The Chemical Company

Submission for
Verification of Eco-Efficiency Analysis Under
NSF Protocol P352, Part B

BiGro Colored Mulch Eco-Efficiency Analysis
Final Report - October 2014

Submitted by:

BASF Corporation
Product Stewardship
100 Park Avenue, Florham Park, NJ, 07932

Prepared by:

Thomas Laginess, Senior Sustainability Specialist, BASF

Laura Phillips, Product Development Manager, BASF

Alexander Gerding, Business Manager, BASF

Brent Packer, Product Development Specialist, BASF

Rebecca Lister, Product Development Specialist, BASF

Table of Contents

1. Purpose and Intent of this Submission

1.1. The purpose of this submission is to provide a written report of the methods and findings of BASF Corporation's "BiGro Colored Mulch Eco-Efficiency Analysis", with the intent of having it verified under the requirements of NSF Protocol P352, Part B: Verification of Eco-Efficiency Analysis Studies. The study evalautes the addition of an inoculant being called "BiGro" to colored mulch and the application of this colored mulch in landscaping. The BiGro technology allows for use benefits to plants such as less water and fertilizer needed for plants. The BiGro colored mulch is compared against colored mulch without this inoculant and benefits are quantified when using the BiGro technology. There are also two different processing equipments evaluated in this analysis. One of these processing equipments (Sahara) can incorporate the BiGro technology while the other equipment (Second Harvester) can not use the BiGro technology.

1.2. The BiGro Colored Mulch Eco-Efficiency Analysis was performed by BASF according to the methodology validated by NSF International under the requirements of Protocol P352. More information on BASF's methodology and the NSF validation can be obtained at http://www.nsf.org/info/eco_efficiency.

2. Content of this Submission

2.1. This submission outlines the study goals, procedures, and results for the BiGro Colored Mulch Eco-Efficiency Analysis study, which was conducted in accordance with BASF Corporation's Eco-Efficiency Analysis methodology. This submission will provide a discussion of the basis of the eco-analysis preparation and verification work.

2.2. As required under NSF P352 Part B, along with this document, BASF is submitting the final computerized model programmed in Microsoft® Excel. The computerized model, together with this document, will aid in the final review and ensure that the data and critical review findings have been satisfactorily addressed.

3. BASF's Eco-Efficiency Analysis Methodology

3.1. Overview:

BASF Eco-Efficiency Analysis involves measuring the life cycle environmental impacts and life cycle costs for product alternatives for a defined level of output. At a minimum, BASF Eco-Efficiency Analysis evaluates the environmental impact of the production, use, and disposal of a product or process in the areas of cumulative energy consumption, abiotic resource depletion, emissions, toxicity, land use, risk and water use. The Eco-Efficiency Analysis evaluates the life cycle costs associated with the product or process by calculating the costs related to, at a minimum, materials, labor, manufacturing, waste disposal, and energy.

3.2. Preconditions:

The basic preconditions of this Eco-Efficiency Analysis are that all alternatives that are being evaluated are being compared against a common functional unit or Customer Benefit (CB). This allows for an objective comparison between the various alternatives. The scoping and definition of the Customer Benefit are aligned with the goals and objectives of the study. Data gathering and constructing the system boundaries are consistent with the CB and consider the environmental and economic impacts of each alternative over their life cycle in order to achieve the specified CB. An overview of the scope of the environmental and economic assessments is defined below.

3.2.1. Environmental Impact Categories:

For BASF Eco-Efficiency Analysis environmental impact is characterized using thirteen categories, at a minimum, including: cumulative energy consumption, abiotic resource depletion, global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), photochemical ozone creation potential (POCP), water emissions, solid waste emissions, toxicity potential, land use, water use and risk potential. These are shown below in Figure 1. Categories shown in yellow represent the seven main environmental impacts that are used to construct the environmental fingerprint, categories in blue represent all elements of the emissions category, and categories in green show the elements evaluated within air emissions.

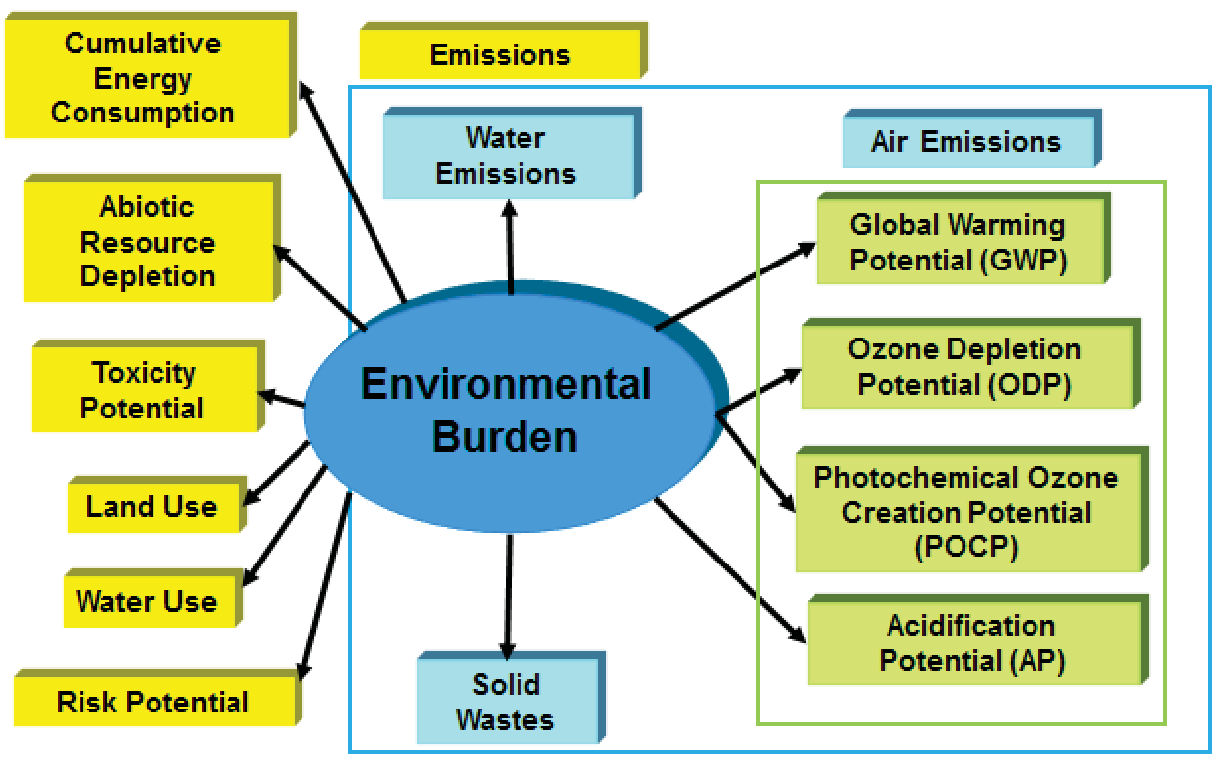

Figure 1. Environmental Impact categories

3.2.2. Economic Metrics:

It is the intent of the BASF Eco-Efficiency Analysis methodology to assess the economics of products or processes over their life cycle and to determine an overall total cost of ownership for the defined customer benefit ($/CB). The approaches for calculating costs vary from study to study. When chemical products of manufacturing are being compared, the sale price paid by the customer is predominately used. When different production methods are compared, the relevant costs include the purchase and installation of capital equipment, depreciation, and operating costs. The costs incurred are summed and combined in appropriate units (e.g. dollar or EURO) without additional weighting of individual financial amounts.

The BASF Eco-Efficiency Analysis methodology will incorporate:

- the real costs that occur in the process of creating and delivering the product to the consumer;
- the subsequent costs which may occur in the future (due to tax policy changes, for example) with appropriate consideration for the time value of money; and
- Costs having ecological aspect, such as the costs involved to treat wastewater generated during the manufacturing process.

In Eco-Efficiency Analysis costs are quantified for each alternative. These alternatives are then aggregated and totaled to show the total cost of each alternative as it relates to the common customer benefit (CB).

3.3 Work Flow:

A representative flowchart of the overall process steps and calculations conducted for this Eco-Efficiency Analysis is summarized in Figure 2 below.

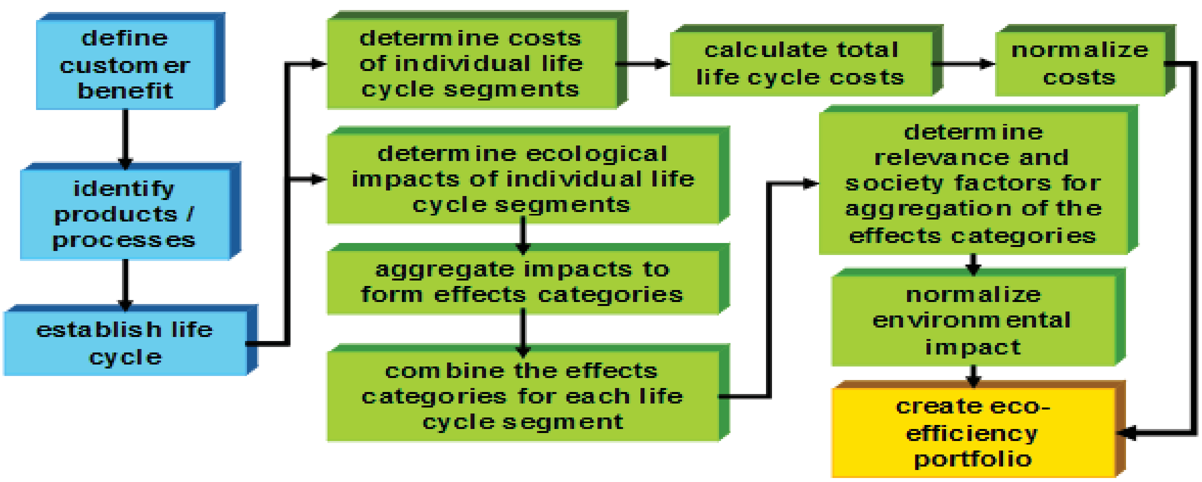

Figure 2. Overall process flow for BASF Eco-Efficiency Analysis methodology

4. Study Goals, Context and Target Audience

4.1. Study Goals:

The general goal defined for the BiGro Colored Mulch Eco-Efficiency Analysis was to quantify the benefits in sustainability performance of BiGro inoculant in colored mulch. This analysis evaluated colored mulch with and without the BiGro inoculant produced on the Sahara mixing equipment. There was also a third alternative, colored mulch without BiGro inoculant mixed on Second Harvester equipment, to show the impact of different mixing equipment. The Second Harvester equipment was not capable to utilize the BiGro inoculant in the mixing step due to deficiencies of the equipment. Study results will be used as the basis to guide further product development and marketing of such mulch to show the sustainable benefits of inoculants. As well as provide the necessary information to allow a clear comparison between the environmental life cycle and total cost impact aspects as measured by BASF's Eco-Efficiency Analysis tool. It will also facilitate the clear communications of these results to key stakeholders in the landscaping industry who are challenged with evaluating and making strategic decisions related to the sustainable development associated with landscaping. The specific sub-goals were to:

1. The study specifically compares colored mulch mixed on two different equipments, Sahara and Second Harvester.
2. To compare the amounts of inputs required by the BiGro mulch and non-BiGro mulch to achieve the same level of plant growth.

The BiGro Eco-Efficiency Analysis study used internal data from BASF experience with their mixing equipment and from plant test results done in the lab.

Study results will be used as the basis to guide further product development and marketing decisions that will result in more sustainable mulch. As well as provide the necessary information to allow a clear comparison between the environmental life cycle and total cost impacts as measured by BASF's Eco-Efficiency Analysis tool. It will also facilitate the clear communications of these results to key stakeholders in the landscaping industry who are challenged with evaluating and making strategic decisions related to more sustainable landscaping. The use of this information may be used for Leadership in Energy & Environmental Design (LEED) certification credits, but needs to be explored further.

4.2 Design Criteria:

The BiGro Colored Mulch study used data mainly documented by BASF and from BASF test results. The data in the study included general data such as production inputs, equipment, fuel, packaging, distribution/retail, use of the mulch and benefits of mulch (use phase). The study was technology driven and goals, target audience, and context for decision criteria used in this study are displayed in Figure 3. The geographical boundaries as related to the Customer Benefit are the use of mulch in commercial and residential landscaping applications within the United States of America.

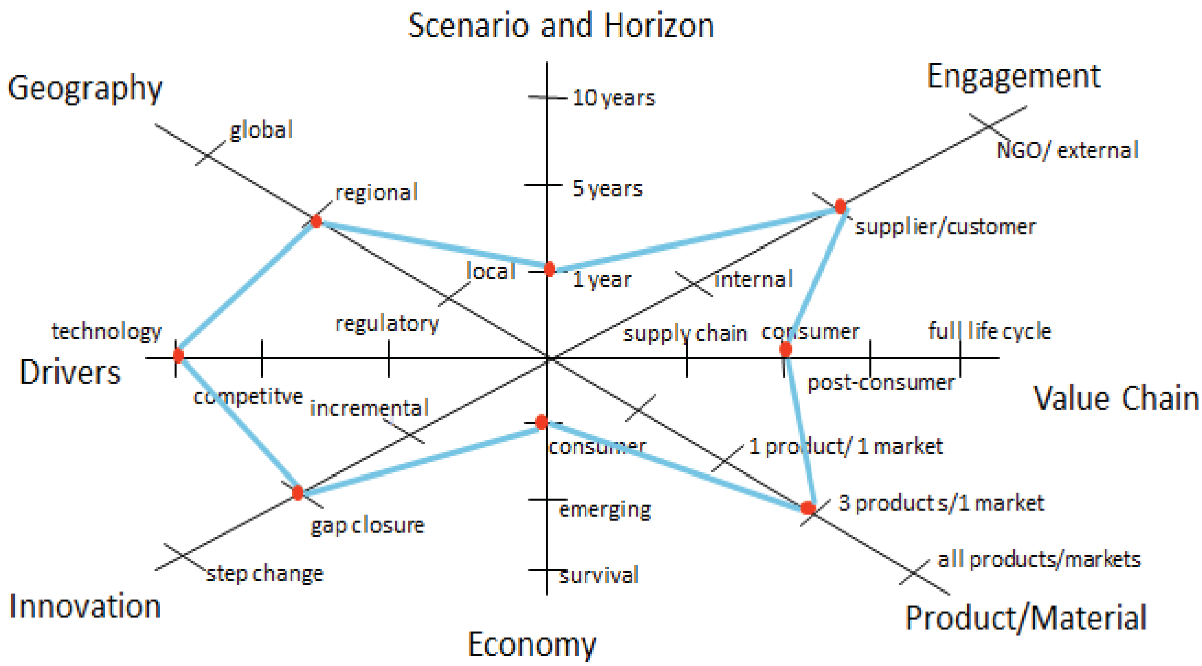

Figure 3. Context of BiGro Colored Mulch Eco-Efficiency Analysis

4.3. Target Audience:

The target audience for the study has been defined as landscaping professionals, household consumers and retail stores who sell mulch to the general public. The study will also be promoted to any trade associations or groups within North America who focus on landscaping or mulch. It is planned to communicate study results in marketing materials and possibly at trade conferences.

5. Customer Benefit, Alternatives and System Boundaries

5.1. Customer Benefit:

The Customer Benefit (CB) applied to all alternatives for the base case analysis is the production, use and benefits of one cubic yard of colored mulch, packaged in bags. This study specifically evaluates all input data that is needed to produce the CB, the packaging of the CB and the logistics and use of the CB by the end user. The justification for selecting this CB is because the unit is a widely accepted in the landscaping industry within the United States.

5.2. Alternatives:

The product alternatives compared as the Base Case under the BiGro Colored Mulch Eco-Efficiency Analysis study are (1) Colored mulch produced on Second Harvester equipment, (2) Colored mulch produced on Sahara equipment and (3) Colored mulch produced on Sahara equipment with BiGro inoculant added in the color mixing step. These alternatives in the Base Case support the study goals established in section 4.1 by comparing the equipment, comparing the inputs and evaluating the benefits of the BiGro inoculant. The study also looks at the electricity required for each of the mixing equipment, which is based on actual production data. These alternatives were selected as they represent technology advancement both in equipment and in inoculant technology. Figure 4 shows a representation of the CB and selected alternatives evaluated in this study.

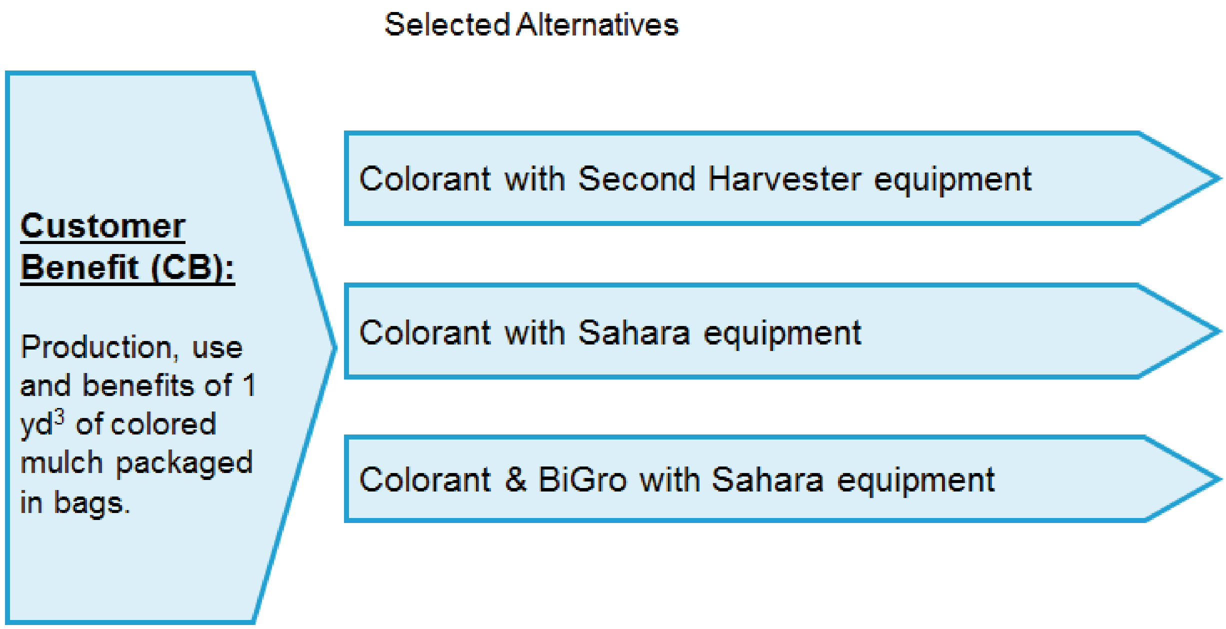

Figure 4. System Alternatives - BiGro Colored Mulch EEA

5.3. System Boundaries:

The system boundaries define the specific elements of the production, use and disposal phases that were considered as part of the analysis. In this study, only the production and use phases were analyzed and the disposal phase in all the alternatives was the degrdation of the mulch over time. The system boundaries for the three alternatives evaluated in this study are shown in Figures 5 and 6. Sections identified in gray (disposal) were excluded from the analysis as they represented identical end of life impacts for all alternatives. The justification for these boundaries is that these are the major impact categories for the production of mulch. The major differences between all the alternatives are colorant input formulas, mixing equipment energy, fuel use due to handling and benefits of mulch in the use phase.

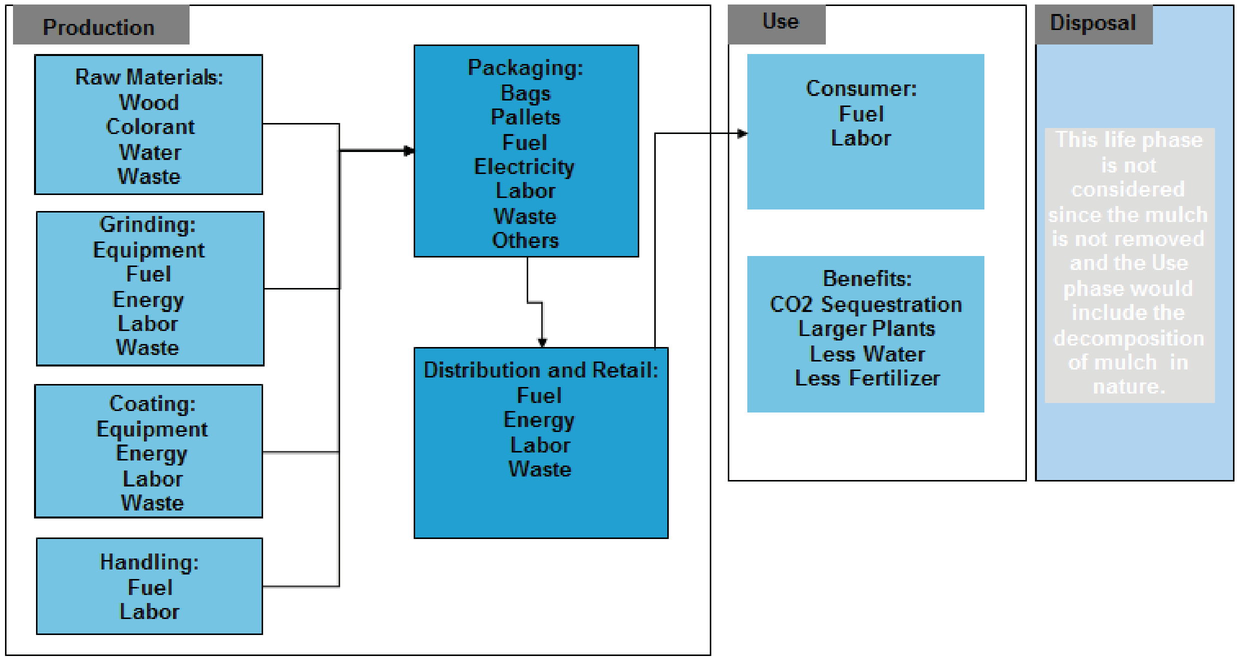

Figure 5. System boundaries - Colored Mulch

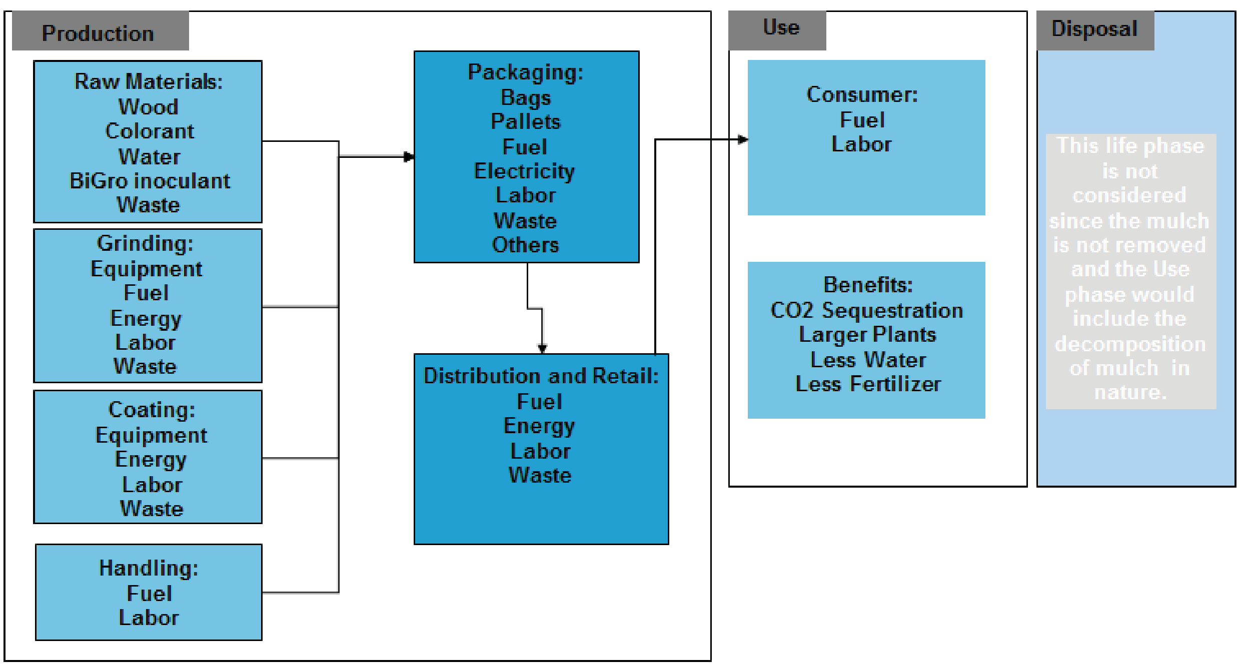

Figure 6. System boundaries - BiGro Colored Mulch

5.4 Scenario Analyses:

In addition to the base case analysis, an additional scenario was evaluated to determine the sensitivity of the studies final conclusions and results to key input parameters. Scenario#1 evaluates no benefits of the BiGro inoculant for fertilizer by putting the fertilizer needed for each alternative the same. The results of the Scenario are discussed in Section 8.4:

5.4.1. Scenario #1: No fertilizer benefits with BiGro inoculant.

5.4.2. Scenario #2: The same input amounts to make the colored mulch.

6. Input Parameters and Assumptions

6.1. *Input Parameters*:

A comprehensive list of input parameters are included for this study and considered all relevant material and operational characteristics. The data source for this study was BASF's North America Agricultural Products Division. The input values from this data are absolute values and the data is from the mixed formulas as shown in Table 1. The performance data is information gathered from test results showing the enhanced performance of plants when using BiGro inoculant with colored mulch.

The BiGro Colored Mulch study evaluates the production of the Customer Benefit (CB), which is one cubic yard of colored mulch used in landscaping, supplied in bags and the eventual benefit to plants. In the application of colored mulch, the eventual degradation of the colored mulch to compost is assumed and additional mulch would be applied the next year or the year after. The input amounts used per yd^3 colored mulch are shown in Table 1.

For the purposes of this study, most of the inputs evaluated such as wood, wood grinding, bags, pallets, etc are the same and the difference between the alternatives is the colored formula for the mixing equipment, the use of BiGro inoculant and the benefits of using or not using the BiGro inoculant. In comparing the different mixing equipments (Sahara and Second Harvester) the amount of water that is needed for the colorant mixing is less with the Sahara equipment. Because of the difference in water input in the colored mixing, the weight of the final product mixed with Second Harvester will be heavier since the CB defines a 1 yd^3 volume.

For the benefits of the BiGro inoculant, less water and fertilizer is needed when using the BiGro. The BiGro technology allows plants to survive with less water because the BiGro technology contains a water management component in the formulation. This component helps the mulch to hold more water and hold that water longer resulting in higher soil moisture contents. The higher soil moisture contents create an environment that requires less watering, conserves water and the microbial provides the increased plant vigor. From BASF test results, the microbial in the BiGro improves the availability of nutrients in the soil for increase uptake into the plant, thus requiring less fertilizer with BiGro. The application rate of the mulch and the number of plants that are affected by the mulch applications are the same.

Plant vigor is measured by plant dry mass, plant height, and total plant nutrients (N, P, and K). The plant dry mass is a measure of the dry mass of the plant from the soil interface to the top. The plant height is a measure of the height from the soil interface to the top. The total plant nutrients are a measure of the amount of N, P, and K that are present in the plant at the time of harvest.

The eco-toxicity of the mulch was considered for the study but there was no eco-toxicity of the colored mulch with or without the BiGro inoculant. For the toxicity value, only human toxicity was evaluated for both the production and use of the colored mulch.

The assumptions in the study were;

The same colored mulch is analyzed for each of the alternatives. The colored mulch evaluated is the average information from red, black and brown mulch, which includes a combination of iron oxide and carbon black.

The applied thickness for the mulch is 3 inches thick, so 1 yd^3 of mulch will cover 108 square feet. In this 1 square foot 1 plant is planted in this area, so 108 plants benefit from 1 yd3.

The weight of wood used is set at 500 lbs/ yd^3 for all the alternatives. The difference in the alternatives is in the raw materials to add the colorant and water amount needed for mixing equipment.

For all the alternatives the 1 yd^3 of mulch is packaged in 2 ft^3 bags, so 13.5 bags would be used.

The plant benefits analyzed from the use of the mulch were carbon sequestration, plant residue, water savings, fertilizer benefits.

The transportation fuel needed is based on the total weight of the final 1 yd^3 of mulch. The weights for the different equipments were established as:

- Second Harvester = 322.9 kg/ yd^3
- Sahara = 267.9 kg/ yd^3
- Sahara with BiGro = 268.0 kg/ yd^3

Fuel consumption due to the weight of the mulch is calculated for transportation and handling in the complete process. The distances used for this analysis are:

- Production to store 320 km
- Handling production & distributor 1 km
- Store to consumer 10 km

Diesel and gasoline cost is $3.50/gal.

Liquid propane (LP) cost is $2.25/gal.

Table 2 shows the input amounts for distribution, use of mulch and use benefits of the mulch.

Table 1: Input data usage rates per cubic yard for Base Case BiGro Colored Mulch.

Base Case

Mulch Inputs	Colored - Second Harvester	Colored - Sahara	BiGro Colored - Sahara	Units:
Production				
Production Equipment	**Harvester**	**Sahara PRO**	**Sahara PRO**	
Wood Stock Material	500.000	500.000	500.000	lbs/yd^3
Production Equipment - Wood Grinder	0.0000067	0.0000067	0.0000067	lbs/yd^3
Wood Grinder - Fuel Consumption	0.0766667	0.0766667	0.0766667	gal/yd^3
Production Equipment - Front End Loader	0.0000067	0.0000067	0.0000067	lbs/yd^3
Front End Loader - Fuel Consumption (grinding)	0.033	0.033	0.033	gal/yd^3
Front End Loader - Operator Labor (grinding)	0.003	0.003	0.003	hrs/yd^3
Production Equipment - Coating System	0.0000067	0.0000067	0.0000067	lbs/yd^3
Coating System Electricity Consumption	0.149	0.287	0.287	kWh/yd^3
Maintenance Parts & Labor - Coating System	0.00035	0.00021	0.00021	hrs/yd^3
Front End Loader - Fuel Consumption (coating)	0.067	0.033	0.033	gal/yd^3
Front End Loader - Operator Labor (coating)	0.007	0.003	0.003	hrs/yd^3
Colorant	3.160	2.850	2.850	lbs/yd^3
BiGRO	0.000	0.000	0.250	lbs/yd^3
Water	25.000	10.500	10.500	gal/yd^3
Additives	0.121	0.109	0.109	lbs/yd^3
Mulch Packaging	**Bag**	**Bag**	**Bag**	
Bag	1.013	1.013	1.013	lbs/yd^3
Packing Equipment - Bagging/Palletizing System	0.000	0.000	0.000	lbs/yd^3
Bagging/Palletizing System - Electricity Consumption	0.556	0.556	0.556	kWh/yd^3
Bagging/Palletizing System - Operator Labor	0.044	0.044	0.044	hrs/yd^3
Pallet	0.193	0.193	0.193	$pallet/yd^3$
Stretch wrapping	0.101	0.101	0.101	lbs/yd3
Pallet Handling Equipment - Fork Truck	0.000	0.000	0.000	lbs/yd^3
Fork Truck - Fuel Consumption	0.005	0.005	0.005	gal/yd^3
Fork Truck - Operator Labor	0.003	0.003	0.003	hrs/yd^3

Table 2: Input data values for distribution and use of BiGro Colored Mulch.

Base Case				
Mulch Inputs	**Colored - Second Harvester**	**Colored - Sahara**	**BiGro Colored - Sahara**	**Units:**
Distribution and Retail				
Transportation (Fuel)	1.550	1.286	1.286	gal/yd^3
Handling (Fuel)	0.005	0.004	0.004	gal/yd^3
Shelf Space (Energy)	0.504	0.504	0.504	MJ/yd^3
Shelf Space (Area)	3.857	3.857	3.857	ft^2/yd^3
Labor	0.007	0.007	0.007	$hours/yd^3$
Use of Mulch				
Handling (Fuel)	0.000	0.000	0.000	gal/yd^3
Transportation (Fuel)	0.048	0.040	0.040	gal/yd^3
Labor	0.675	0.675	0.675	hrs/yd^3
Use Benefits:				
Plant mass - oxygen output	97.710	97.710	115.540	$g\ O_2/yd^3$
Plant mass - carbon dioxide uptake	134.352	134.352	158.868	$g\ CO_2/yd^3$
Plant mass - plant residue (direct N20)	3229.200	3229.200	3229.200	$g\ C/yd^3$
Water needed (benefit)	228.622	228.622	202.177	gal/yd^3
N-fertilizer benefit	2.250	2.250	2.250	lbs/yd^3
P-fertilizer benefit	0.750	0.750	0.750	lbs/yd^3
K-fertilizer benefit	0.300	0.300	0.300	lbs/yd^3
N-fertilizer needed per plant	1.998	1.998	0.999	lbs/yd^3
P-fertilizer needed per plant	0.626	0.626	0.313	lbs/yd^3
K-fertilizer needed per plant	1.264	1.264	0.632	lbs/yd^3

6.2. Cost Inputs

6.2.1. User Costs

User costs were evaluated for each alternative based on the individual mulch input materials, operational inputs, packaging inputs, distribution, handling, labor, shelf space, use benefits. Table 3 and 4 lists the total cost including fixed cost and the operating costs for all of the process steps.

Table 3: Input data costs per cubic yard for Base Case BiGro Colored Mulch.

Base Case

Mulch Inputs	**Colored - Second Harvester**	**Colored - Sahara**	**BiGro Colored - Sahara**	**Units:**
Production				
Production Equipment	Harvester	Sahara PRO	Sahara PRO	
Wood Stock Material	$5.00	$5.00	$5.00	US$/yd^3
Production Equipment - Wood Grinder	$0.33	$0.33	$0.33	US$/yd^3
Wood Grinder - Fuel Consumption	$0.27	$0.27	$0.27	US$/gal
Production Equipment - Front End Loader	$0.11	$0.11	$0.11	US$/yd^3
Front End Loader - Fuel Consumption (grinding)	$0.12	$0.12	$0.12	US$/gal
Front End Loader - Operator Labor (grinding)	$0.05	$0.05	$0.05	US$/yd^3
Production Equipment - Coating System	$0.06	$0.25	$0.25	US$/yd^3
Coating System Electricity Consumption	$0.01	$0.03	$0.03	US$/kWh
Maintenance Parts & Labor - Coating System	$0.07	$0.06	$0.06	US$/yd^3
Front End Loader - Fuel Consumption (coating)	$0.23	$0.12	$0.12	US$/gal
Front End Loader - Operator Labor (coating)	$0.10	$0.05	$0.05	US$/yd^3
Colorant	$2.43	$2.19	$2.19	US$/lbs
BiGRO	$0.00	$0.00	$1.38	US$/lbs
Water	$0.05	$0.02	$0.02	US$/gal
Additives	$0.00	$0.00	$0.00	US$/lbs
			13.5	2 ft3/yd^3
Mulch Packaging	Bag	Bag	Bag	
Bag	$3.92	$3.92	$3.92	US$/yd^3
Packing Equipment - Bagging/Palletizing System	$0.30	$0.30	$0.30	US$/yd^3
Bagging/Palletizing System - Electricity Consumption	$0.06	$0.06	$0.06	US$/kWh
Bagging/Palletizing System - Operator Labor	$0.53	$0.53	$0.53	US$/yd^3
Pallet	$1.45	$1.45	$1.45	US$/yd^3
Stretch wrapping	$0.10	$0.10	$0.10	US$/yd^3
Pallet Handling Equipment - Fork Truck	$0.03	$0.03	$0.03	US$/yd^3
Fork Truck - Fuel Consumption	$0.01	$0.01	$0.01	US$/gal
Fork Truck - Operator Labor	$0.03	$0.03	$0.03	US$/yd^3

Table 4: Input data costs for distribution and use of BiGro Colored Mulch.

Base Case				
Mulch Inputs	**Colored - Second Harvester**	**Colored - Sahara**	**BiGro Colored - Sahara**	**Units:**
Distribution and Retail				
Transportation (Fuel)	$5.42	$4.50	$4.50	US$/yd^3
Handling (Fuel)	$0.01	$0.01	$0.01	US$/yd^3
Shelf Space (Energy)	$0.05	$0.05	$0.05	US$/yd^3
Shelf Space (Area)	$0.00	$0.00	$0.00	US$/yd^3
Labor	$0.07	$0.07	$0.07	US$/yd^3
Use of Mulch				
Handling (Fuel)	$0.00	$0.00	$0.00	US$/yd^3
Transportation (Fuel)	$0.17	$0.14	$0.14	US$/yd^3
Labor	$6.75	$6.75	$6.75	US$/yd^3
Use Benefits:				
Water needed (benefit)	$0.46	$0.46	$0.40	US$/yd^3
N-fertilizer benefit	$1.02	$1.02	$1.02	US$/lbs
P-fertilizer benefit	$1.08	$1.08	$1.08	US$/lbs
K-fertilizer benefit	$1.20	$1.20	$1.20	US$/lbs
N-fertilizer needed per plant	$1.02	$1.02	$1.02	US$/lbs
P-fertilizer needed per plant	$1.08	$1.08	$1.08	US$/lbs
K-fertilizer needed per plant	$1.20	$1.20	$1.20	US$/lbs

7. Data Sources

7.1. Environmental:

The environmental impacts for the production of the three alternatives were calculated from eco-profiles (a.k.a. life cycle inventories) for the individual components and for fuel usage. Life cycle inventory data for these eco-profiles were from several data sources, including BASF specific manufacturing data and from publicly available information. Overall, the quality of the data was considered medium-high to high. None of the eco-profile data was considered to be of low data quality. A summary of the eco-profiles is provided in Table 5.

Table 5: Summary of eco-profiles used in the BiGro Colored Mulch Eco-Efficiency Analysis

Eco-Profile	Source, Year	Comments
Wood chips waste	DE Avg., 2003	BEST database[1]
Production equipment	RER Avg., 2006	BEST database
Diesel Use - US	US Avg., 1999	BEST database
Colorant	BASF Avg., 2013	BEST database
BiGro inoculant	BASF Avg., 2013	BEST database
Water	BASF data, 2010	BEST database
Additives	DE Avg., 1998	BEST database
LDPE Bags	DE Avg., 2005	BEST database
Electricity	US Avg., 1999	BEST database
Pallet production	GB Avg., 1996	BEST database
Propane production/deliver	US Avg., 1999	BEST database
Gasoline production/deliver	US Avg., 1999	BEST database
Urea Fertilizer	Agrium, 2005	BEST database
MAP Fertilizer	U of Minnesota., 2010	BEST database
K-Fertilizer	DE Avg., 1997	BEST database
BASF data sources are internal data, while the others are external to BASF. Internal data is confidential to BASF; however, full disclosure can be provided to NSF International for verification purposes.		

7.2. Amounts and Costs:

A summary of the data sources for the environmental amounts and economic data of the individual components are provided in Table 6. All of this information was obtained from the BASF Agricultural Products Division.

Table 6: Summary of data sources for environmental and economic data

Base Case	
Mulch Inputs	**Source:**
Production	
Wood Stock Material	BASF Technical Sevices Industry Knowledge
Production Equipment - Wood Grinder	BASF Technical Sevices Industry Knowledge
Wood Grinder - Fuel Consumption	BASF Technical Sevices Industry Knowledge
Production Equipment - Front End Loader	BASF Technical Sevices Industry Knowledge
Front End Loader - Fuel Consumption (grinding)	BASF Technical Sevices Industry Knowledge
Front End Loader - Operator Labor (grinding)	BASF Technical Sevices Industry Knowledge
Production Equipment - Coating System	BASF Technical Sevices Industry Knowledge
Coating System Electricity Consumption	BASF Technical Sevices Industry Knowledge
Maintenance Parts & Labor - Coating System	BASF Technical Sevices Industry Knowledge
Front End Loader - Fuel Consumption (coating)	BASF Technical Sevices Industry Knowledge
Front End Loader - Operator Labor (coating)	BASF Technical Sevices Industry Knowledge
Colorant	BASF Technical Sevices Industry Knowledge
BiGRO	BASF Technical Sevices Industry Knowledge
Water	BASF Technical Sevices Industry Knowledge
Additives	BASF Technical Sevices Industry Knowledge
Mulch Packaging	
Bag	BASF Technical Sevices Industry Knowledge
Packing Equipment - Bagging/Palletizing System	BASF Technical Sevices Industry Knowledge
Bagging/Palletizing System - Electricity Consumption	BASF Technical Sevices Industry Knowledge
Bagging/Palletizing System - Operator Labor	BASF Technical Sevices Industry Knowledge
Pallet	BASF Technical Sevices Industry Knowledge
Stretch wrapping	BASF Technical Sevices Industry Knowledge
Pallet Handling Equipment - Fork Truck	BASF Technical Sevices Industry Knowledge
Fork Truck - Fuel Consumption	BASF Technical Sevices Industry Knowledge
Fork Truck - Operator Labor	BASF Technical Sevices Industry Knowledge
Distribution and Retail	
Transportation (Fuel)	US Transportation Energy Data Book
Handling (Fuel)	US Transportation Energy Data Book
Shelf Space (Energy)	Calculated Data based on eco-profile
Shelf Space (Area)	Calculated Data
Labor	BASF Technical Sevices Industry Knowledge
Use of Mulch	
Handling (Fuel)	US Transportation Energy Data Book
Transportation (Fuel)	US Transportation Energy Data Book
Labor	BASF Technical Sevices Industry Knowledge
Use Benefits:	
Time of use	BASF Technical Sevices Industry Knowledge
Plant mass - oxygen output	BASF Technical Sevices Industry Knowledge
Plant mass - carbon dioxide uptake	BASF Technical Sevices Industry Knowledge
Plant mass - plant residue (direct N20)	BASF Technical Sevices Industry Knowledge
Water needed (benefit)	BASF Technical Sevices Industry Knowledge
N-fertilizer benefit	Recycled Organic Unit – U. of NSW, USDA
P-fertilizer benefit	Recycled Organic Unit – U. of NSW, USDA
K-fertilizer benefit	Recycled Organic Unit – U. of NSW, USDA
N-fertilizer needed per plant	BASF Technical Sevices Industry Knowledge
P-fertilizer needed per plant	BASF Technical Sevices Industry Knowledge
K-fertilizer needed per plant	BASF Technical Sevices Industry Knowledge

8. Eco-Efficiency Analysis™ Results and Discussion

8.1. Environmental Impact Results:

The environmental impact results for the BiGro Colored Mulch Eco-Efficiency Analysis are generated as defined in Section 3.2.1., Environmental Burden Metrics. The results discussed in Section 8.1.1 through 8.3 (depicted in Figures 7 through 24) are for the Base Case only and do not represent any of the Scenarios.

8.1.1. Cumulative energy consumption:

Energy use is dominated by the mulch production and the distribution and retail. The BiGro alternative was the best out of all alternatives. In mulch production the majority of the energy use is from the processing of the wood to wood chips. The difference in the amount of colorant used with the different mixing equipments is the difference in energy between alternatives. The distribution and retail energy demand is due to the fuel use and the weight differences between the alternatives. The main difference between the alternatives is from the benefits of the use of the BiGro inoculant. Energy demand was critical to the study having a calculation factor of 16%. Figure 7 shows the key drivers for the cumulative energy consumption. Non-renewable energy sources were analyzed in this study, but made up only 13% of the total energy sources.

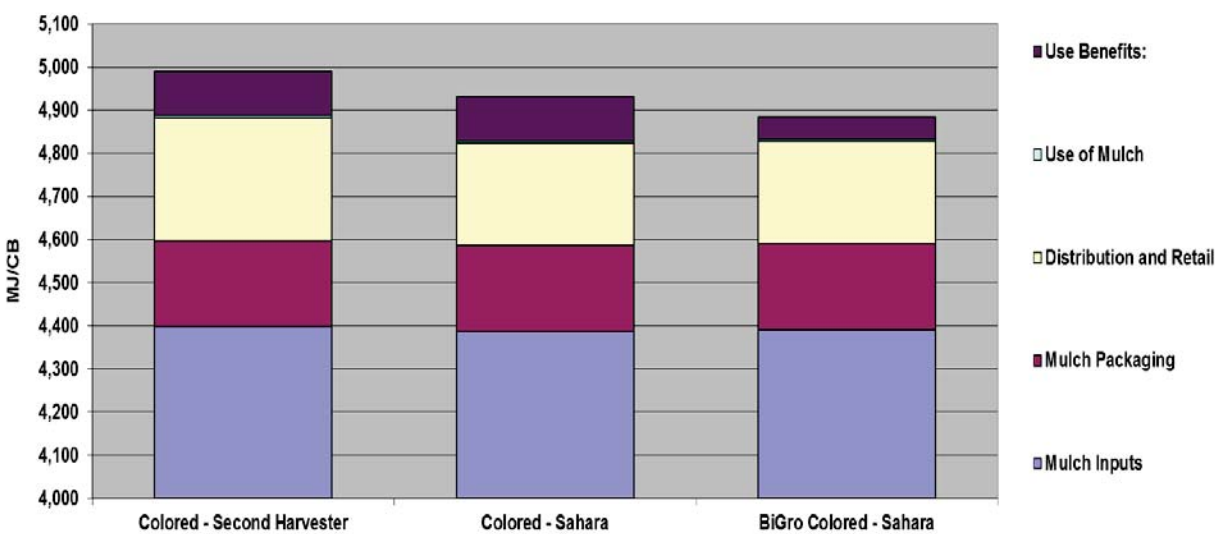

Figure 7. Cumulative energy consumption

8.1.2. Abiotic resource depletion:

Figure 8 shows that the key driver for the raw material or abiotic resource depletion is dominated by the mulch production inputs and the fuel used in the transportaion of the mulch due to weight differences. The BiGro alternative was the best out of all alternatives. The differences between the alternatives is due to the fuel used in the transportation, with a slight diffences between the alternatives in the production due to raw materials and processing conditions and from the benefits of using the BiGro inoculant. In all of the alternatives, the amount of resources used is very small for the defined Customer Benefit of 1 yd3 of mulch. Abiotic depletion was minor to the study having a calculation factor of 3%

Per the BASF Eco-Efficiency Analysis™ methodology, individual raw materials are weighted according to their available reserves and current consumption profile. These weighting factors are appropriate considering the context of this study. Oil resources are the main contributor due to the fuel use differences between the alternatives. Figure 9 shows the overall use of individual raw materials for the colored mulch production.

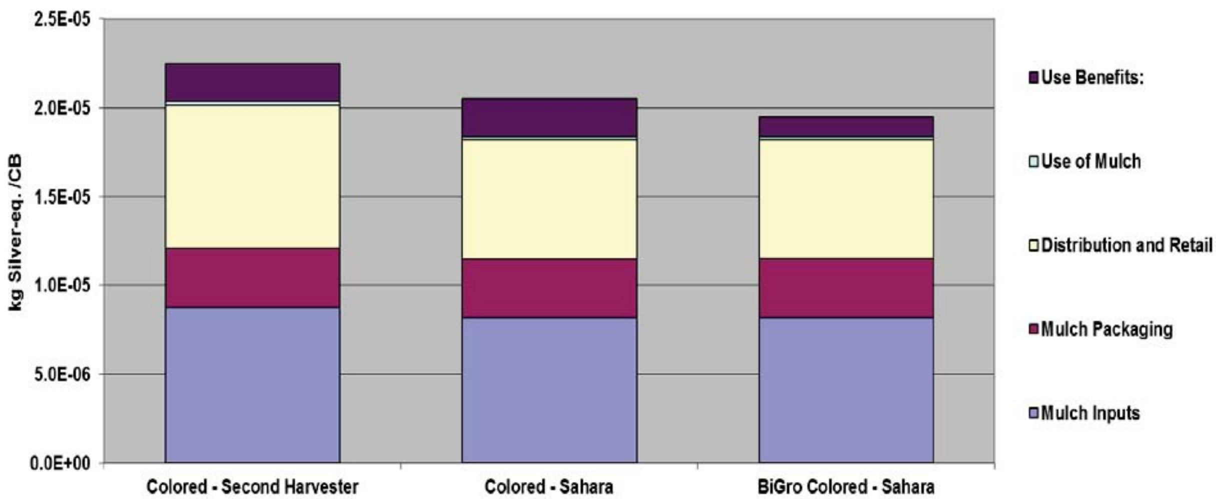

Figure 8. Abiotic resource depletion by Module

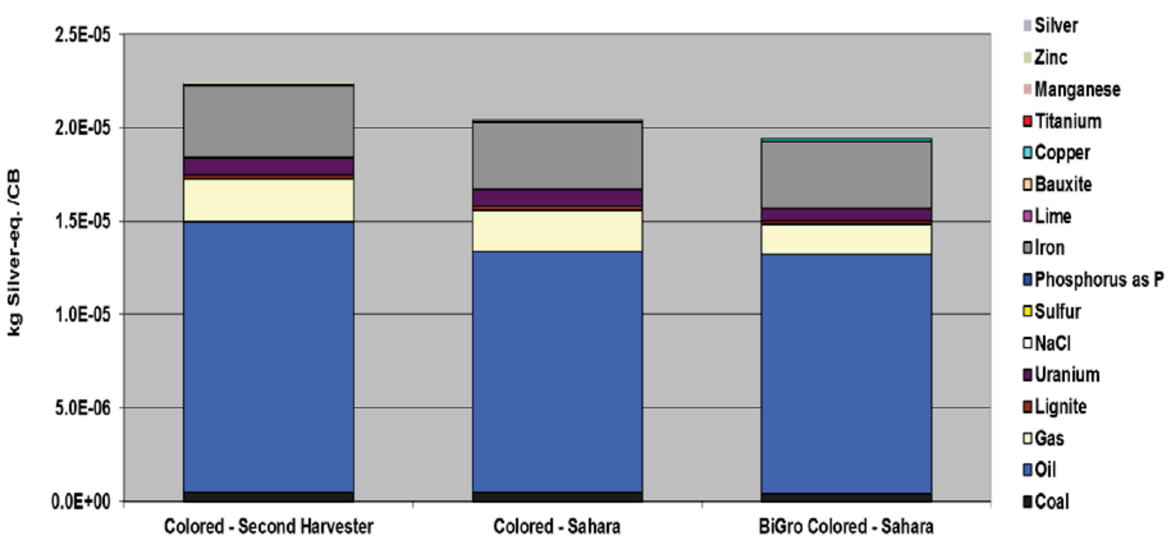

Figure 9. Abiotic resource depletion by Type

8.1.3. Air Emissions:

8.1.3.1. Global Warming Potential (GWP): GWP emissions are dominated by the distribution and retail fuel use in the transportation, this is due to the difference in weights of the altertatives. The BiGro Colored-Sahara alternative was the best out of all the alternatives, followed by the Colored- Sahara alternative. The difference between these two alternatives is mainly from the benefits with using the BiGro inoculant. There was also GWP from the production of the mulch and from the packaging. The main advantage of the BiGro Colored-Sahara alternative is from the benefits of less fertilizer and the savings in emissions from this. GWP was minor to the study having a calculation factor of 2%. Figure 10 shows the overall GWP emission for colored mulch production.

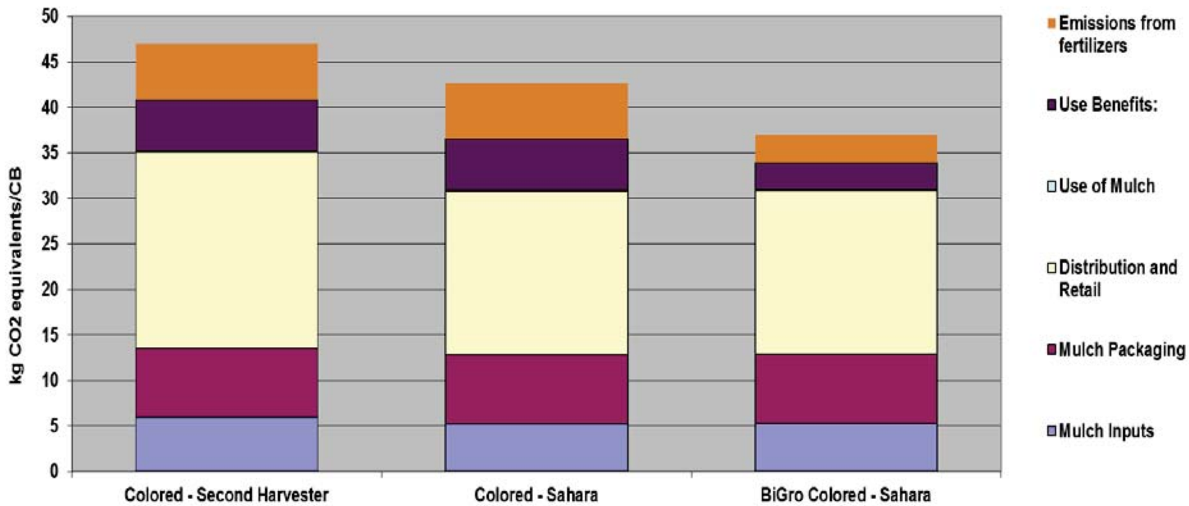

Figure 10. Global warming potential

8.1.3.2. Photochemical ozone creation potential (POCP, smog): Emissions with Photochemical Ozone Creation Potential are dominated by the distribution and retail from the fuel use. This is due to the difference in weights of the alternatives. The BiGro Colored-Sahara alternative and the Colored-Sahara alternative were very similar for POCP, with a slight advantage to BiGro from the benefits of using the BiGro inoculant. The Second Harvester alternative had a higher weight, thus more in distribution and retail. There was also POCP from the production of the mulch and a small amount from the packaging. POCP had minor impact to the study having a calculation factor of 2% and the results are shown in Figure 11.

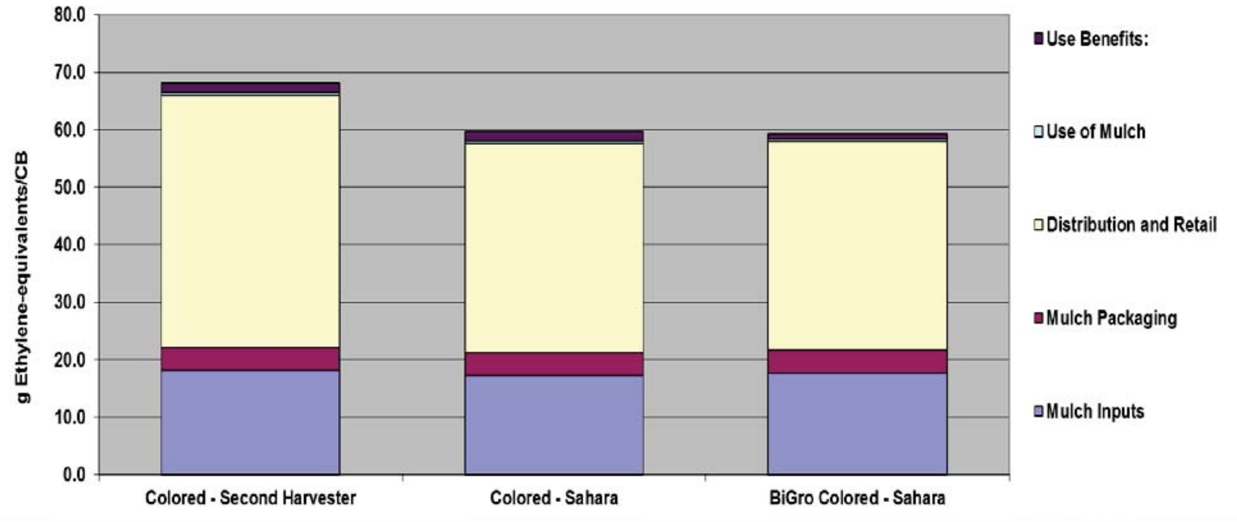

Figure 11. Photochemical ozone creation potential

8.1.3.3. Ozone depletion potential (ODP): Overall, the ODP emissions are very small having a calculation factor of 0.2%. The ODP is mainly from the mulch production and all the alternatives were similar for ODP emissions. The BiGro Colored-Sahara alternative has a slight advantage to the other alternatives from the benefits of using the BiGro inoculant. There was also a very small amount of ODP from the packaging. This environmental category results are shown in Figure 12.

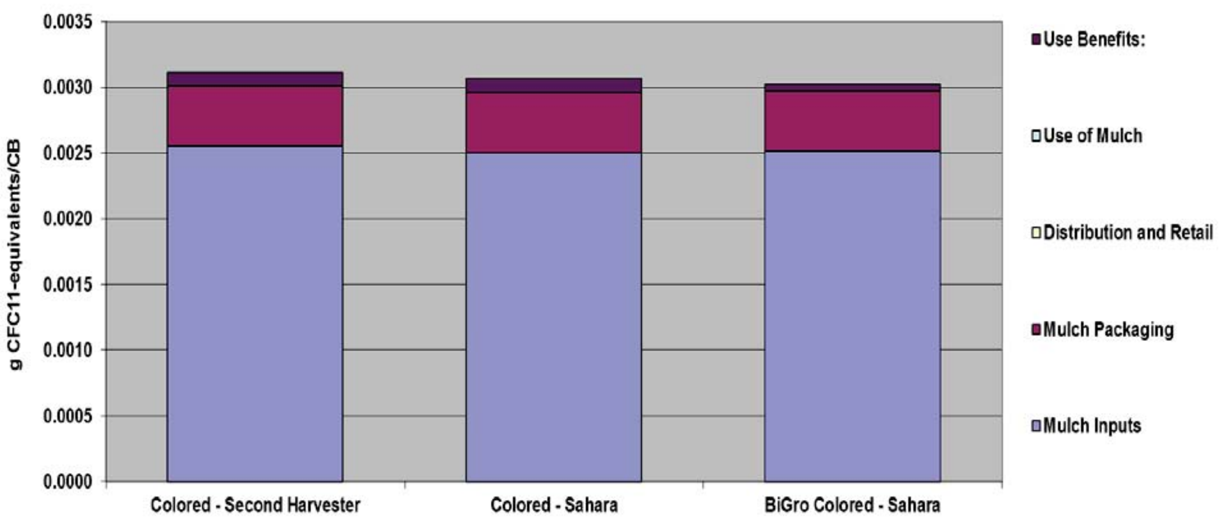

Figure 12. Ozone depletion potential

8.1.3.4. Acidification potential (AP): AP emissions are dominated by the distribution and retail from the fuel use and this is due to the difference in weights of the alternatives. The BiGro Colored-Sahara alternative was the best out of all alternatives, followed by the Colored-Sahara alternative. The difference between these two alternatives is mainly from the benefits with using the BiGro inoculant. There was also AP from the production of the mulch and from the packaging. AP had minor impact to the study having a calculation factor of 3% and the results can be seen in Figure 13.

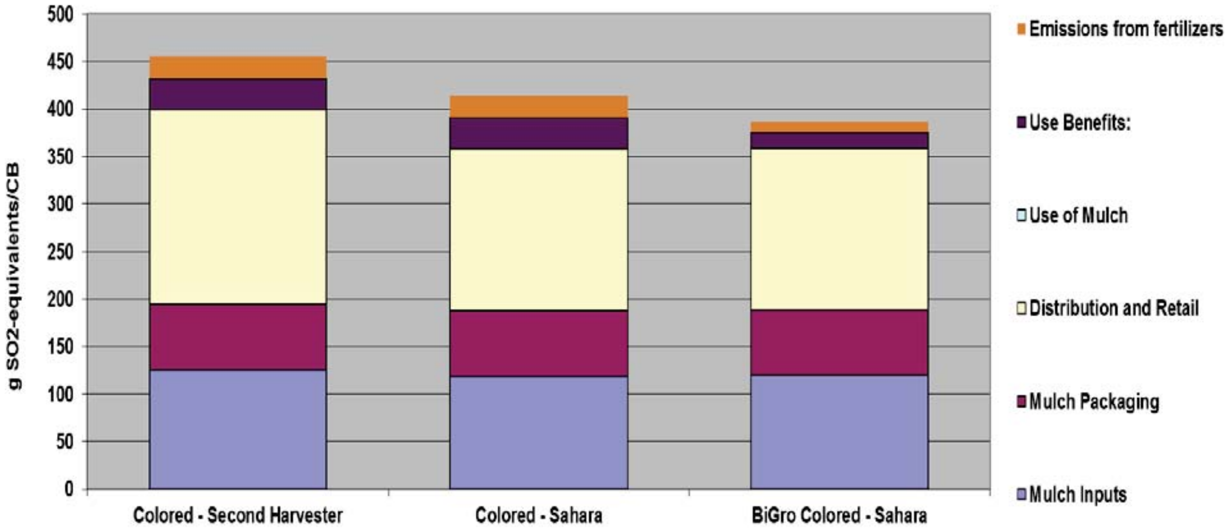

Figure 13. Acidification potential

Figure 14 below, shows the relative impacts of the four air emissions: GWP, POCP, ODP and AP. These values are normalized and weighted based on the calculation factors (see Figure 28 for the calculation factor percentage). The calculation factor is a calculation of the relative environmental factors and the social weighting factors.

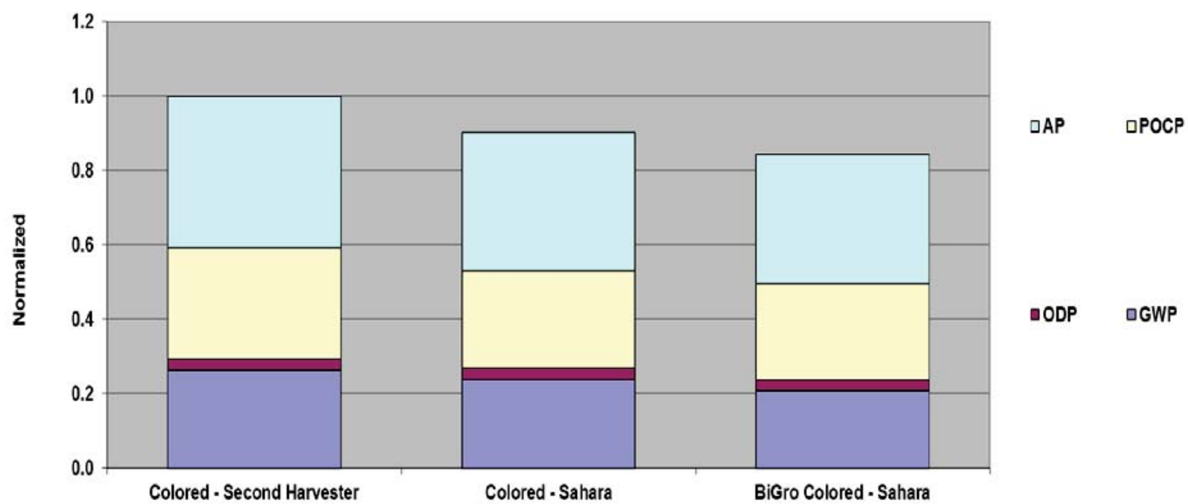

Figure 14. Overall Relative Inpacts of Air Emissions

8.1.4. Water emissions:

The impact from water emissions (Grey water) is calculated using a critical volume approach to the toxicity of the raw materials. The alternative with BiGro Colored-Sahara has the least amount of water emissions due to the benefits of reduced fertilizer from using the BiGro inoculant. The main substances of concern emitted from fertilizers are leaching through the soil and from heavy metals. According to literature sources[2] mineral fertilizers contain a substantial amount of heavy metals (up to 2 g per kg). A worst case scenario was used here. There is also benefit from the N- and P- fertilizer emissions since less fertilizer is needed in the BiGro alternative. Up to 10% of fertilizer N (depending on climate and region) ends up as a water emission and up to 1% of fertilizer P ends up as water emission.[3] Both the N-water-emissions and P-water-emissions are included as part of the Eco-Efficiency Analysis base case. There is some water emissions due to the production of the mulch and a little from the packaging. Water emission has a major impact to the study having a calculation factor of 36%; Figure 15 displays the water emissions of this study.

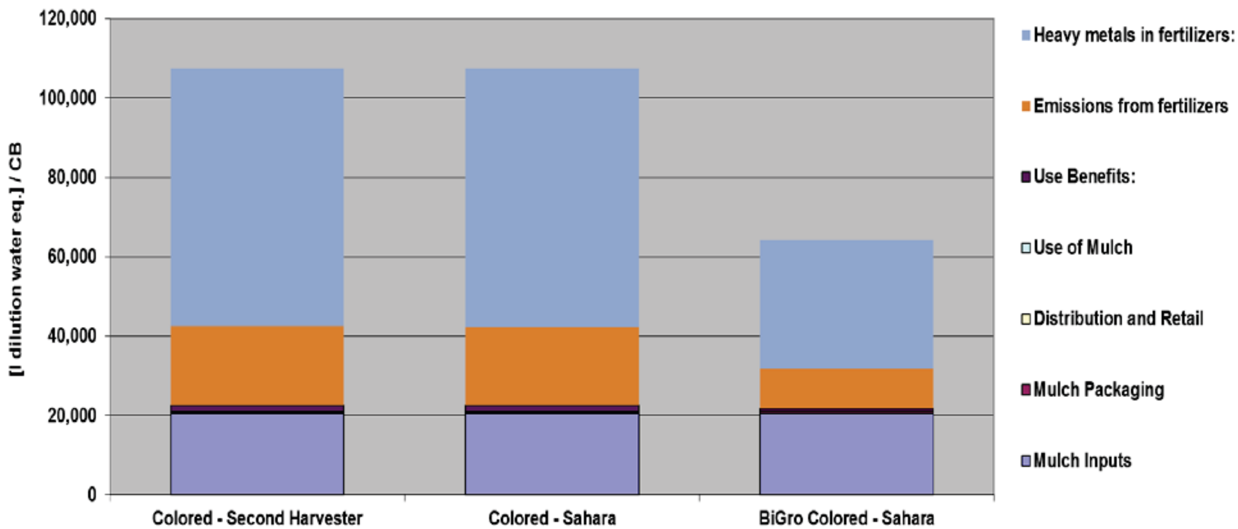

Figure 15. Water emissions

8.1.5 Solid waste generation:

The impact from solid wastes is dominated by the distribution and retail from the fuel use; this is due to the difference in weights of the alternatives. The BiGro Colored-Sahara alternative and the Colored-Sahara alternative were very similar for solid waste, with a slight advantage to BiGro from the benefits of using the BiGro inoculant. The Second Harvester alternative had a higher weight, thus more waste in distribution and retail. There was also solid waste from the production of the mulch and from the packaging. Solid waste has a minor impact to the study having a calculation factor of 1.8%. These waste values include municipal, hazardous, construction and mining waste. Hazardous waste is generated from production of fertilizers and diesel fuel. Figure 16 displays the solid waste emissions for the three alternatives.

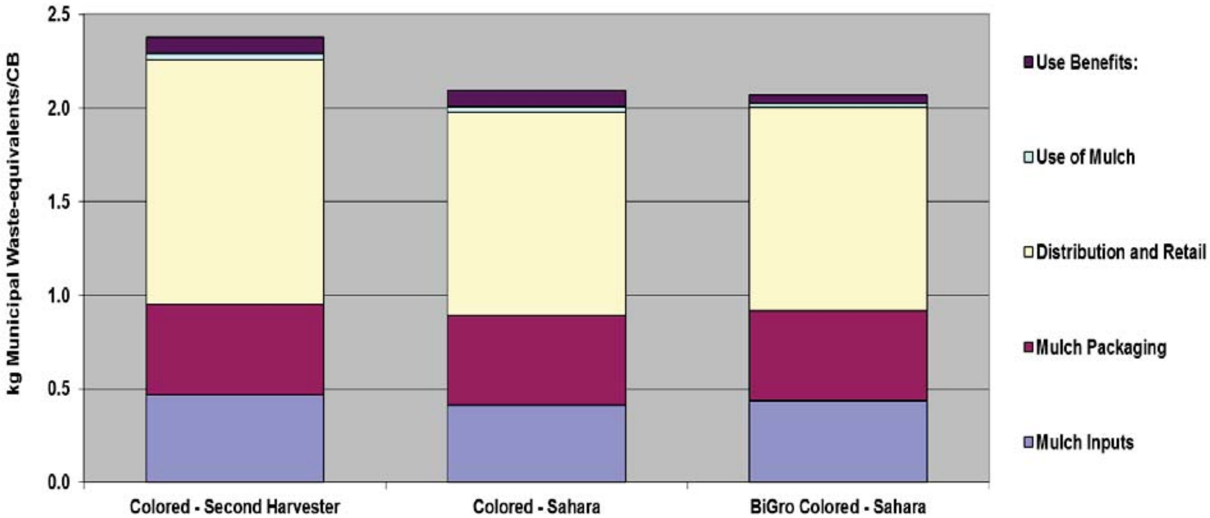

Figure 16. Solid waste generation

8.1.6 Land use:

As displayed in Figure 17, land use is assessed for each alternative. The land use impact assessment takes into account an Ecosystem Damage Potential[4] (EDP), where land use is evaluated by land occupation and land transformation metrics. The land use impact assessment takes into account the damage functions and generic characterization factors for quantifying damages to ecosystems from land occupation and land transformation. EDP is based on an assessment of the impacts of land use on species diversity. This land use methodology is accepted by LCA organizations.

Land use is dominated by the mulch production with a little impact from the distribution and retail, packaging and use benefits. The alternative with BiGro Colored-Sahara has a slight advantage over all the other alternatives even though there is additional input materials used in the BiGro inoculant process. The slight benefit comes from the benefits of using BiGro in the mulch application. The land use impact on the study is very small having a calculation factor of 2%. The land use impact assessment takes into account damage functions and generic characterization factors for quantifying damages to ecosystems from land occupation and land transformation. EDP is based on an assessment of the impacts of land use on species diversity.

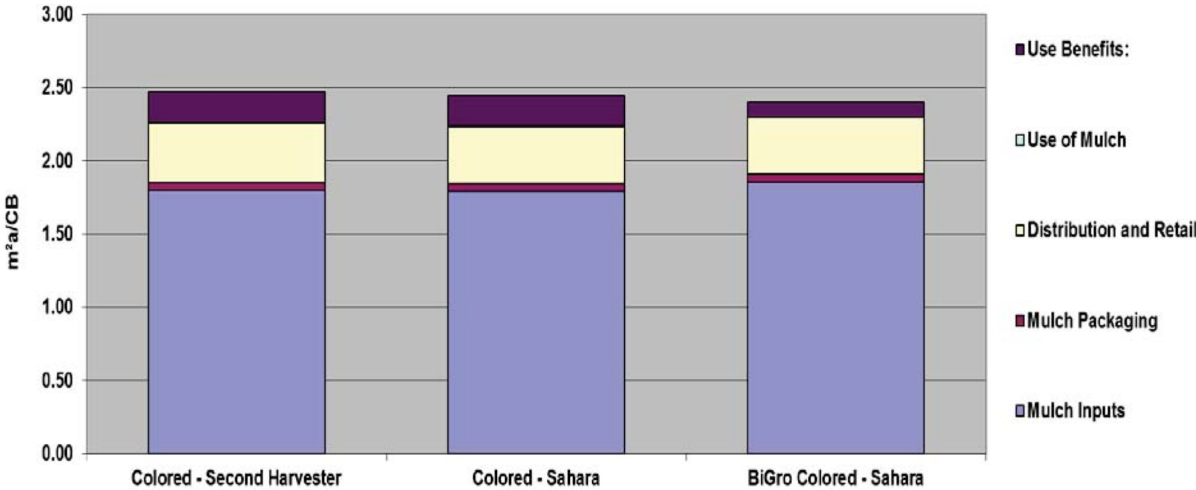

Figure 17. Land use – EDP assessment

8.1.7 Toxicity potential:

The main driver for toxicity is from the fuel used in distribution and retail, due to the difference in the weight of the mulch. There is also toxicity from the raw materials needed to make the mulch in all the alternatives. The alternative BiGro Colored-Sahara has a slight advantage over all the other alternatives due to the benefits of using BiGro in the mulch application. From BASF test results less fertilizer and less water is needed with BiGro to have the same plant growth. There is a minor impact in toxicity from packaging and in the use of the mulch such as transportation and handling. Toxicity potential does have a major impact on the study having a calculation factor of 19%. Usually in application of materials or chemicals intentionally released or applied into the environment, i.e. fertilizers and pesticides, eco-toxicity is integrated. However in this study there was no eco-toxic from the application of the colored mulch.

For the toxicity in the Production phase of the raw materials, not only were the final toxicity of the products considered but the entire pre-chain of chemicals required to manufacture the products were considered as well. For the toxicity of the chemicals used by the consumer in the Use phase, the toxicity scoring for the consumer uses the R-phrase for the toxicity of the final products and the relevant material quantities. In this study only the additional use of fertilizer needed for the plants was assessed. Figure 18 shows the toxicity of the three alternatives. For the normalization, the highest toxicity potential alternative was set to a value of 1 and the other alternative was proportioned to this value.

The use of nanoparticles were not evaluated in the chemical inputs for any of the alternatives, therefore the toxicity of nanoparticles was not evaluated in the study results.

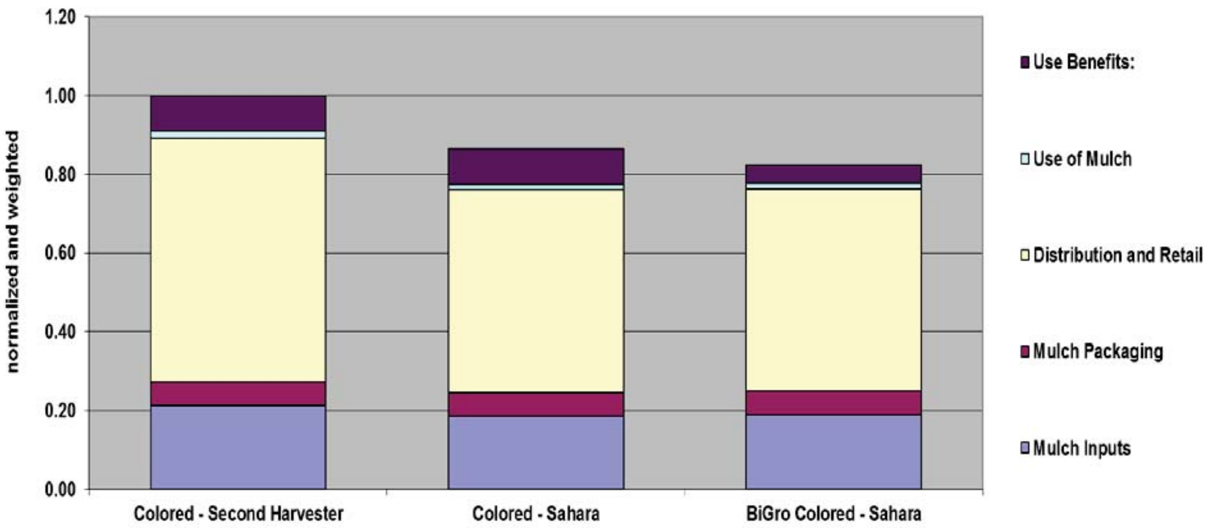

Figure 18. Overall Toxicity potential

8.1.8 Risk potential (Occupational Illnesses and Accidents potential):

All the materials and activities accounted for in the various life cycle stages were assigned specific NACE codes. NACE (Nomenclature des Activities Economiques) is a European nomenclature which is very similar to the NAICS codes in North America. The NACE codes are utilized in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the business economy and is broken down by specific industries. Specific to this impact category, the NACE codes track, among other metrics, the number of working accidents, fatalities and illnesses and diseases associated with certain industries (e.g. chemical manufacturing, petroleum refinery, inorganics etc.) per defined unit of output. By applying these incident rates to the amount of materials required for each alternative, a quantitative assessment of risk is achieved. Figure 19 shows the risk potential for each of the individual modules for the production and use of colored mulch.

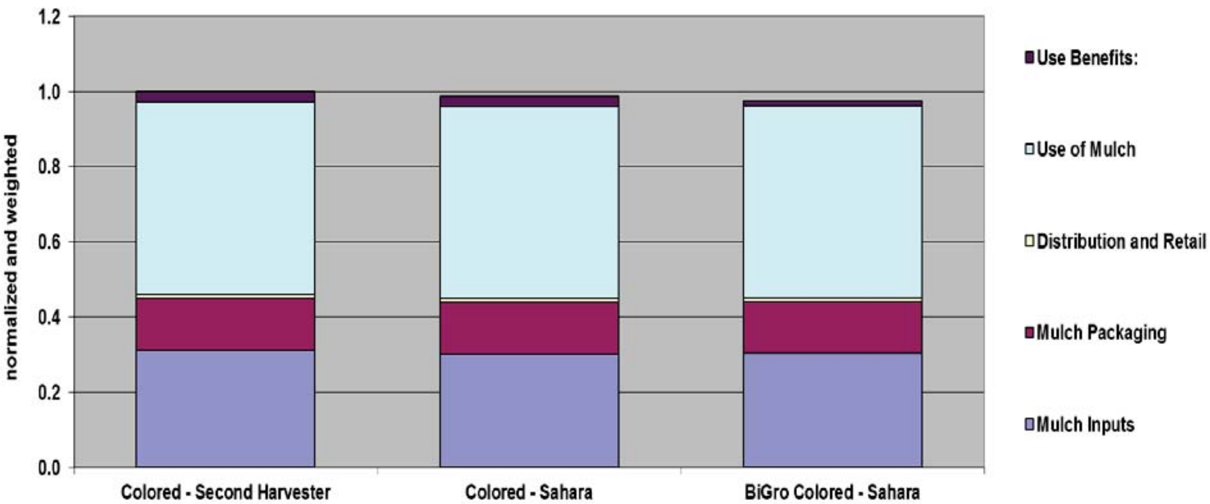

Figure 19. Risk potential by modules

In Figure 20, the greatest Risk (Occupational illnesses (diseases) and accidents) mainly come from the use of the mulch and from the production of the mulch, with the greatest risk is due to exposure. All the alternatives were similar for risk, with the BiGro Colored-Sahara alternative having slightly less risk due to the benefits of less fertilizer needed. The impacts from occupational diseases clearly outweighes the impacts from working accidents. Risk potential does have an impact on the study having a calculation factor of 11%.

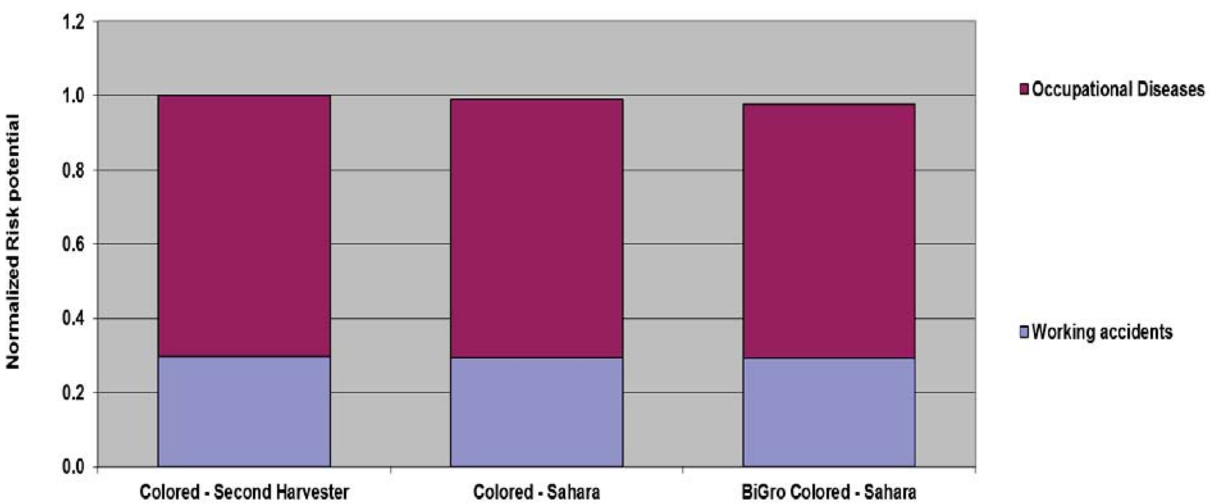

Figure 20. Occupational Illnesses and Accidents

8.1.9 Consumptive Water Use:

In Eco-Efficiency Analysis, water use is assessed as a separate environmental impact category. The method for assessing freshwater consumption is a method described by Pfister, Köhler and Hellweg[5] [6]. In this method, only consumptive water use is assessed and no green water is evaluated (precipitation and soil moisture). Consumptive water use consists of water used in production of the CB and water used or saved for plants. The method also includes a regionalization factor which is based on GIS data as applied at the watershed levels. Details of the corresponding regionalized damage factors are available in supplementary material provided in the Pfister et al publication.

The consumptive water use is dominated by the use benefits of the alternatives. The alternative with the BiGro inoculant was the best alternative since the inoculant provides a huge water savings benefit to the plant and thus is captured in the benefits. There is also water usage in the production, with the BiGro Colored-Sahara and Colored Sahara alternatives having the best results due to less water usage in making the colored mulch. Consumptive water has a minor impact on the study having a calculation factor of 4%. Figure 21 shows the graph of the total consumptive water used weighted with the regional factor.

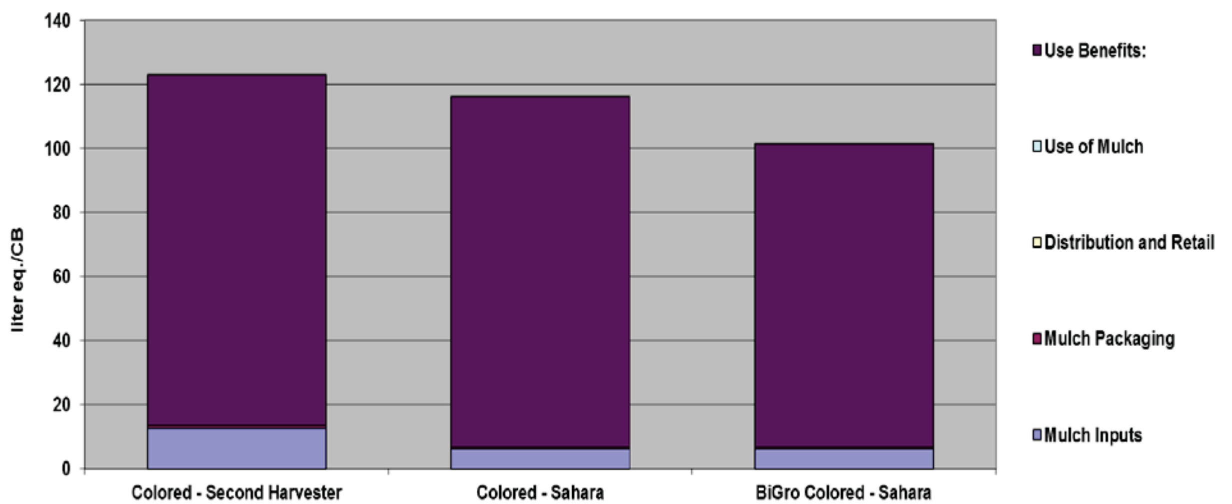

Figure 21. Consumptive Water Use

8.1.10 Environmental fingerprint:

Following normalization, or normalization and weighting with regards to the emissions categories, the relative impact for all seven of the environmental categories for each alternative was calculated. The actual normalized environmental category values from the study are shown in Table 7 and the graph of these values are shown in the environmental fingerprint, Figure 22. A value of 1 represents the alternative with the highest impact in the concerning category, all other alternatives are rated in relation to 1.

Table 7: Normalized environmental category values for BiGro Colored Mulch EEA.

	Colored - Second Harvester	Colored - Sahara	BiGro Colored - Sahara
Energy	1.00	0.99	0.98
Abiotic Resource Depletion	1.00	0.91	0.87
Consumptive Water Use	1.00	0.95	0.82
Greenhouse Gases	1.00	0.91	0.79
AP	1.00	0.91	0.85
POCP	1.00	0.88	0.87
ODP	1.00	0.98	0.97
Water Emissions	1.00	1.00	0.60
Solid Wastes	1.00	0.88	0.87
Occupational Illnesses and Accidents	1.00	0.99	0.98
Land Use	1.00	0.99	0.97
Toxicity Potential	1.00	0.87	0.82

The BiGro Colored-Sahara is better than all the other alternatives in all the environmental categories as shown in the environmental fingerprint. As discussed previously in the individual impact categories, the major impact is the water emissions from the savings of fertilizer. With the BiGro inoculant this fertilizer savings has a major impact due to heavy metal impurities in the fertilizers. There is also an advantage in air emissions from the reduction of fuel use in distribution.

The greatest environmental advantages in BiGro Colored-Sahara alternative over the other alternatives can be noticed in the following categories:

- Emissions
- Consumptive Water Use
- Abiotic Resource Depletion
- Toxicity Potential

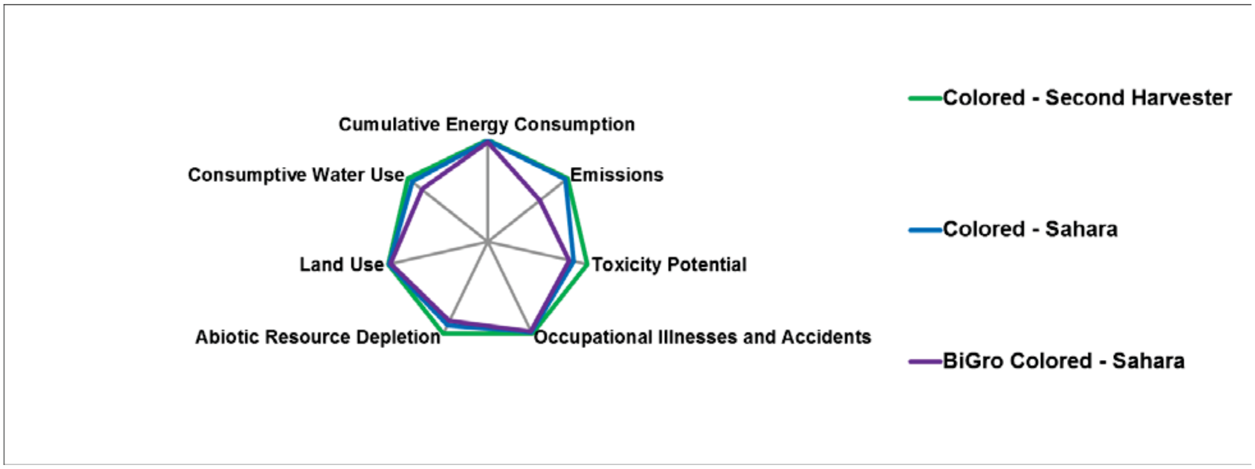

Figure 22. Environmental fingerprint BiGro Colored Mulch

8.2 Economic Cost:

Figure 23 represents the graph of the costs for each of the alternatives based on the total cost. The life cycle cost data for colored mulch are generated as defined in Section 7 of the BASF EEA methodology and described in section 6.2 above. The results of the life cycle cost analysis found that the production, packaging, distribution and use of the colored mulch were all major factors for costs, while the benefits of using the mulch was a minor factor. The Colored-Sahara alternative was the least for cost due to less production inputs to make the colored mulch. Table 8 lists the individual cost at each of the modules in the study.

The cost analysis is based on data from a "point in time" mainly from data supplied from BASF and other outside sources. Although this cost data may vary throughout the year, the input data costs are average fixed amounts.

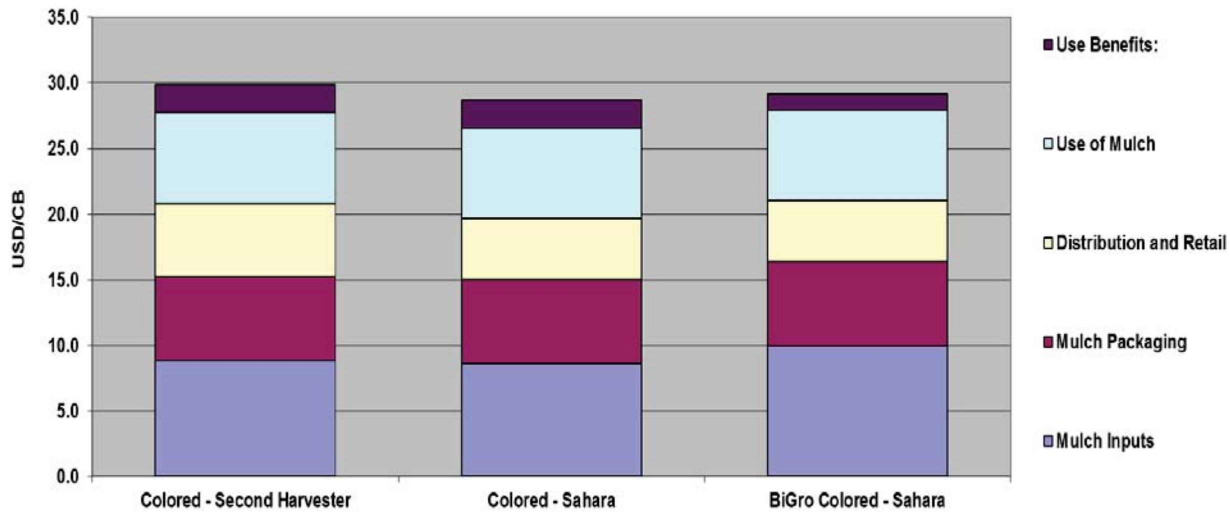

Figure 23. BiGro Colored Mulch costs

Table 8: Economic cost values for BiGro Colored Mulch

Total Costs	**Colored - Second Harvester**	**Colored - Sahara**	**BiGro Colored - Sahara**
Mulch Inputs	**$8.83**	**$8.60**	**$9.97**
Mulch Packaging	**$6.42**	**$6.42**	**$6.42**
Distribution and Retail	**$5.55**	**$4.63**	**$4.63**
Use of Mulch	**$6.92**	**$6.89**	**$6.89**
Use benefits:	**$2.16**	**$2.16**	**$1.26**

8.3 *Eco-Efficiency Analysis Portfolio (Single Score)*:

The Eco-efficiency analysis portfolio for the BiGro Colored mulch EEA has been generated as defined in Section 9.5 of the BASF EEA methodology. Utilizing relevance and calculation factors, the relative importance of each of the individual environmental impact categories are used to determine and translate the fingerprint results to the position on the environmental axis for each alternative shown. For a clearer understanding of how weighting and normalization is determined and applied please reference Section 8 of BASF's Part A submittal to P-352. Specific to this study, the worksheets "Relevance" and "Evaluation" in the EEA model provided to NSF as part of this verification process should be consulted to see the specific values utilized and how they were applied to determine the appropriate calculation factors. Specific to the choice of environmental relevance factors and social weighting factors applied to this study, factors for the USA (national average) were utilized. The environmental relevance values utilized were last reviewed in 2011 and the social weighting factors were recently updated in 2011 by an external, qualified 3rd party.

Figure 24 displays the Base Case (BC) eco-efficiency portfolio, which shows the results when all seven individual environmental categories are combined into a single relative environmental impact and combined with the life cycle cost impact. Because environmental impact and cost are equally important, the most eco-efficient alterative is the one with the largest perpendicular distance above the diagonal line.

The results from this study find that the BiGro Colored-Sahara alternative is the most eco-efficient alternative due to its combination of lower environmental burden but not having the lowest life cycle economic cost. The benefits of the use of the BiGro inoculant are the main reason this alternative is the most eco-efficient. Comparing the other two alternatives, the Colored-Sahara is more eco-efficient than the Second Harvester equipment alternative and this is due to less inputs being required to make the colored mulch with the Sahara mixing equipment.

The Scenarios in the next section will help to identify the critical factors that have an influence on the final results. The main differences between all the alternatives is the input amounts needed for the mixing equipment and the benefits from using colored mulch with and without the BiGro inoculant.

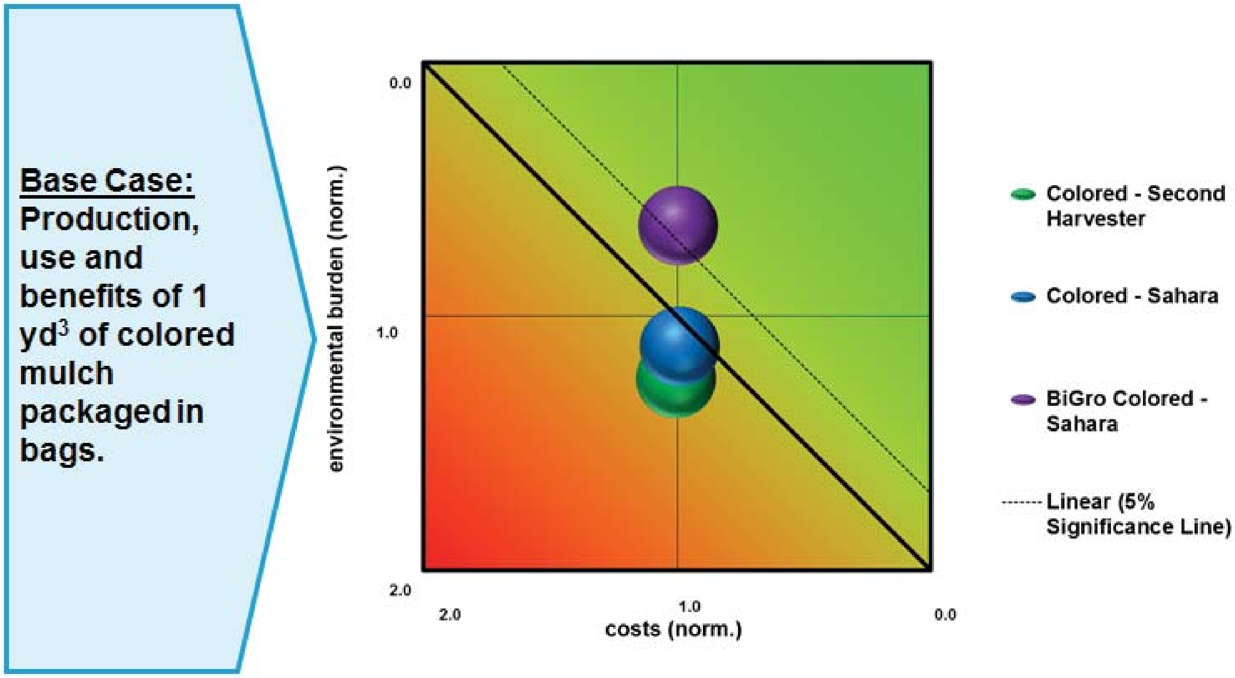

Figure 24. Eco-Efficiency Portfolio Base Case – BiGro Colored Mulch

8.4 Scenario Analysis:

In addition to the base case analysis, additional scenarios were evaluated to determine the sensitivity of the studies final conclusions and results to key input parameters. These scenarios are hypothetical technological or operational improvements.

8.4.1 Scenario #1: No fertilizer benefits with BiGro inoculant.

In this scenario analysis the fertilizer amounts needed for all the plants are set at the same value. There is no fertilizer benefit given to the BiGro alternative. The input amounts required to make the mulch are the same as the Base Case. This scenario shows that the fertilizer benefit from using BiGro inoculant is the major inpact in the study. This proves that further work should be done on the analysis of the benefits of using BiGro inoculant to get the full impact of the life cycle impact of the BiGro inoculant. Figure 25 shows the Eco-efficiency Portfolio results of Scenario #1 and the changes from the base case. Figure 26 shows the Environmental Fingerprint of Scenario #1, with the two alterntives using the Sahara equipment as being the best alternatives.

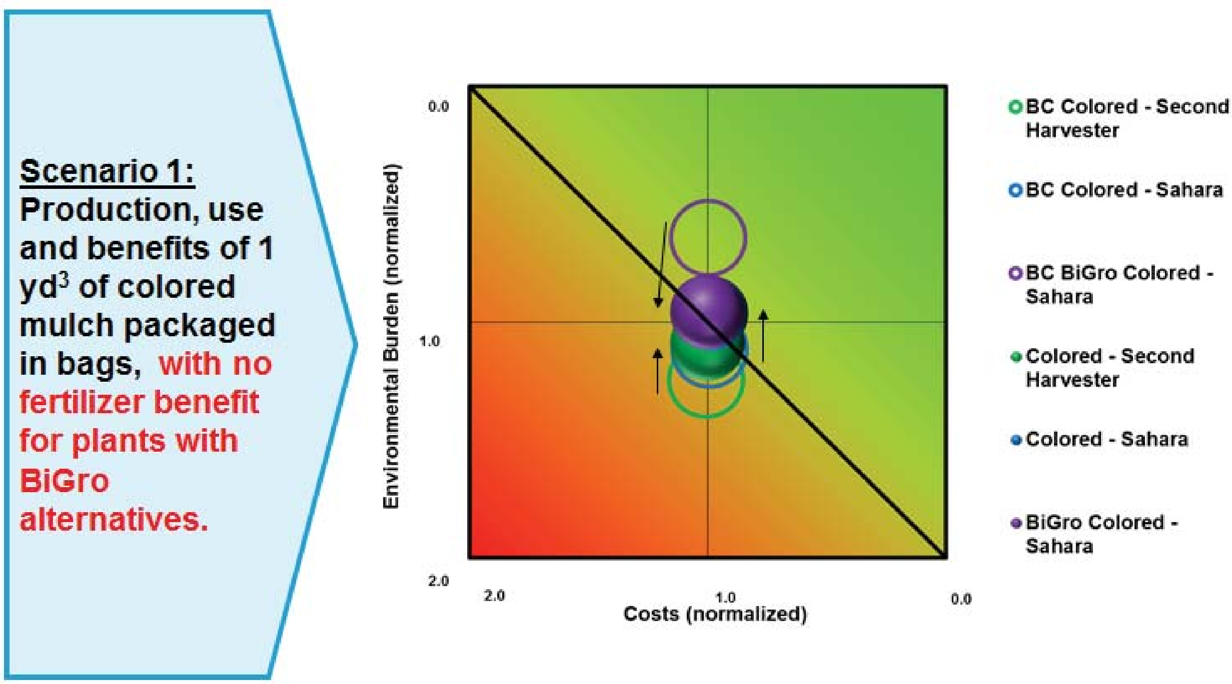

Figure 25. Eco-Efficiency Portfolio BiGro Colored Mulch – Scenario #1

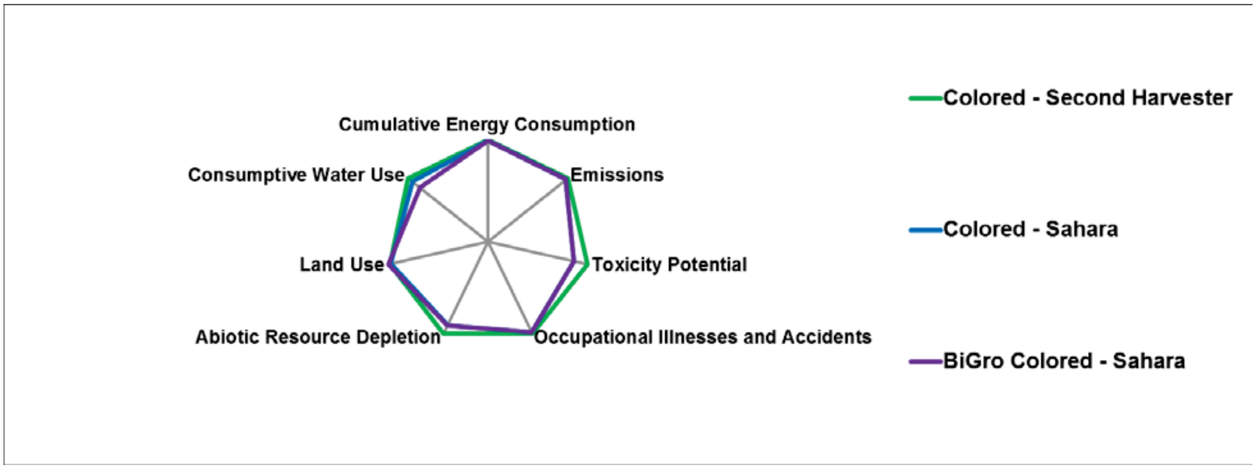

Figure 26. Environmental fingerprint BiGro Colored Mulch – Scenario #1

8.4.2 Scenario #2: The same input amounts to make the colored mulch.

In this scenario analysis, the input amounts were the same to make the colored mulch independent of the mixing equipment. The BiGro alternative still had the BiGro added in this alternative with the other alternatives not having the BiGro. The equipment processing electricity was not changed in this Scenario, only the amounts of the input materials. This Scenario will show if the input amounts have a major impact on the overall study results.

With the input of all the alternatives the same, the BiGro Colored-Sahara alternative still is the most eco-efficient. This proves that the input materials have an impact on the study results, but they are not the major impact influencer. There is advantage seen in 4 environmental categories (emissions, water use, toxicity and abiotic resource) with the BiGro alternative being better than the other two alternatives. The other two alternatives are exactly the same and overlap each other in the environmental fingerprint. For costs, there is a slight advantage with the alternative without the BiGro due to the cost of the addition of the BiGro inoculant. Figure 27 shows the Eco-efficiency Portfolio results of Scenario #2 and Figure 28 shows the Environmental Fingerprint of Scenario #2.

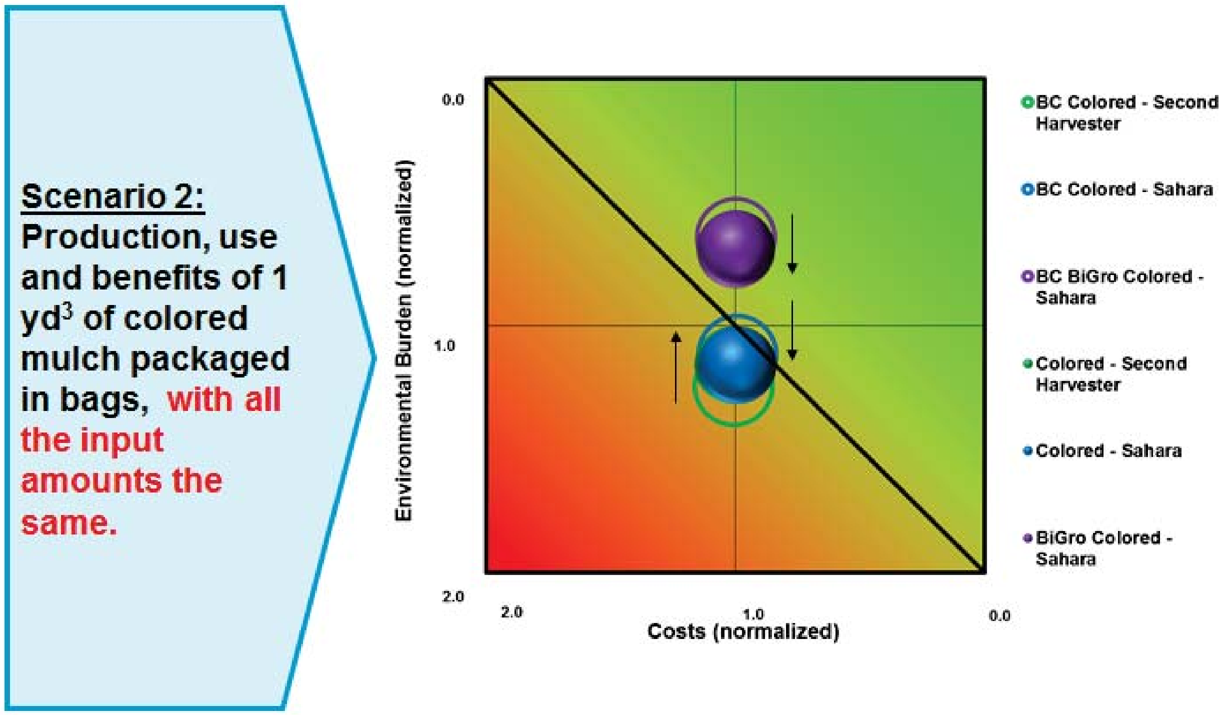

Figure 27. Eco-Efficiency Portfolio BiGro Colored Mulch – Scenario #2

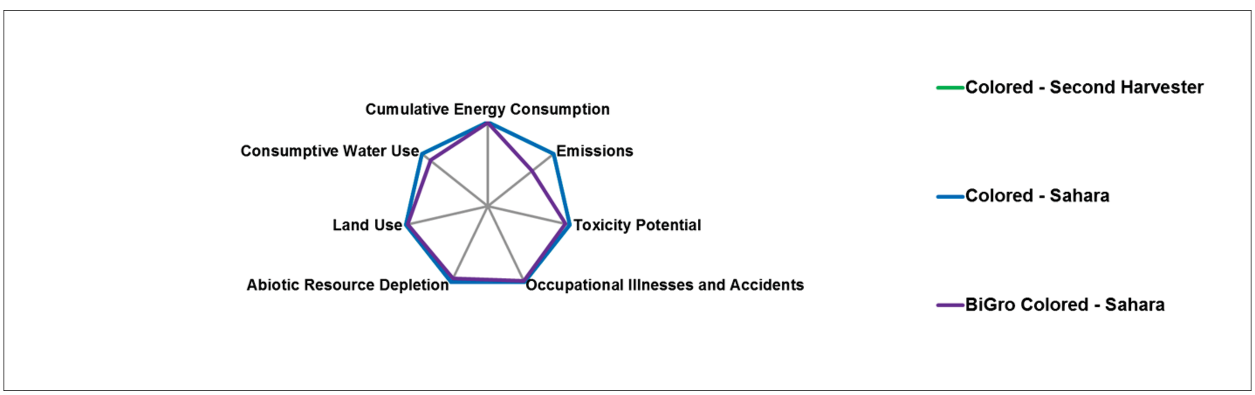

Figure 28. Environmental fingerprint BiGro Colored Mulch – Scenario #2

9. Data Quality Assessment

9.1. Data Quality Statement:

The data used for parameterization of the BiGro Colored Mulch Eco-Efficiency Analysis was sufficient with most parameters of high data quality. Moderate data is where industry average values or assumptions pre-dominate the value. No critical uncertainties were identified within the parameters and assumptions that could have a significant effect on the results and conclusions. Table 9 provides a summary of the data quality for the BiGro Colored Mulch study.

Table 9: Data quality evaluation for BiGro Colored Mulch parameters

Data	Source	Quality
Life Cycle Inventories	BEST database	Med-High
Compositional data	BASF Corporation	High
Data for Alternatives	BASF Corporation	High
Production and application impacts	BASF Corporation	Med-High
Life Cycle Costing	BASF Corporation Industry rates Public rates	Med-High
Toxicity Potential	BEST database	Med-High
Risk Data	NACE Codes	Med-High

10. Sensitivity and Uncertainty Analysis

10.1. Sensitivity and Uncertainty Considerations:

A sensitivity analysis of the final results indicates that the environmental impacts were more influential or relevant in determining the final relative eco-efficiency positions of the alternatives. This conclusion is supported by reviewing the GDP-Relevance factor calculated for the study. The GDP-Relevance indicates for each individual study whether the environmental impacts or the economic impacts were more influential in determining the final results of the study. For this study, the GDP-Relevance indicated that the environmental impacts were significantly more influential in impacting the results than the economic impacts (reference the "Evaluation" worksheet in the Excel model for the GDP-Relevance calculation). The main assumptions and data related to environmental impacts were:

- Inputs
- Emissions
- Fertilizer Benefit Rates

As the data quality related to these main contributors were of high to moderate high quality and scenario variations were run related to them (see section 8.4) , this strengthened our confidence in the final conclusions indicated by the study. Looking at the calculation factors of the study, see Figure 29, indicates that the impact with the highest overall relevance to the study was water emsisions, followed by toxicity potential. This is to be expected, as the study dealt with a small amount of differences between the alternatives and the largest impact was from the fertilizer benefit. The calculation factor is determined by taking the geometric mean of the environmental relevance and the social weighting factors. In the air emissions, AP is considered the most important air emissions, followed by GWP and POCP. The Calculation factors are utilized in converting the environmental fingerprint results (Figure 22) into the final total eco-efficiency portfolio (Figure 24). The impacts with the highest calculation factors were similar to the environmental relevance factors, with regards to the seven main impact categories. The input parameters that were related to these impact categories have sufficient data quality to support a conclusion that this study has a low uncertainty. The social weighting factors considered for this study did influence some minor reprioritization of the impact categories represented in the emissions and air emissions sub-categories.

Most of the input parameters for this study were taken from data gathered from BASF Corporation's Agricultural Products division, which would be considered highly credible. The Transportaion data was taken from publicly available sources and would be considered highly credible.

Calculation Weighting Factors	% of Overall Study
Energy	16.19%
Resources	3.33%
Consumptive Water Use	3.58%
Greenhouse Gases	2.08%
AP	3.24%
POCP	2.36%
ODP	0.24%
Water Emissions	35.75%
Solid Wastes	1.86%
Occupational Illnesses and Accidents	10.60%
Land Use	1.47%
Toxicity Potential	19.30%
SUM	100.0%

Figure 29. Calculation factors that are used in the sensitivity and uncertainty analysis

10.2. Critical Uncertainties:

There were no significant critical uncertainties from this study that would limit the findings or interpretations of this study. The data quality, relevance and sensitivity of the study support the use of the input parameters and assumptions as appropriate and justified.

11 Limitations of Eco-Efficiency Analysis™ Study Results

11.1. Limitations:

These BiGro Colored Mulch Eco-Efficiency Analysis results and its conclusions are based on the specific comparison of the production, for the described customer benefit, alternatives and system boundaries. Transfer of these results and conclusions to other production methods or products is expressly prohibited. In particular, partial results may not be communicated so as to alter the meaning, nor may arbitrary generalizations be made regarding the results and conclusions.

12. References

[1] BEST Database consists of data from Boustead Consulting Ltd UK, The Boustead Model 5.1.2600.2180 LCA database and Ecoinvent data v2.0 database.

[2] Levels of Nonnutritive Substances in Fertilizers, Report to the Legislature, Washington State Department of Agriculture and Washington State Department of Ecology, December 2007 http://agr.wa.gov/PestFert/Publications/docs/2007Non-NutritiveFertRptFINAL.pdf

[3] FAO Corporate Document Repository, Control of water pollution from agriculture- FAO irrigation and drainage paper 55, Chapter 3: Fertilizers as water pollutants, 1996. http://www.fao.org/docrep/W2598e/w2598e06.htm

[4] Koellner, T., and Scholz, R., *Assessment of Land Use Impacts on the Natural Environment, Part 1: An Analytical Framework for Pure Land Occupation and Land Use Change*, International Journal LCA 12(1) 16-23, 2007.

[5] Saling, P.; Maisch, R.; Silvani, M.; König, N. Int. J. LCA, 10(5), 364-371 (2005).

[6] Pfister, S. Koehler, A. and Hellweg, S., *Assessing the Environmental Impacts of Freshwater Consumption in LCA*, Environmental Science & Technology Publication, American Chemical Society, April 23, 2009.