EXECUTIVE BRIEF

Environmental Benefits of Biotechnology in Brazil

"The RR soybean 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 – UNFPA, 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.

The overall purpose of this study is to analyze the environmental impacts generated by the adherence to RR Soybean 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 soybean 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 RR technology.

Methodology

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

With a view at developing a better understanding of the issue of the adoption of RR soybean, 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:

- First phase: detailed review of the scientific literature and interviews with consulting companies in the visited areas;
- Second phase: field survey with rural producers in the chosen states.

Phase I

In a first moment, the methodology used to elaborate the study included a detailed revision of the scientific literature related to environmental impacts resulting from the cultivation of the RR soybean in Brazil and in the world, in an attempt to identify relevant data.

Still in this first stage, technical visits were made to regions that are reference in the production of soybean 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 Paraná were studied, as these two are the main soybean producing regions in Brazil. The production models for the conventional soybean and RR soybean were taken as reference. 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 soybean crop, having the conventional and transgenic (RR) 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 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 m^2) for area, kilogram (kg) for mass, and liters or m^3 for volume.

Phase II

The second stage 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 RR technology.

In the first part of the questionnaire, with general themes, was intended to obtain the opinion of rural producers regarding themes like genetics and biology of the RR soybean, the influence of transgenics in the physical environment (soil, air, 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 RR soybean. With the purpose of providing information to assist the studies on the environmental impact of the RR soybean 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.

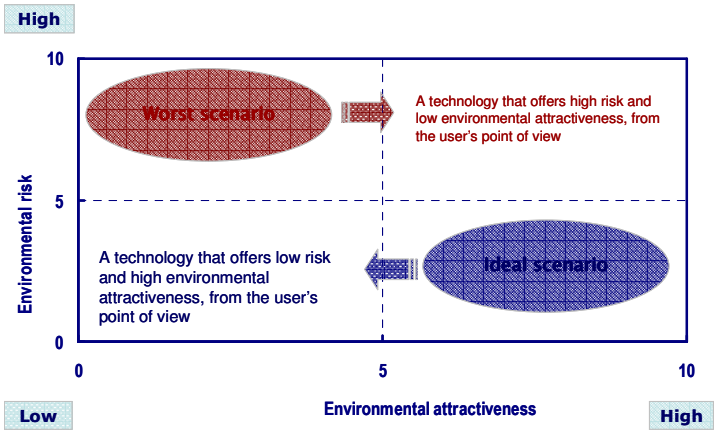
Provided that, W is the weight assigned to each variable, ranging from 0.0 to 1.0, with total equal 1.0.

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 fundaments 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 surveyes in the states selected in the study.

By means of the analysis of matrixes elaborated for the RR soybean, 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.



Fonte: Céleres Ambiental

Once the questionnaire is defined, the interviews were distributed in Brazil according to the sampling described in the methodology. The main criterion used to distribute the interviews in the states was the relative weight of each of them over the total area planted with soybean in the 2007/08 crop year.

First phase results

Water is a vital natural resource because it is an essential input for production and a strategic resource for economic development. Water is

vital for the maintenance of biological, geological and chemicals cycles that keep ecosystems in balance, and 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 preserving the environment because it allows the rational use of natural resources. The adoption of biotechnology, where the RR soybean, enables a reduction in the number of applications of herbicides, resulting in various environmental gains, like significantly reducing the volume of water used to prepare the spray volume used in soybean crops, reducing the volume of diesel oil used as fuel in sprayers and, consequently, a reduction in the emission of greenhouse gases released into the atmosphere.

Using the region in the west of Mato Grosso and Paraná as reference, for every 120 liters of liquid per hectare sprayed, it is possible to save 240 liters of water per hectare, per year, saving two herbicide sprayings over the RR soybean fields.

Environmental problems are caused by the intensification of the natural resources use, particularly fossil fuels (Kaya & Yokobori, 1997), however, in several urban centers in the world, emissions from vehicles are increasingly contributing to the deterioration of air quality and environmental damage (Kojima & Lovei, 2000).

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

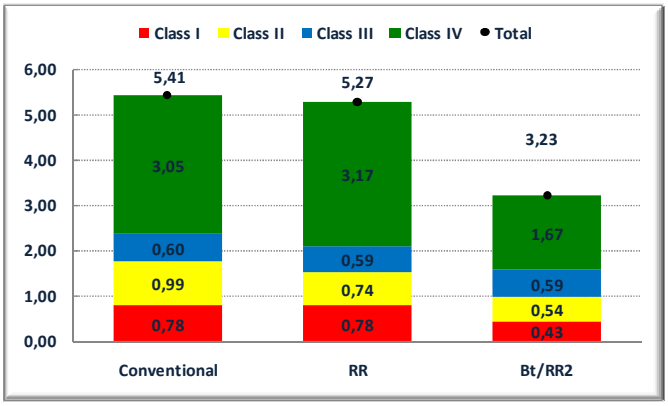
Examining the regions of Paraná and west of Mato Grosso and considering the diesel oil consumed by the agricultural machinery in the RR soybean fields, we may infer that two liters of diesel oil are saved per hectare annually in a scenario of minus two herbicide applications over RR soybean fields.

With the drop in the sprayings over RR soybean fields, it was possible to observe that a large amount of fossil fuels was saved, and, consequently, there was a decrease in the emission of gases that contribute to the greenhouse effect, which can be translated into a major benefit, in view of the weight these gases carry in aggravating global heating.

Considering the regions of Paraná and west of Mato Grosso, the saving of 2 herbicide sprayings over RR soybean fields implies 0.0052 tons of CO_2 per hectare are no longer released into the atmosphere, i.e., 5.2 kilos of CO_2 per hectare per year.

In the state of Mato Grosso the adoption of RR soybean further allowed a drop in the total volume of active ingredients per hectare at around 2.58%. For toxicological class II, a quite aggressive class to the environment and human health, there was a very substantial drop. The volume of active ingredients under class II was reduced by 25.3%, per hectare, just by adopting biotechnology.

Figure 1. Profile of the use of active ingredients employed in soybeans in the west of Mato Grosso, per kg of a.i./ha.

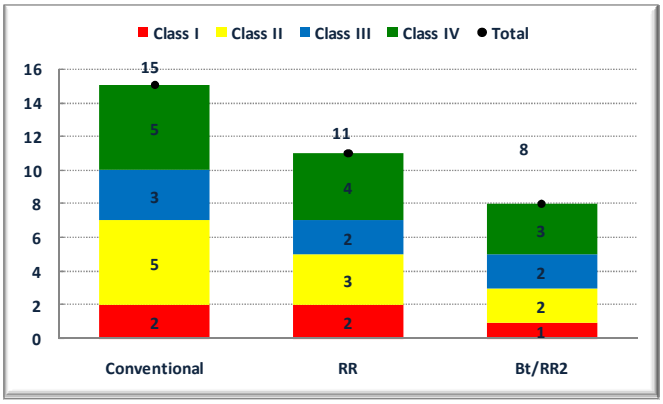


Source: Céleres Ambiental based on technical field visits.

Upon simulating the adoption of the Bt/RR2 trait, the ingredients under toxicological class I would be reduced by 44.8%, whereas those under toxicological class II would undergo a drop of 45.4%. The approval of new traits reinforces even more the social-environmental benefits that can be achieved and the significance of the technology for the preservation of the natural resources and the health of the rural worker.

In addition to the change in the profile of the toxicological class of the products used, the adoption of RR soybean has a direct impact on a smaller number of agrochemicals used in the management of the cultivar. For conventional soybeans, 15 products are used, while for RR soybean only 11 products are necessary, a drop of 26.6%, which further contributes to the decrease in the volume of transported products, which significantly benefits logistics and the impact caused by packages discarded into the environment.

Figure 2. Profile of the use of active ingredients employed in soybeans in the west of Mato Grosso by number of products used.



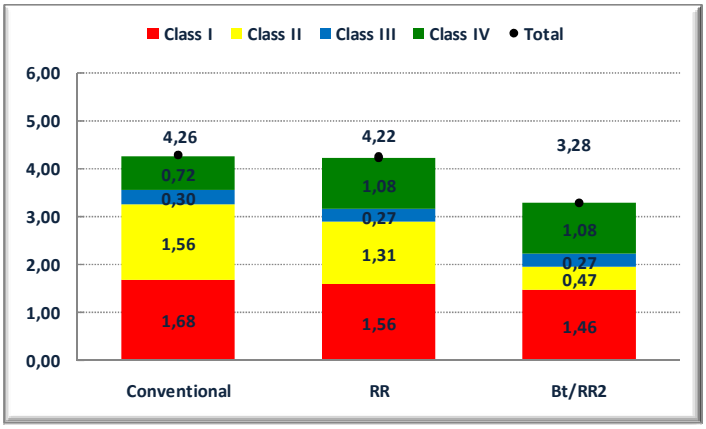
Source: Céleres Ambiental based on technical field visits.

In the state of Paraná, it was observed that with the adoption of RR soybean there is a decrease by 0.94% in the total volume of the active ingredient per hectare (a.i./hectare), used in the cultivar. Although it seems small, the decreased use of toxicological class I and II products, considered the most aggressive to the environment and human health, amounted to 7.14% and 16%, respectively.

The approval of Bt/RR2 soybean would bring about more environmental benefits. The volume of active ingredients would be reduced by 23%, with a saving of 13% in active ingredients under class I, and 70% in active ingredients under class II. Thus, we may perceive that the advantages

increase as the new traits are approved and adopted.

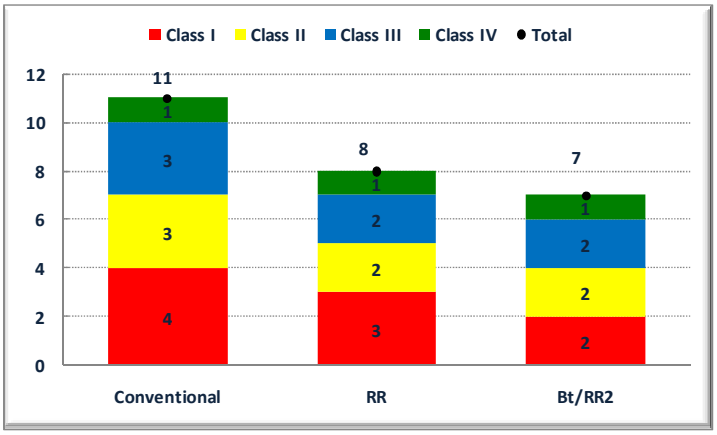
Figure 3. Profile of the use of active ingredients employed in soybeans in Paraná, per kg of a.i./ha.



Source: Céleres Ambiental based on technical field visits.

Regarding the total number of products used in the soybean crop, we can observe that there is a saving of 27% with the adoption of RR soybean, reducing by 25% the use of toxicological classification I products, and by 33% of classification II products.

Figure 4. Profile of the use of active ingredients employed in soybeans in Paraná by number of products used.



Source: Céleres Ambiental based on technical field visits.

Based on interviews with the state of Mato Grosso's technical staff and on the access to the herbicide technological package used in the conventional crop and RR soybean cultivar, it was possible to analyze the level of persistence of these products in the soil according their respective half-lives.

Some herbicides used on conventional soybeans have a prolonged residual effect, and can remain in the soil for up to 1,000 days. Such as was observed in the case of Mato Grosso, in Paraná, the herbicides that are too persistent in the environment are no longer being used in the RR soybean cultivars, reducing the permanence of residues over an extended period of time in the soil, which can be confirmed by comparing the lists of products for the herbicide technological packages used in the conventional and RR soybean.

Phase II results

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

The rural producers were questioned about the benefits observed regarding water, soil, wildlife, and air quality improvement after adopting RR soybean.

In the case of water, most rural producers reported that they perceived some difference in the quality of the water, and according to the vast majority, this difference brings about an advantage to their activity. The main comments were regarding the improvement in the quality of the springs. RR soybean enables the replacement of products under a more aggressive toxicological classification by products under a less aggressive toxicological classification, decreasing the contamination of the water resources.

Regarding wildlife locally and surrounding the farm, a great part of the interviewed noticed that there is some difference in the number of animals observed. Nearly 30% of the producers noticed a large difference in the wildlife in the property and surrounding it, the number of animals observed in the farms increased and some animals reappeared. For the great majority of the interviewed, this difference is a major advantage for their business. Furthermore, according to reports, zero tillage and the use of products that are less aggressive to the environment promote the return of some groups of wildlife such as: mammals, insects, and birds.

The farmers also noticed an improvement in the soil quality with the growing of RR soybean. The RR technology is already connected to zero tillage in Brazil and the benefits earned from this practice have already been proven. The improvement in the erosion processes, less compacted soils, and greater water retention are benefits noticed by the farmers in the soil quality with the growing of RR soybean.

Although a large part of the interviewed find it difficult to measure the improvement in the quality of the air after RR soybean have been adopted, it has been verified that most noticed some difference in the air after adopting the biotechnology. It is further 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 entrances of machines into the field, and, consequently, a smaller volume fossil fuel is burnt.

Based on the literature reviewed and field visits, the indicators considered as being the most significant and their respective weights regarding RR soybean 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 opinion was used as a guideline 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 RR soybean in Brazil.

	SCORE CRITERIA*		Weight
	MIN	MAX	(0% to 100%)
Higher tolerance to herbicides	0	10	20.0%
Reduction in the use of agricultural agrochemicals	0	10	17.0%
Better quality and sustainability of production with the use of the technology	0	10	14.0%
Better protection and environmental preservation through the use of conservationist agricultural practices	0	10	13.0%
Simplicity to use the technology	0	10	12.0%
Biotechnology events released through more rigorous biosafety procedures	0	10	9.0%
Reduction in the emission of greenhouse gases	0	10	8.0%
Better optimization of production factors	0	10	7.0%
Weighted Environmental Attractiveness			**100.0%**

The bibliography provided the factors indicated as being the most relevant regarding the RR soybean cultivar in Brazil for the environmental risk matrix. This occurred because the Brazilian soybean producer still finds it very difficult to measure the environmental risks of the soybean crop.

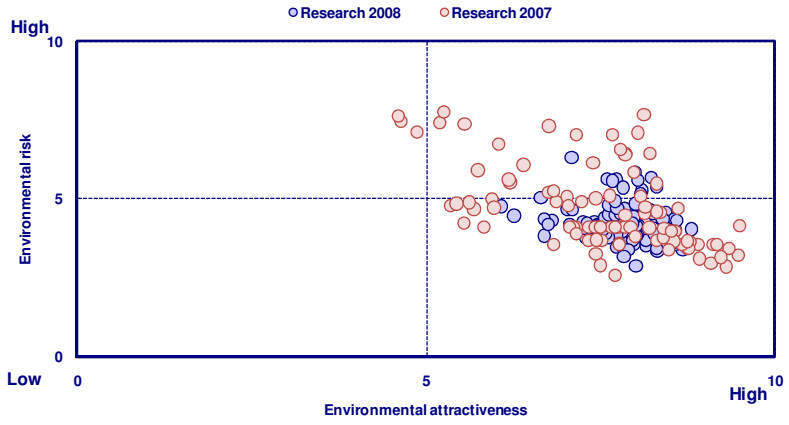
Figure 2. Environmental risk matrix for RR soybean in Brazil.

	SCORE CRITERIA*		Weight
	MIN	MAX	(0% to 100%)
Inappropriate use of glyphosate in the handling of soybean crop	10	0	28.0%
Dependence of farmers to acquire the technology	10	0	19.0%
Lack of knowledge by farmers about biosafety procedures	10	0	16.5%
Restriction to the consumption of transgenic products	10	0	15.0%
Development of resistance by weeds	10	0	12.5%
Undesirable effects in non-target organisms	10	0	5.0%
Uncertainties about the spot of insertion and expression of the genes inserted	10	0	4.0%
Weighted Environmental Risk			**100.0%**

The analysis of the field data and of the results of the interviews did not only show, but above all, reinforced the benefits of RR soybean. Thus, the simple interpretation of the results obtained from the attractiveness and environmental risk matrices, in which the sum of the relationship between the attractiveness weight and relevance overrides the sum of the variables resulting from environmental risks, shows favorable results towards the adoption of RR soybean in Brazil.

The comparison between the researches conducted in the years of 2007 and 2008 reveals that RR soybean offer medium environmental risk, which has been decreasing year after year, and a continuous high level of environmental attractiveness. The environmental attractiveness can be observed by the strong acceptance of the technology reflected by the significant levels of adoption of the same since its approval in Brazil.

Figure 3. Attractiveness/risk environmental matrix for RR soybean in Brazil - 2007 and 2008 researches.



Source: Céleres Ambiental

During the years over which RR soybean have been adopted, the producers have consolidated their opinion on the benefits earned from the technology. In the case of Bollgard cotton, the Brazilian cotton growers believe that the most up to date traits will bring about more benefits as the results from this technology were below projections. Thus, while RR soybean, in spite of the differences observed between the producing regions in Brazil, have proven to be an efficient technology, Bollgard cotton has fallen short of expectations of Brazilian producers.

Examining the social-environmental benefits from adopting RR soybean in Brazil

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 allows for the rational use of natural resources.

Using the regions of Paraná and west of Mato Grosso as samples, and extrapolating the data to a domestic scenario, we may estimate that approximately 3.1 billion liters of water is saved in the RR soybean fields in the 2007/08 crop year (Figure 0.8). This sum was estimated based on an average of 120 liters of liquid sprayed per hectare and the reduction of 2 herbicide sprayings, which is a saving of 240 liters of water per hectare. This estimate was based on the projection of planting 13,092 thousand hectares with RR soybean in the 2007/08 crop year (CÉLERES, 2008).

Figure 1. Water volume reduction in RR soybean fields in the 2007/08 crop year in Brazil.

Solution applied (l/ha)	Number of applications reduced with the RR Soybean		
	1	2	3
	Volume of water saved (billion l/year)		
100	1,3	2,6	3,9
110	1,4	2,9	4,3
120	1,6	3,1	4,7
130	1,7	3,4	5,1
140	1,8	3,7	5,5
150	2,0	3,9	5,9
160	2,1	4,2	6,3

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

Considering the consumption of diesel oil consumed by agricultural machinery used in RR soybean fields in the states of Mato Grosso and Paraná, we can observe a saving of 2 liters of fossil fuel per hectare, in a scenario where there has been a decrease of 2 herbicide sprayings over the GM cultivar.

Based on data gathered and summarized in the abovementioned states, and furthermore, taking into account the panting projection of 13,092 thousand hectares with RR soybean for the 2007/08 crop year (CÉLERES, 2008), a sprayer with an average yield of 12 hectares/ hour, it is possible to predict an annual saving for Brazil of 26.2 million liters of diesel oil by the simple adoption of RR soybean.

Figure 2. Diesel oil volume decrease in RR soybean fields in Brazil in the 2007/08 crop year.

Yield (ha/h)	Number of applications reduced with the RR Soybean		
	1	2	3
	Volume of diesel saved (million l/year)		
10	15,7	31,4	47,1
11	14,3	28,6	42,8
12	13,1	26,2	39,3
13	12,1	24,2	36,3
14	11,2	22,4	33,7
15	10,5	20,9	31,4
16	9,8	19,6	29,5

Source: Céleres Ambiental, 2008

Once a potential decrease in the emissions of greenhouse gases is acknowledged as a result of the adoption of RR soybean in Brazil, we may conclude that, even assuming a conservative view in respect to the decrease in the frequency of sprayings, the decrease in the CO_2 emissions is significant given the dimension of soybean planted areas in Brazil.

The annual carbon gas volume that is no longer released into the atmosphere per hectare (5.2 kilos of CO_2) seems small; however, predicting an area of 13,092 thousand hectares planted with RR soybean for the 2007/08 crop year, and considering a sprayer with an average yield of 12 hectares/hour, we may observe an annual drop in CO_2 released into the atmosphere of 67.5 thousand tons.

Figure 3. Reduction in GEE (greenhouse gas) emission in tCO_2 resulting from a decrease in diesel use in RR soybean fields in Brazil - 2007/08 crop year.

Yield (ha/h)	Number of applications reduced with the RR Soybean		
	1	2	3
	Reduced emissions in tCO2 (thousand tCO2/year)		
10	40,5	81,0	121,6
11	36,8	73,7	110,5
12	33,8	67,5	101,3
13	31,2	62,3	93,5
14	28,9	57,9	86,8
15	27,0	54,0	81,0
16	25,3	50,7	76,0

Source: Céleres Ambiental, 2008

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

Figure 12. Area assumptions for GM soybean adoption.

	Total area	Lower	Upper	Potential
96/97	11.903,2	31,0	62,0	1.785,5
97/98	13.710,6	195,0	358,0	4.798,7
98/99	13.260,6	479,7	798,2	8.619,4
99/00	13.749,0	682,8	1.340,9	9.624,3
00/01	14.090,6	1.158,8	1.873,7	10.145,3
01/02	16.477,8	1.627,4	2.663,9	12.028,8
02/03	18.614,3	2.051,7	3.363,6	13.774,6
03/04	21.281,1	3.652,6	4.736,1	15.960,8
04/05	23.482,8	4.594,9	5.709,7	17.847,0
05/06	22.288,7	7.775,4	9.144,6	17.831,0
06/07	20.685,3	10.198,8	11.763,5	17.996,2
07/08	21.284,8	7.992,1	13.292,7	18.730,6
08/09	21.933,0	12.205,0	13.933,9	19.739,7
09/10	24.161,1	16.682,3	18.259,2	21.986,6
10/11	25.904,9	19.636,3	21.326,5	23.573,5
11/12	26.715,1	21.332,7	23.136,2	24.310,8
12/13	28.237,1	23.030,6	24.787,4	25.695,8
13/14	30.089,5	25.041,5	26.784,9	27.381,4
14/15	30.913,7	25.846,8	27.623,5	28.131,5
15/16	31.708,7	26.697,5	28.391,9	28.854,9
16/17	34.038,9	28.658,0	30.533,7	30.975,4
17/18	35.143,1	29.641,1	31.588,6	31.980,2

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

Advancing towards the analysis of the environmental benefits earned from the adoption of RR soybean, we projected two scenarios for calculating the following factors: water, diesel oil, and carbon gas reduced over the next decade, i.e., from 2008/09 to 2017/18. It is worth stressing that the adoption or not of RR soybean does not change in any way the total area planted with the crop, since the RR soybean technology does not predict gains in productivity.

In the first scenario projected, assuming the adoption of RR soybean, the total area planted with this cultivar is expected to reach 288.8 million hectares, being that out of this total, 246.4 million hectares refer to RR soybean, and only 42.5 million hectares to conventional soybeans. The rate of potential adoption of RR soybean would therefore amount to up to 85.3% of the total planted with such cultivar over a decade, *i.e.* between 2008/09 and 2017/18.

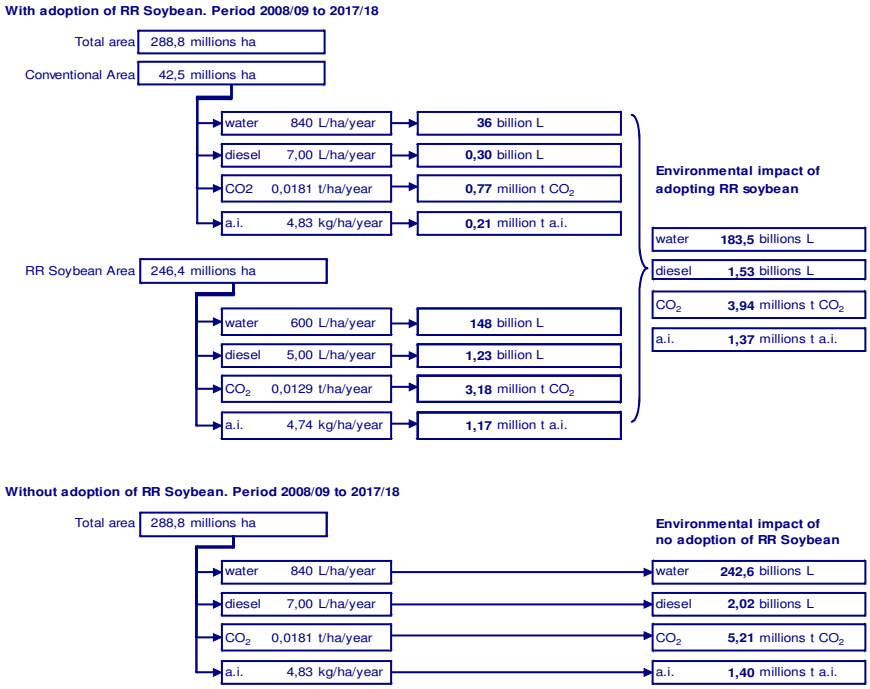
In the second scenario we considered a total area planted with only conventional soybean, amounting to 288.8 million hectares, since the RR soybean technology does not presuppose a gain in productivity, as is the case for Bollgard cotton and YieldGard corn.

Bearing these two scenarios in mind, with and without the adoption of RR soybean, we initially projected the environmental impact of each one of the scenarios.

In the case of the first scenario, in which RR soybean are grown, the analysis of the environmental impact of the conventional crop and the GM cultivar took into account the following factors: water use for the preparation of the liquid sprayed over the fields, diesel oil consumption needed to feed the agricultural machinery, carbon gas emissions released into the atmosphere from the burning of fossil fuels, and the volume of active ingredient used. Through the results from each one of the crops, conventional and GM, it was possible to obtain the total environmental impact of the soybeans.

The analysis of the total environmental impact for the first scenario, with the adoption of RR soybean, was calculated by adding up the impacts from the conventional crop and the GM cultivar.

Figure 13. Summary of environmental impacts from soybeans in Brazil, period from 2008/09 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 harvest operations.
2/ For conventional soybeans we considered 7 sprayings of agrochemicals applied with self-propelled sprayers of 2,000 liters. For RR soybean we considered 5.7 sprayings, based on field results derived from this study.

Source: Céleres Ambiental based on field survey.

Considering the difference between the environmental impact caused by both scenarios, we could establish a net benefit for growing RR soybean in Brazil over the upcoming decade. Thus, the benefit reaches 59.1 billion liters in water saved, which volume would be enough to supply a city with 1,35 million inhabitants over the next decade, or nearly 135 thousand inhabitants per year. 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.

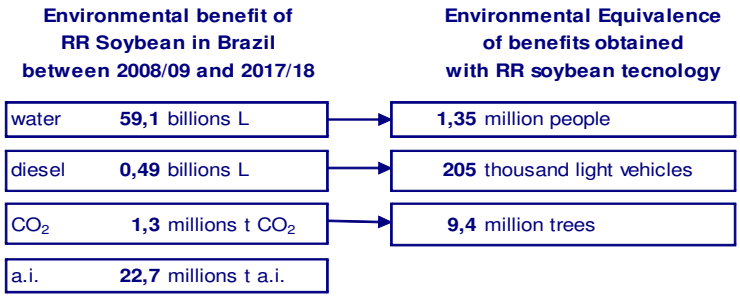
The environmental benefit achieved with RR soybean is no less significant and considerable in analyzing the reduction in diesel oil use. We calculated this benefit at 492.7 million liters of diesel, which will be saved over the upcoming decade, taking the adoption rates of this technology into account as previously discussed in this study. Such fossil fuel volume would be enough to supply nearly 205 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, by means of economic motivation.

For CO_2 emissions, the net benefit from the adoption of RR soybean would avoid the emission of 1.27 million of tCO_2 into the atmosphere over the next decade, which, in turn, corresponds to nearly 9.3 million trees being preserved. The botanical species considered for calculating the conversion were those found in the riparian forest. The adoption of RR soybean and of other varieties 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 22.7 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 RR soybean in Brazil.

Figure 14. Summary of the environmental benefits resulting from RR soybean growing in Brazil. 2008/09 to 2017/18 crop year.



Observations:
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

Soybeans require a large scale of herbicide applications, due to the large quantity and diversity of weeds that attack this crop. The adoption of RR soybean enables the replacement of more toxic and harmful herbicides to the environment and human health by glyphosate, benefiting the preservation of natural resources and minimizing the impacts generated in the ecosystem.

The adoption of the RR soybean, with the use of the glyphosate, is an encouraging and propelling tool for conservationist practices like non-tillage planting, providing less revolving of the soil, and therefore, better preservation of the soil, lower emissions of greenhouse effect gases, and the use of products whose residual effect in the soil and water is lower when compared to products used in conventional soybean crops. Also, it enables better flexibility in production, demanding less time from producers, and optimizing the agricultural machinery.

The environmental loss from not adopting RR soybean, approached in this study, shows the high impact on the social environmental benefit caused by conventional soybean when compared to RR soybean, regarding the following factors: reduced water and diesel oil consumption, decrease in the CO_2 emissions, and decrease in the quantity of the active ingredient in the soil.

The investment in new studies to develop and launch other biotechnological traits for soybeans only tends to optimize the benefits described herein, thereby, creating the need for a favorable institutional environment that facilitates research as a means of optimizing the net results obtained from biotechnology.

Brazil is one of the strictest countries regarding environmental risk assessments of transgenic cultivars, where several safety measures are required to deter potential socio-environmental damages. This demonstrates that the transgenics released for use and commercialization are as safe as conventional cultivars, or even safer, as

the conventional ones are not subject to the same safety criteria.

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. Hélvio Felice, 119, Altamira

Uberlândia (MG) – CEP: 38411-414

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