of 0.0077 tons per hectare, released into the atmosphere, i.e., 7.7 Kilos of CO₂ per hectare per year, using the same sprayer described above.

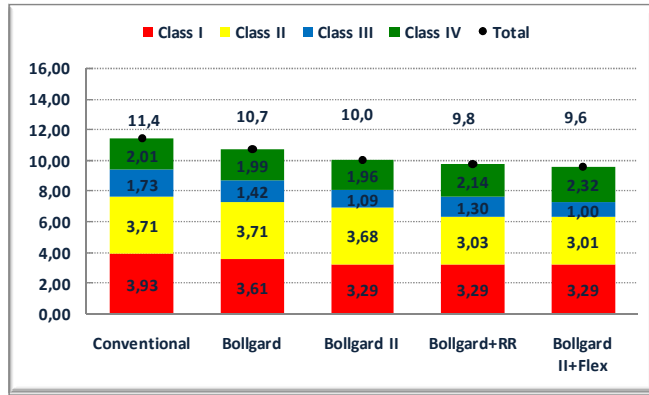
One of the main problems faced by the cotton growers from some of the Brazilian regions, such as the west of Bahia and the central region of Mato Grosso is the high incidence of infestation of the cotton bollworm, particularly, the *Spodoptera frugiperda*, which minimizes the benefits of Bollgard cotton, as most insecticides employed for the control of the cotton bollworm, in the cotton fields, are also efficient in the control of the cotton leafworm (*Alabama argillacea*), of the pink bollworm (*Pectinophora gossypiella*), and the tobacco bollworm (*Heliothis virescens*), which pests are controlled by the plants developed by the Bollgard technology. However, even with this scenario in place, the prior field studies and the technical data from research studies conducted in Brazil showed a decrease from 2 to 4 insecticide sprayings over the Bollgard cotton fields, in circumstances in which the pest management indicates that only the Bollgard target-insects have been controlled, which can be considered the worst scenario in terms of reducing insecticide sprayings.

The Bollgard technology ensures even more tranquility in the control of the pink bollworm (*Pectinophora gossypiella*), which is difficult to supervise due to the moth's night habits, and in the increase in efficiency of the cotton leafworm (*Alabama argillacea*) control during the crop's initial growth phases, enabling the optimization of farming machinery in other activities.

Based on the management observed in other fields in the west of Bahia, the Bollgard technology allows a decrease by 5.8% in the total quantity of the active ingredient per hectare (a.i./hectare), and an 8.1% the decrease in the volume of active ingredients under toxicological classification I, the most aggressive to the environment and human health.

However, the adoption of new technological traits, such as Bollgard II, Bollgard + RR, and Bollgard II + Flex, according to estimates obtained from the field survey, would potentially trigger an even more significant decrease in the employment of active ingredients per hectare under toxicological class I, possibly reaching a decrease by up to 16% for the Bollgard II, Bollgard + RR, and Bollgard II + Flex technologies. For toxicological class II, the active ingredients could be decreased by up to 18.8% per hectare with the adoption of Bollgard II + Flex or Bollgard + RR, showing that the greatest benefit achieved, in this case, consists in the decrease in the volume of active ingredients under toxicological classifications that are more aggressive to the environment and the rural worker's health.

Figure 1. Profile of the use of active ingredients employed in cotton in the west of Bahia, per kg of a.i./ha.

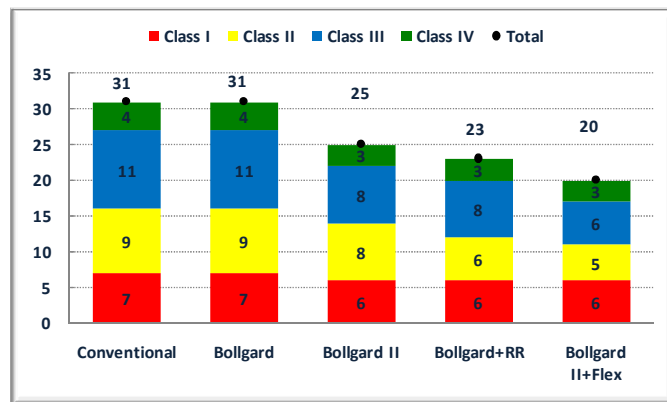


Source: Céleres Ambiental based on technical field visits.

Besides directly reducing the usage of the active ingredient per hectare, the adoption of the new products would have a direct impact in reducing the number of agrochemicals employed in the management of the cotton fields, with implications on logistics, as a smaller volume of transported inputs would be needed; on the environment due to the smaller volume of discarded packages; on management as the need for storage would decrease; on security as it would diminish the risk of agrochemicals being stolen in farms, and, above all, by greatly facilitating the production process management.

According to the cotton management observed in the west of Bahia, we could conclude that the number of products employed in the conventional and Bollgard crop remains the same, showing that the approval of the new technological traits will bring huge social, environmental, and economic benefits for cotton growing in Brazilian. This occurs because, according to estimates, there has been a gradual decrease in the number of products employed with the adoption of Bollgard II, Bollgard + RR, and Bollgard II + Flex, enabling a reduction of up to 11 products in the technological cotton package with the use of Bollgard II +Flex.

Figure 2. Profile of the use of active ingredients employed in cotton in the west of Bahia by number of products used.

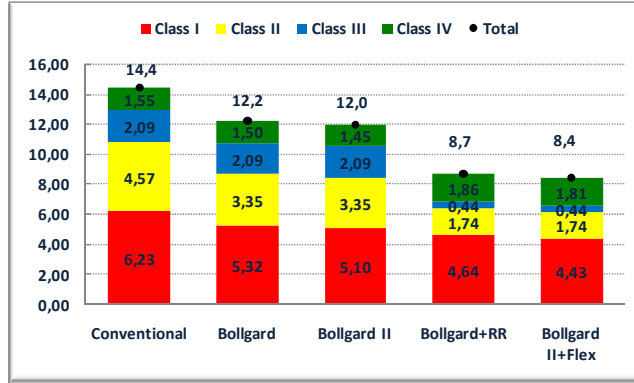


Source: Céleres Ambiental based on technical field visits.

On the other hand, for the central region of Mato Grosso, in the case of the management observed in areas planted with cotton, the Bollgard technology reduces by 15% the total volume of active ingredients used, per hectare, in the Bollgard cotton plant when compared to the conventional one, however, the adoption of the new technological

discoveries may lead to drop of up to 41.7% in volume of the active ingredient per hectare, in the case of a projection concerning Bollgard II + Flex. For toxicological classification II, the decrease in volume of active ingredients from conventional to Bollgard cotton is expected to be 26.7%, with a substantial decrease in volume of active ingredients under this classification in the event of approval of the Bollgard + RR, and Bollgard II + Flex traits, which would mean a 62% drop.

Figure 3. Profile of the use of active ingredients employed in cotton in Mato Grosso.

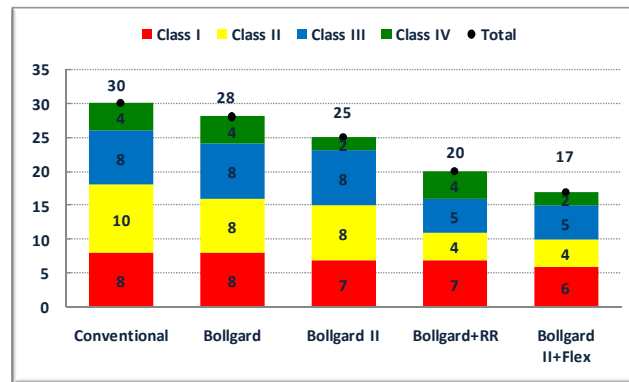


Source: Céleres Ambiental based on technical field visits.

As projected for the west of Bahia, the central region of Mato Grosso is also expected to undergo a significant decrease in the number of agrochemicals employed in cotton fields with the adoption of new traits. The positive impacts are realized with the decrease in volume of transported products, which benefits logistics; a smaller volume of discarded packages, avoiding negative impacts on the environment; a reduced need for storage due to a reduction in the volume of products; the reduced risk of agrochemicals being stolen in farms, providing for greater security in the farming zones; the improved production process management; and, furthermore, the benefit of the rural worker's health.

According to the cotton management analyzed in the central region of Mato Grosso, we observed the reduction of 2 products when comparing conventional to Bollgard cotton, however, this reduction may comprise up to 17 products, or in other words, the number of products employed in this crop would be reduced by 43.3%. This data only reinforces the need for approval of the other technological traits so that Brazil may achieve the positive results that have already been confirmed in countries in which these traits have already been approved.

Figure 4. Profile of the use of active ingredients employed in cotton in Mato Grosso by number of products used.



Source: Céleres Ambiental based on technical field visits.

Phase II results

By means of environmental questionnaires, conducted during the field visits, it was possible to gather relevant social-environmental information related to cotton growing in Brazil. The questions asked in the surveys included both the quantitative and qualitative aspects related to the possible social-environmental benefits from adopting the Bollgard cotton technology, with a view at gathering information on this subject with farmers.

The farmers were questioned about the benefits observed regarding water, soil, wildlife, and air quality improvement after adopting Bollgard cotton.

In the case of water, most farmers reported that they perceived some difference in the quality of the water, and according to the vast majority, this difference brings about some advantage to their activity. The main comments were regarding the improvement in the quality of the springs. Bollgard cotton enables the springs to be better preserved and less contaminated.

Regarding wildlife locally and surrounding the farm, a great part of the interviewed commented that there is some difference in the number of animals observed. For the great majority of the interviewed, this difference is a major advantage for their business. Furthermore, according to reports, the Bollgard cotton cultivar promotes an increase in the population of beneficial insects, particularly of the natural enemies of pests.

The farmers also perceived an improvement in soil quality after adopting Bollgard cotton. This technology allows for a decreased circulation of machines in the plantations and a reduction of insecticide sprayings. Although it is a benefit that is difficult to measure, the approval of new traits would only intensify this view, since there would be a lot less traffic of machines once the new traits are in place.

Although a large part of the interviewed find it difficult to measure the improvement in the quality of the air after Bollgard cotton has been adopted; it has been verified that most perceived some difference in the air after adopting the biotechnology. It is yet possible to observe that the farmer sees this difference in the air quality as an advantage. According to most reports, the difference in air quality is due to a smaller number of entries of machines into the field, and, consequently, a smaller volume of burnt fossil fuel.

The analysis of the information collected in the field and of the results from the interviews not only showed, but above all, reinforced the benefits of the Bollgard technology.

Based on the literature reviewed and field visits, the indicators considered as being the most significant and their respective weights regarding Bollgard cotton in Brazil are shown in the attractiveness and environmental risk matrices below.

It is worth stressing that for the environmental attractiveness matrix, the farmer's perception was used to determine the factors listed and considered as being the most relevant in the analysis. Thus, the results of the field interviews provided the weights obtained.

Figure 1. Environmental attractiveness matrix for Bollgard cotton in Brazil.

	SCORE CRITERIA*		Weight
	MIN	MAX	(0% to 100%)
Reduction in agrochemicals use	0	10	27,1%
Increased protection against pests and diseases	0	10	20,0%
Biotech events released through more strict procedures for biosafety	0	10	18,8%
Greater safety conditions for workers	0	10	15,3%
Better quality and sustentability of production	0	10	9,4%
Better optimization of production factors	0	10	9,4%
Weight Environmental Attractiveness			100,0%

The bibliography provided the factors indicated as being the most relevant regarding Bollgard cotton in Brazil for the environmental risk

matrix. This occurred because the Brazilian cotton producer still finds it very difficult to measure the environmental risks of the cotton cultivar.

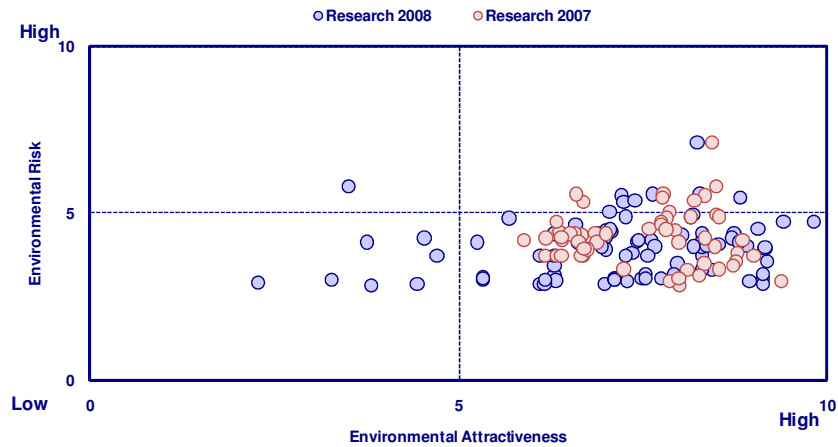
Figure 2. Environmental risk matrix for Bollgard cotton in Brazil.

	SCORE CRITERIA*		Weight (0% to 100%)
	MIN	MAX	
Contamination of conventional crops by gene flow	10	0	25.0%
Dependence of farmers to acquire the technology	10	0	17.0%
Development of resistance by target plagues	10	0	15.0%
Lack of knowledge by farmers on biosafety procedures	10	0	13.0%
Reduced biodiversity	10	0	12.0%
Appearance of undesirable new species and substances	10	0	10.0%
Uncertainties about the spot of insertion and expression of the genes inserted	10	0	8.0%
Weighted Environmental Risk			100.0%

The results of the environmental attractiveness analysis based on each field survey studies revealed that Bollgard cotton is a technology with medium environmental risk and positive environmental attractiveness, which was observed by the acceptance of the technology expressed by the adoption of the same since its approval in Brazil.

By means of a comparative study of the results of the 2007 and 2008 field survey studies regarding the attractiveness/environmental risk matrix, it was possible to observe that the Brazilian cotton grower's expectations around the Bollgard technology decreased.

Figure 3. Comparative study of the 2007 and 2008 attractiveness/risk environmental matrix of Bollgard cotton in Brazil.



Source: Céleres Ambiental based on technical field visits.

The approval by other countries that adopt GM crops of biotechnological traits that are more suitable to the hardships encountered in cotton growing increases the farmer's level of anxiety in having the same access to the technological tools used by his competitors, which would explain this decrease in expectations from Brazilian producers.

Although acceptance of biotechnology is unquestionable, the approval of new traits would enable the future social-environmental benefits, already experienced by farmers, to be even greater.

Examining the social-environmental benefits from adopting Bollgard cotton in Brazil

The analysis of the data obtained in the technical field visits showed that the adoption of Bollgard cotton provided relevant benefits in terms of environmental preservation and more safety for rural workers. The decrease in water consumption, the savings in diesel oil, and the drop in the emission of carbon gas are some of the benefits reaped with the adoption of Bollgard cotton.

Minimizing the use of natural resources implies in reducing the negative impacts on the environment, favoring the preservation of ecosystems. Biotechnology is an important tool within this context, as it enables rationing the use of natural resources such as water and the fossil fuel.

In this context it is evident the need to estimate and also quantify the social-environment benefits that would be achieved for the Brazilian cotton growers by the simply adoption of Bollgard cotton.

In the regions of the west of Bahia and in the center of Mato Grosso, where one may observe a quite conservative situation in relation to the reduction of insecticide sprayings over the Bollgard cotton fields, the annual reduction of water observed was of 450 liters per hectare. Based on this analysis and extrapolating the data to a domestic scenario, considering the projection of planting 170.9 thousand hectares with Bollgard cotton in the 2007/08 crop year (CÉLERES, 2007), and the reduction of 3 insecticide sprayings, it may be inferred that water consumption will drop by approximately 61.5 million liters of water per year.

Figure 1. Water volume reduction in the preparation of the mixture sprayed over Bollgard cotton fields in Brazil. 2007/08 crop year.

Solution applied (l/ha)	Number of applications reduced with the Bollgard Cotton					
	1	2	3	4	5	6
	Volume of water saved (million l/year)					
100	17,1	34,2	51,3	68,4	85,5	102,6
110	18,8	37,6	56,4	75,2	94,0	112,8
120	20,5	41,0	61,5	82,0	102,6	123,1
130	22,2	44,4	66,7	88,9	111,1	133,3
140	23,9	47,9	71,8	95,7	119,7	143,6
150	25,6	51,3	76,9	102,6	128,2	153,8
160	27,3	54,7	82,0	109,4	136,7	164,1

1/ Considering a self-propelled sprayer with a load capacity of 2,000 liters.

2/ Considering a self-propelled sprayer with an average consumption of 12 l of diesel/hr.

Source: Céleres Ambiental based on field survey

Along the same line of reasoning, based on data gathered and summarized in the states of Bahia and Mato Grosso, and still, taking into account the same planting projection for the 2007/08 crop year (CÉLERES, 2007), it is possible to predict an annual savings for Brazil of 513 thousand liters of diesel oil annually considering a decrease of 3 insecticide sprayings over Bollgard cotton fields.

Figure 2. Diesel oil volume decrease in Bollgard cotton fields in Brazil. 2007/08 crop year.

Yield (ha/h)	Number of applications reduced with the Bollgard Cotton					
	1	2	3	4	5	6
	Volume of diesel saved (thousand l/ano)					
10	205	410	615	820	1.026	1.231
11	186	373	559	746	932	1.119
12	171	342	513	684	855	1.026
13	158	316	473	631	789	947
14	147	293	440	586	733	879
15	137	273	410	547	684	820
16	128	256	385	513	641	769

Source: Céleres Ambiental, 2007. Considering a projection of 170.9 thousand ha planted with Bollgard cotton in the 2007/08 crop year (Data: Céleres)

Once a potential decrease in the emissions of greenhouse gases is acknowledged as a result of the adoption of Bollgard cotton in Brazil, we may conclude that, even assuming a conservative view in respect to the decrease in the frequency of sprayings, the numbers are considered significant.

The annual carbon gas volume that is no longer released into the atmosphere per hectare seems small; however, examining a 170.9-thousand ha area planted with Bollgard cotton in the 2007/08 crop year, we may observe an annual drop in CO₂ released into the atmosphere of 1.323 thousand tons.

Figure 3. Drop in GEE emission in tCO₂ resulting from a decrease in diesel use in Bollgard cotton fields in Brazil. 2007/08 crop year.

Yield (ha/h)	Number of applications reduced with the Bollgard Cotton					
	1	2	3	4	5	6
	Reduced emissions in tCO ₂ (tCO ₂ /year)					
10	529	1.058	1.587	2.116	2.645	3.174
11	481	962	1.443	1.924	2.405	2.886
12	441	882	1.323	1.763	2.204	2.645
13	407	814	1.221	1.628	2.035	2.442
14	378	756	1.134	1.512	1.889	2.267
15	353	705	1.058	1.411	1.763	2.116
16	331	661	992	1.323	1.653	1.984

Source: Céleres Ambiental, 2007. Considering an estimate of 170,9 thousand ha planted with Bollgard cotton in the 2007/08 crop year (Data: Céleres)

Out of the current major cotton producers, only Brazil has abundant natural resources, particularly, available harvestable areas to meet such demand for growth. However, the need to reconcile the cotton production growth with the growth of other agricultural products shows that the Brazilian average productivity growth rate of cotton needs to be maintained. Thus, so that Brazil captures an important share of this rise in global consumption, it is necessary for the country to double its planted area, growing from its current 1,086 thousand hectares to 2,396 thousand hectares in the 2017/18 harvest. In order to bear such growth need, the Brazilian cotton sector rely on the biotechnology as an important tool to request a smaller environmental footprint, as planted area and usage of other natural resources due to the higher yield potential observed in the transgenic cotton varieties.

Starting from the growth rate in the local cotton yield, observed in the last ten crop year, to reach the cotton production required by 2017/18 crop year it will be necessary the planting of 2.52 million hectares while with Bollgard cotton adoption (assuming the yield improvement yet observed in the Brazilian cotton areas) the need of planted area might be smaller, that means 2.4 million hectares by 2017/18.

In the considered scenario, the increase of expected planting for the next decade it is around 130 thousand hectares per year. However, at the accumulated for the next ten years, not adopting transgenic cotton in Brazil will force local producers to plant 1,434 thousand hectares. Such additional planting, throughout the considered timeline, has strong implication under the environmental burden perspective.

The following area assumptions were used as reference to the adoption of Bollgard cotton between 2008/09 and 2017/18 (Figure 12).

Figure 12. Area assumption of GM cotton adoption

	Total area	Lower	Upper	Potential
06/07	1.101,9	82,1	148,0	716,2
07/08	1.086,2	138,0	170,9	869,0
08/09	960,9	155,0	189,0	768,7
09/10	1.159,7	610,4	726,8	927,7
10/11	1.481,4	965,1	1.135,7	1.185,1
11/12	1.532,3	1.047,6	1.204,6	1.225,8
12/13	1.614,1	1.158,3	1.287,6	1.291,3
13/14	1.973,6	1.436,2	1.578,9	1.578,9
14/15	2.115,5	1.556,3	1.692,4	1.692,4
15/16	2.188,7	1.627,7	1.750,9	1.750,9
16/17	2.239,6	1.683,4	1.791,7	1.791,7
17/18	2.396,0	1.801,0	1.916,8	1.916,8

Source: CÉLERES. Based on own projections, figures in thousands of hectares

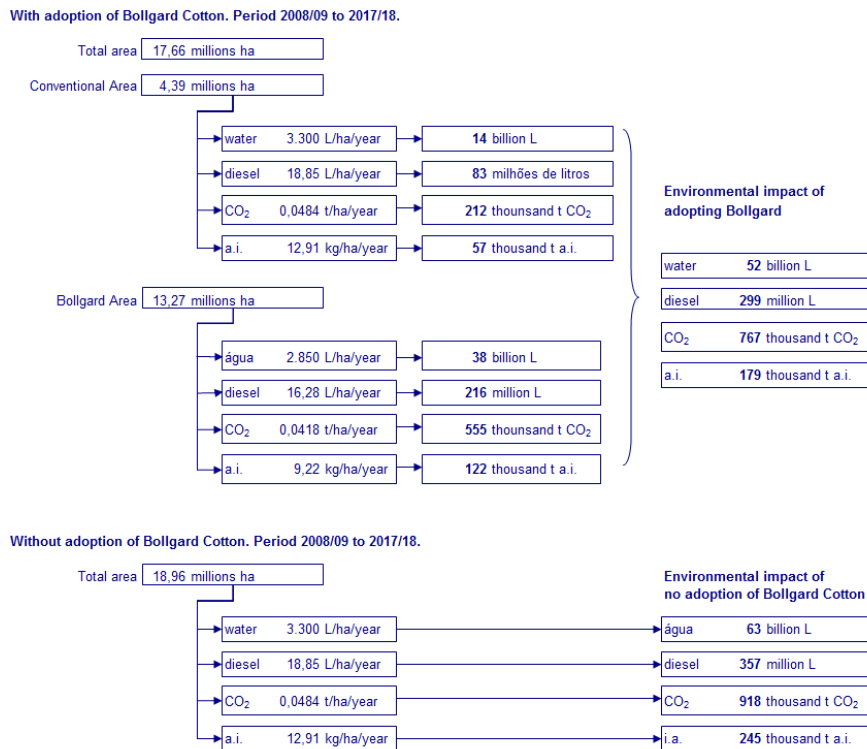
Taking into account an annual projection of cotton planted over the next decade, assuming that Bollgard cotton is adopted, and having already analyzed the expected impact of productivity, the total planted area with the fiber over this period is projected to reach 17.6 million hectares, being that out of this total, approximately 13.3 million hectares are planted with Bollgard cotton and 4.3 million hectares with conventional cotton (Figure 1.11). Considering such rate of adoption over the period under consideration, the average adoption of the

Bollgard cotton in Brazil is expected to reach 75.6% of the total planted with the fiber.

On the other hand, supposing Brazil does not adhere to Bollgard cotton, for the purpose of calculating the net environmental benefit resulting from the adoption of this technology, circa 19 million hectares of planted area would be needed between 2008/09 and 2017/18. Such increase results from the fact that conventional varieties are less potentially productive than Bollgard cotton.

Bearing these two scenarios in mind, with and without the adoption of Bollgard cotton, we initially projected the environmental impact on each one of the scenarios. For the analysis of the total environmental impact on the scenario of the adoption of Bollgard cotton, we took into consideration the remaining area remaining with conventional cotton. The same concept was applied to determine the environmental impact for conventional cotton. At the end, the net benefit from the adoption of Bollgard cotton in Brazil was estimated by difference, between 2008/09 and 2017/18.

Figure 13. Summary of the environmental impacts caused by cotton growing in Brazil. 2007/08 to 2017/18.



Observations:

^{1/} To calculate the environmental impact we only considered the diesel used in the sprayings of agrochemicals. We did not take into consideration the soil preparation or harvesting operations.

^{2/} For conventional cotton we considered 22 sprayings of agrochemicals applied with self-propelled sprays of 2,000 liters. For Bollgard cotton we considered 19 sprayings, based on field results derived from this study.

Source: Céleres Ambiental based on field survey.

The premises used for establishing the gains resulting from the adoption of Bollgard cotton regarding diesel oil, water, and CO₂ emission were based on results obtained in this study, through field interviews and summarized data.

Considering the difference between the environmental impact caused by both technologies, we could establish a net benefit for Bollgard cotton of 10.2 billion liters in water saving, which volume would be enough to supply a city with 234.3 thousand inhabitants during a decade. This is a clearly considerable volume of water that is saved from being consumed by the simple adoption of a technology that is

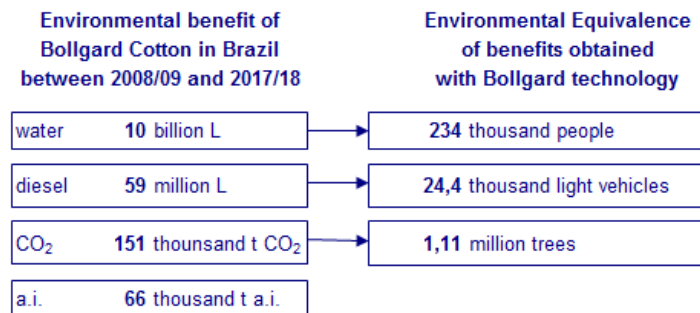
proven to be secure and efficient by different countries throughout the world.

The environmental benefit achieved with Bollgard cotton is no less significant or considerable in reducing diesel oil use. We calculated this benefit amounts to 58.6 million liters of diesel, which will be saved over the upcoming decade, taking the adoption rates of this technology into account as previously discussed in this study. Such fossil fuel volume would be enough to supply nearly 24.4 thousand average-sized pick up trucks, such as the S-10 models. In times in which fossil fuels are increasingly scarce, and, consequently, more expensive, it is an environmental benefit that has all of the elements necessary to stimulate the adoption of this technology.

For CO₂ emissions, the net benefit from the adoption of Bollgard cotton would avoid the emission of 150.5 thousand tCO₂ into the atmosphere over the next decade, which, in turn, corresponds to nearly 1.1 million trees being preserved. The botanical species considered for calculating the conversion were those found in the riparian forest. The adoption of Bollgard cotton and of other traits developed by biotechnology is naturally aligned with the view disseminated by the current themes such as carbon neutralization and sustainability.

Finally, the last environmental benefit examined in the study was the employment of active ingredients. Due to the decrease observed in the fields in this research, the environmental benefit from this item reaches 65.8 thousand tons of chemical products which are saved from being released into the environment over the next decade, which is, undoubtedly, a clear benefit from the adoption of Bollgard cotton in Brazil.

Figure 14. Summary of the environmental benefits resulting from Bollgard cotton growing in Brazil



Observation:
 UN recommendation for the water supply: 120 liters per capita per day
 Calculation of kilometers: 24,000 km/year with a 10-km/liter yield
 Coefficient used for conversion of trees: 7.38 trees/ton of CO₂ saved
 Source: Céleres Ambiental based on in-house research

Final considerations

According to the observations made in this study, the non-adherence to the Bollgard technology implies various environmental losses, with a rise in cotton planted areas over the upcoming years, which will consequently translate into the need to open up new planting areas.

The environmental benefits achieved with the adoption of biotechnology are clear. Bollgard cotton allows for reducing the number of insecticide sprayings over the plantations, and warrants innumerable social-environmental benefits, such as: decrease in water used in the sprays, decrease in the fossil fuel (diesel oil) used and, consequently, decrease in the quantity of carbon gas released into the atmosphere, soil protection and conservation, preservation of natural enemies, in addition to promoting the maintenance of local biodiversity.

The adoption of Bollgard cotton allows for the reduction in the volume of active ingredients in the soil, which implies less agrochemicals will be used in the plantations, favoring among other factors, the preservation of hydric and soil resources, and the decrease in volume of packages discarded in the environment.

The growing rate in the adoption of Bollgard cotton reinforces the high acceptance of the technology in the country. The Brazilian rural producer is experiencing, in addition to economic gains, less dependency on conventional agrochemicals, perceiving the improvement in water quality, wildlife, soil and air, and particularly, in the health of the rural worker. The adoption of the other biotechnological traits only tends to optimize the benefits set forth in this research, placing Brazil on equal conditions with its major competitors in the international market, and with an attitude of greater social-environmental responsibility.

About Céleres Ambiental

It is an environmental consulting firm that operates in the agricultural sector. With a view at better adapting itself to this market's requirements, it has further achieved proven competency in the environmental management of the sugar-alcohol sector related projects. It counts on a multidisciplinary team of highly qualified professionals who expediently respond to the needs of clients by executing different kinds of projects, among which are:

- Environmental Licensing
- Environmental Due Diligence (DDA)
- Site Feasibility Assessment
- Environmental Law Compliance

About the author

Paula Carneiro is director-partner of Céleres Ambiental. Biologist graduated by the Federal University of Uberlândia – MG, specialized in Environmental Management by the Federal University of Viçosa (MG), in specialization in Environmental Law and Sustainability by PUC- São Paulo. Today, she is the Environmental Consultant of sugar and alcohol mills in municipalities in the important 'triangle' of Minas Gerais and Ribeirão Preto – SP. She worked in the elaboration and coordination of diagnostic projects and evaluation of areas for the installation of sanitary landfills and sugar and alcohol mills, environmental licensing, recovery projects of degraded areas, technical projects of reconstitution of the flora, environmental control projects, environmental control reports, environmental impact assessments, environmental impact reports, and others. Today, she is a member of the Board of Information on Biotechnology (CIB).

For further information about this study, please contact Céleres Ambiental:

ambiental@celeres.com.br

www.celeresambiental.com.br

R. Eng. Hélivio Felice, 119, Altamira

Uberlândia (MG) – CEP: 38411-414

Phone.: +55 (34) 3229-1313 – Fax: +55 (34) 3229-4949
