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

# Headline® Fungicide Eco-Efficiency Analysis Final Report - August 2010

**Submitted by:**

BASF Corporation
Product Stewardship
100 Campus Drive, Florham Park, NJ, 07932

**Prepared by:**

Thomas Laginess, Senior Sustainability Specialist

Brigitte Achatz, Senior Sustainability Specialist

Jeff Barnes, Development Group Leader

Tom Holt, Manager Biology Development

Martin Mascianica, Director Commercial Development

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## 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 "Headline® Fungicide 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.

*1.2.* The Headline® Fungicide 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 Headline® Fungicide Eco-Efficiency Analysis (EEA) study, which was conducted in accordance with BASF Corporation's EEA (BASF EEA) 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 EEA Methodology

*3.1. Overview:*

BASF EEA involves measuring the life cycle environmental impacts and life cycle costs for product alternatives for a defined level of output. At a minimum, BASF EEA evaluates the environmental impact of the production, use, and disposal of a product or process in the areas of energy and resource consumption, emissions, toxicity and risk potential, and land use. The EEA also 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 both 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 assessment carried out is defined below.

### *3.2.1. Environmental Burden Metrics:*

For BASF EEA environmental burden is characterized using eleven categories, at a minimum, including: primary energy consumption, raw material consumption, green house gas emissions (GHG), ozone depletion potential (ODP), acidification potential (AP), photochemical ozone creation potential (POCP), water emissions, solid waste emissions, toxicity potential, risk potential, and land use. These are shown below in Figure 1. Metrics shown in yellow represent the six main categories of environmental burden that are used to construct the environmental fingerprint, burdens in blue represent all elements of the emissions category, and green show air emissions.

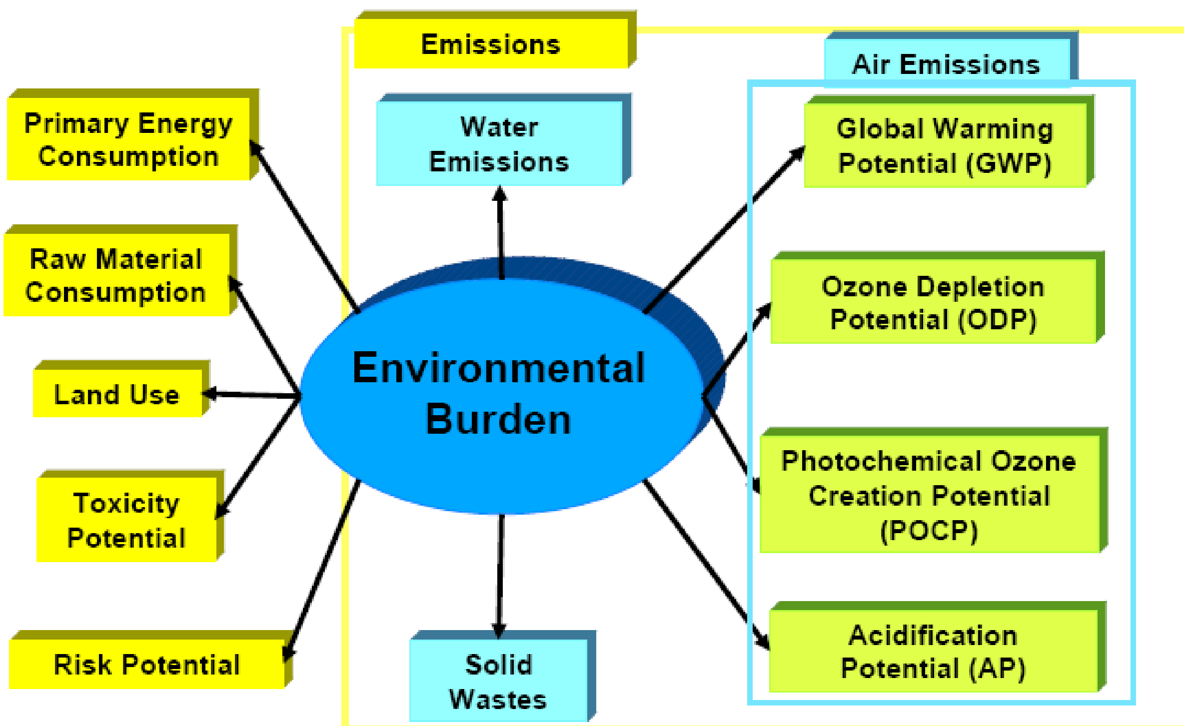



**Figure 1.** Environmental Impact categories

### *3.2.2. Economic Metrics:*

It is the intent of the BASF EEA 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 EEA 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.

### *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.

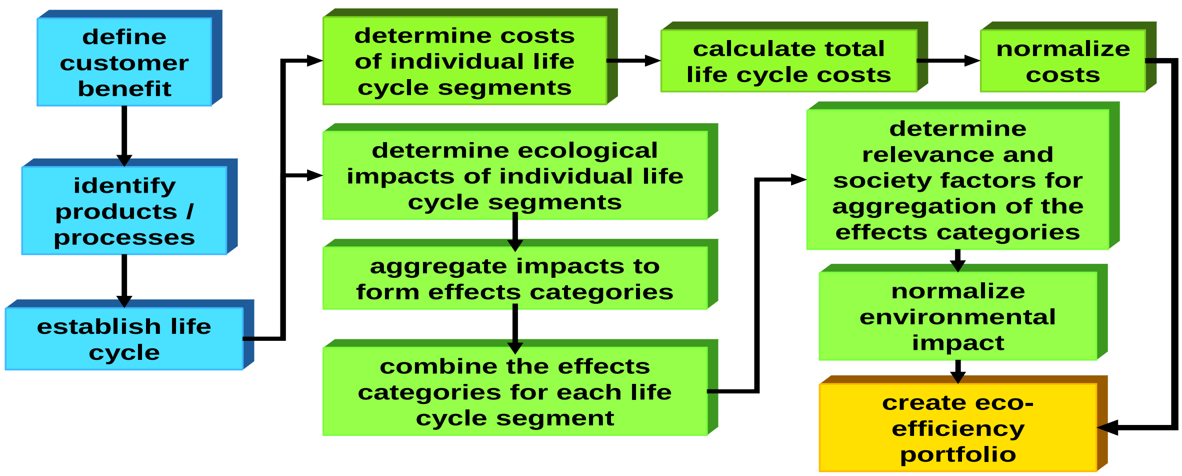



**Figure 2**: Overall process flow for BASF Headline® EEA methodology.

## 4. Study Goals, Context and Target Audience

### *4.1. Study Goals*:

The specific goal defined for the Headline® Fungicide Eco-Efficiency Analysis was to quantify the differences in life cycle environmental impacts and total life cycle costs of corn production technologies in the United States.

The study specifically compares the use of Headline® on corn production and without. Headline® is applied at the VT stage to the R2 stage of the corn plant growth and is applied usually by aerial application. The study considered application of the Headline® fungicide in the state of Iowa, where roughly 20% of the United States corn production is grown. Thus most of the data is used from Iowa State University research on corn production.

The major factor influencing the environmental and cost impact of the use of Headline® and without is the yield increase in the production of corn. Iowa State University research studies, on average, demonstrated a 6.95% increase in corn production yield[1] with the use of Headline® and this was used as the base case scenario. This University information is based on average field trial data done over 2 years at 16 different sites with ISU. BASF has done trials in over 2,400 sites in the last six years and the increase in yield is higher than the 6.95%. For this study, data is used that was produced from University trials at ISU.

The BASF Headline® fungicide provides superior disease control and plant health benefits, resulting in a crop this is more efficient and tolerant of stress. This powerful protection allows you to maximize yield, minimize risk (or protect your investment) and improve standability and harvest efficiency[2]. The composition of Headline® consist of an active ingredient Pyraclostrobin (CAS# 175013-18-0) at 23.6%; a solvent carrier of naphtha (CAS# 64742-94-5) at 57.2%; naphthalene (CAS# 91-20-3) at less than 9.38% and inert ingredients at 9.9%. The composition and content information is based on the data stated on the MSDS[3].

Study results will be used as the basis to guide further product development and marketing decisions that will result in more sustainable production of corn. As well as provide the necessary information to allow a clear comparison between the environmental life cycle and total cost impacts and benefits of using Headline® fungicide. It will also facilitate the clear communications of these results to key stakeholders in the agricultural industry who are challenged with evaluating and making strategic decisions related to the environmental and total costs trade-offs associated with production of corn.

### *4.2 Design Criteria:*

The context of this EEA study compared the life cycle environmental and cost impacts for production of 1 metric ton (1,000 kg) of corn. The Headline® study used data mainly documented by Iowa State University for the production of corn. The data in the study included general data such as yield; seeding such as seed used in corn planting; fertilizers and plant protection such as amounts of N-P-K fertilizer, herbicides, fungicide, additives and application costs; and tilling and harvesting such as diesel use for tractor, diesel use for combine, field work, machinery costs and in the case for Headline® the application by airplane. The study relied on internal information and MSDS were utilized for non-BASF supplier information, as well as field trials for the use of Headline®. The study was technology driven and goals, target audience, and context for decision criteria used in this study are displayed in Figure 3.

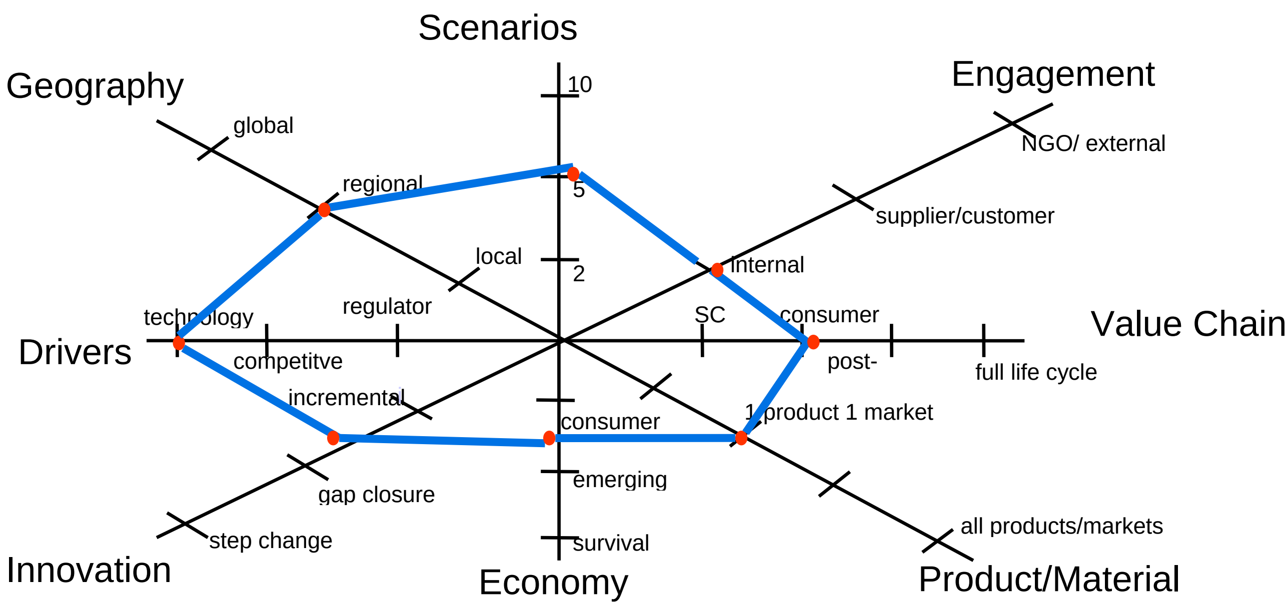



**Figure 3.** Context of Headline® Fungicide Eco-efficiency Analysis

### *4.3. Target Audience*:

The target audience for the study has been defined as agricultural consumers, such as farmers, distributors of agricultural products and trade associations within North America, focusing on the corn production in the state of Iowa. It is planned to communicate study results in marketing materials and at trade conferences.

## 5. Customer Benefit, Alternatives and System Boundaries

### *5.1. Customer Benefit*:

The Customer Benefit applied to all alternatives for the base case analysis is the evaluation of the inputs required to produce 1 metric ton (1,000 kg) of corn in the state of Iowa, which is equivalent to 39.4 bushels of corn (56 lb. per bushel of corn) in one growing season (1 year) in an agricultural condition that deploys crop rotation methods to prevent residual impacts in subsequent growing seasons. This study specifically evaluates an input (Headline® fungicide) that affects crop yield, and is based on the yields reported in the Iowa State University studies referenced in Section 4.1. For the purposes of this study, in situations where inputs (e.g. fertilizer, seed) are the same for all product alternatives, the application rates of those inputs will be the same across all alternatives. Therefore, in situations that increase yield, the amount of inputs required to achieve the CB will decrease, because the yield increase is demonstrating a more efficient use of the inputs. However, the application rate of the inputs will remain the same. The justification for selecting this CB is because the metric unit is a universally accepted or known amount and one metric ton is a large enough amount to be able to understand the concept. This amount is not small, like a bushel where the representative differences might not be expressed in the study.

*5.2. Alternatives*:

The product alternatives compared under this EEA study are (1) Corn production without the use of Headline® fungicide and (2) Corn production with the use of Headline® fungicide. The application rates for all other inputs for the two alternatives are the same. These alternatives were selected as they represent the actual use by farmers. There are other competitors that offer fungicides for corn production, but this study only focused on the BASF product. If a fungicide is not used, there is not an alternative product used in the production of corn.

*5.3. System Boundaries*:

The system boundaries define the specific elements of the production phases that are considered as part of the analysis. The elements for the use and disposal of 1 metric ton of corn were not evaluated in this study. The system boundaries for the two alternatives evaluated in this study are shown in Figures 4 and 5. Sections identified in gray were excluded from the analysis as they represented identical impacts for both alternatives (e.g. transportation, drying, storage, processing and secondary uses). The justification for these boundaries is that these are the major impact categories for the production of corn. The only difference between the two alternatives is the production and application of the Headline® in the one alternative. The use and disposal of the corn was not evaluated because the CB of 1 metric ton for both alternatives was the same.

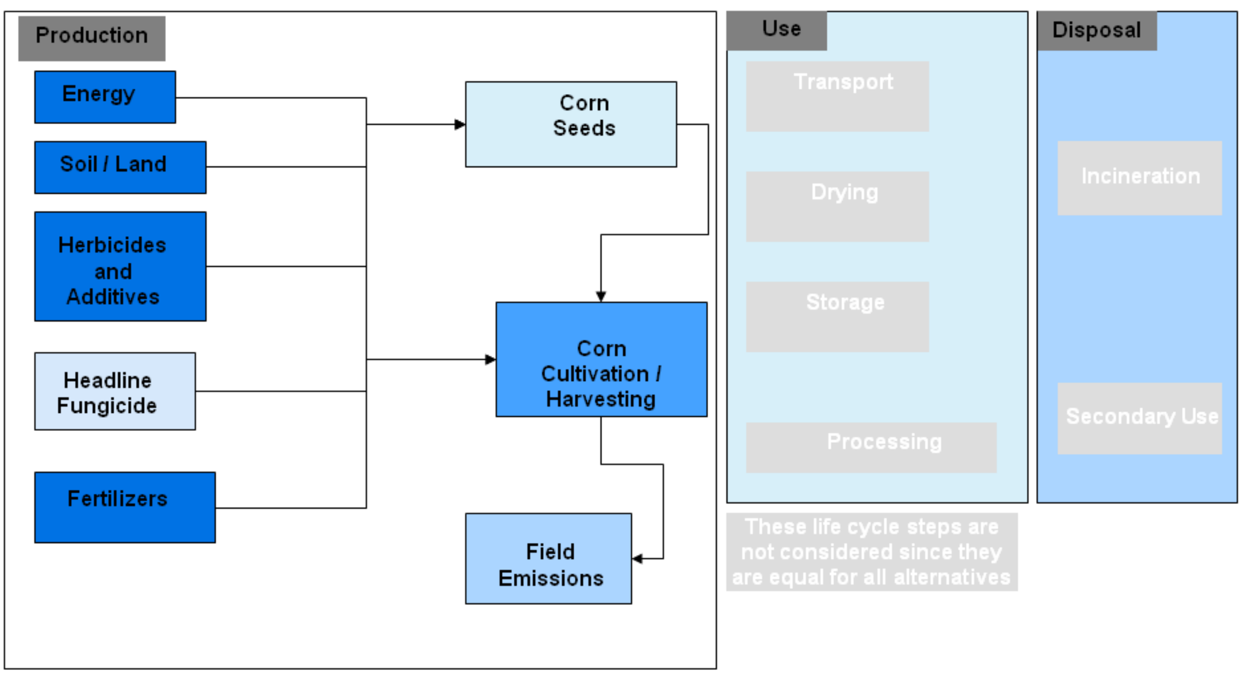



**Figure 4.** System boundaries - Headline® Fungicide application to Corn Production

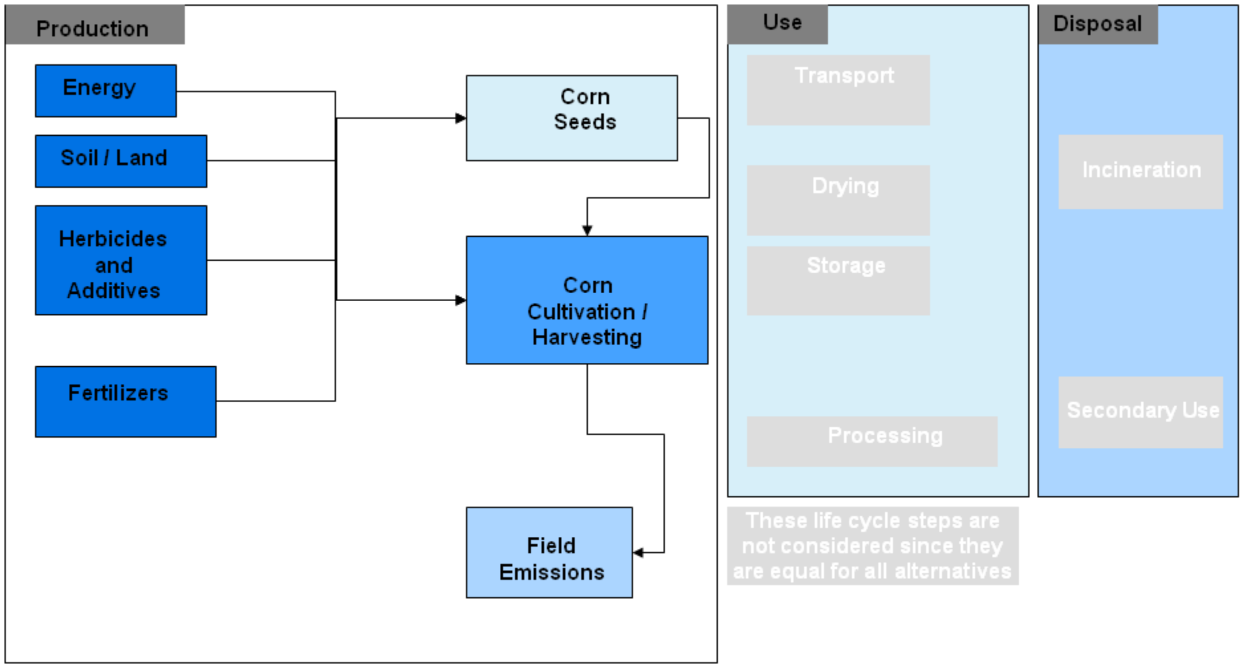



**Figure 5.** System boundaries – Conventional Corn Production (No Fungicide)

### *5.4 Scenario Analyses:*

In addition to the base case analysis, six additional scenarios were evaluated to determine the sensitivity of the study final conclusions and results to key input parameters. Scenario#1, #2 and #3 demonstrate the impact of the yield response with the use of Headline®. Scenario #4 demonstrates the impact when not evaluating the $N_2O$-Emission from the soil. Scenario #5 demonstrates the impact if additional water emissions are considered based on the amount of Nitrogen (N) used for fertilize. Scenario #6 demonstrates the environmental and economical impacts for using Headline®, because land use and yield are equal:

*5.4.1. Scenario #1:* 5% Increase in yield for corn in Headline® application (12% total yield increase over conventional corn production)

*5.4.2 Scenario #2:* 4% Decrease in yield for corn in Headline® application (3% total yield increase over conventional corn production)

*5.4.3 Scenario #3:* 6.5% Decrease in yield for corn in Headline® application (Yields similar)

*5.4.4 Scenario #4:* $N_2O$-Emission from crop soils (8 kg $N_2O$-N per ha and per year according to Intergovernmental Panel on Climate Change, IPCC[4]) not considered

*5.4.5 Scenario #5:* Water emissons (N) 10% of fertilizer N (base case: no N-water-emissions from fertilizer-N) not considered

*5.4.6 Scenario #6:* Evaluation based on one hectare, with yield results equal.

Results from these scenarios will be discussed along with the base case in Section 8, "Eco-efficiency analysis results and discussion."

# 6. Input Parameters and Assumptions

## *6.1. Input Parameters*:

A comprehensive list of input parameters were included for this study and considered all relevant material and operational characteristics. The Generic Data sources included Iowa State University, BASF's North America Agricultural Products Division and United States Department of Agriculture. The input values from this data are absolute values and are the same in each alternative before taking into consideration the increase in yield from the Headline®. The benefit of this increase in yield is the major factor in the study.

The Headline® study evaluates the production of the Customer Benefit (CB), which is one metric ton of corn for one growing season. The production of corn is an annual process, since the seed needs to be planted, the fertilizers and herbicides need to be applied and the corn needs to be harvested to get the CB. In grain agricultural production, crops are usually rotated year after year. If corn is planted in a field one year, the next year a different crop such as soybeans or wheat is planted. The reason for this is the demand of the individual crops on the soil and the nutrients in the soil. The production of corn has a high demand for Nitrogen (N) as shown in the study. If corn is planted year after year on the same land, more N is needed the next year than in the previous year. Soybeans actually produce N during the growing process so there is no demand on N.

The benefit of using the Headline® fungicide to reduce the fungi amount over a period of time was not evaluated in the study. The elimination of the fungi or reduction effects of the fungi in other crops was not evaluated in this study. As for the environmental effects of the fungicide over several years, this data is not available at this time. The study does look at the environmental effects of the Headline® in the Toxicity evaluation, based on the amount used for the one year growing season. The application of the Headline® fungicide is applied to the corn plant in the VT to R2 stage and most of the absorption of the fungicide is through the plant. There maybe some over spray that gets to the soil and this was evaluated in the Toxicity portion of the study. BASF does have some data that shows less fertilizer and less water is needed when the fungicide is applied due to a healthier plant, but this would show even more benefits to using the Headline® fungicide. This data was not used in the study because it is preliminary data and BASF wanted to compare known data from University trials. As for the resistant of the fungi to the Headline® fungicide over time, this is reduced due to crop rotation as stated above.

### *6.1.1. Cultivation Parameters:*

- Yield[5]: 209.2 bu./A (13.137 t/ha) using Headline® vs. 195.6 bu./A (12.283 t/ha) in conventional farming.
- Headline®: 112 g/ha of active ingredient (Pyraclostrobin), additive: plant oil Superb HC (0.55 kg/ha helps penetrating the plant).
- Other Inputs: Inputs for seeds, herbicides and fertilizers per area unit were the same for each alternative. The input amounts used per hectare (ha) are shown in Table 1. The Base Case compares the use of Headline®

vs. Conventional (without Headline®) production of corn. . If the yields were the same for both systems, then the input values would be the same, as shown in Table 1.

**Table 1:** General Input data usage rates per hectare for Base Case Headline® and Conventional application.

| Item | Usage Rate (units/ha) | Base Case Headline® Usage Rate (units/ha) | Base Case Conventional Usage Rate (units/ha) |
|---|---|---|---|
| Amount of corn seed (kg) | 25.12 | 25.12 | 25.12 |
| N-fertilizer (kg) | 224.00 | 224.00 | 224.00 |
| P-fertilizer (kg) | 72.00 | 72.00 | 72.00 |
| K-fertilizer (kg) | 94.00 | 94.00 | 94.00 |
| Harness Xtra (kg) | 2.35 | 2.35 | 2.35 |
| Roundup PowerMax (kg) | 0.87 | 0.87 | 0.87 |
| Water (kg) | 176.85 | 176.85 | 176.85 |
| Headline (kg) | 0.11 | 0.11 | 0.00 |
| Water (kg) | 17.69 | 17.69 | 0.00 |
| Superb HC (kg) | 0.54 | 0.54 | 0.00 |
| Diesel use tractor (L) | 21.00 | 21.00 | 21.00 |
| Diesel use combine (L) | 13.56 | 13.56 | 13.56 |
| Fuel use of aircraft (L) | 0.42 | 0.42 | 0.42 |

Since the Customer Benefit (CB) is fixed, Table 2 shows the input amounts needed to produce the CB. The amounts are varied due to the increase in yield with the Headline® application and are listed as units per CB.

**Table 2:** General Input data usage rates calculated based on Customer Benefit with Base Case Headline® and Conventional application.

| Item | Usage Rate (units/ha) | Base Case Headline® Usage Rate (units/CB) | Base Case Conventional Usage Rate (units/CB) |
|---|---|---|---|
| Amount of corn seed (kg) | 25.12 | 1.91 | 2.05 |
| N-fertilizer (kg) | 224 | 37.14 | 39.64 |
| P-fertilizer (kg) | 72 | 11.94 | 12.74 |
| K-fertilizer (kg) | 94 | 11.95 | 12.75 |
| Harness Xtra (kg) | 2.35 | 0.19 | 0.20 |
| Roundup PowerMax (kg) | 0.87 | 0.07 | 0.07 |
| Water (kg) | 176.846 | 13.49 | 14.40 |
| Headline (kg) | 0.112 | 0.01 | 0.00 |
| Water (kg) | 17.685 | 1.35 | 0.00 |
| Superb HC (kg) | 0.538 | 0.04 | 0.00 |
| Diesel use tractor (L) | 21 | 1.60 | 1.71 |
| Diesel use combine (L) | 13.56 | 1.03 | 1.10 |
| Fuel use of aircraft (L) | 0.42 | 0.03 | 0.00 |

## *6.2. Costs*

### *6.2.1. User Costs*

User costs were evaluated for each alternative. User costs were entered based on the yield production of 1 metric ton of corn. The only difference between the two alternatives is the Headline® costs, crop oil costs and the application cost of applying the Headline® fungicide. The complete list of input data costs for Seed, Fertilizer, Plant protection, Energy and other characteristics for the Headline® application are shown below in Table 3.

**Table 3:** General Input data costs calculated based on Customer Benefit with Base Case Headline® and Conventional application.

| Item | Farmer Cost (US$/unit) | Base Case Headline® Farmer Cost (US$/CB) | Base Case Conventional Farmer Cost (US$/CB) |
|---|---|---|---|
| Corn seed (kg) | $9.83 | $18.80 | $20.10 |
| N-fertilizer (kg) | $0.46 | $7.89 | $8.44 |
| P-fertilizer (kg) | $0.49 | $2.70 | $2.88 |
| K-fertilizer (kg) | $0.55 | $3.90 | $4.17 |
| Harness Xtra (kg) | $18.92 | $3.38 | $3.62 |
| Roundup PowerMax (kg) | $11.36 | $0.75 | $0.80 |
| Water (kg) | $0.00 | $0.00 | $0.00 |
| Herbicide application*(ha) | $29.64 | $2.26 | $2.41 |
| Headline (kg) | $268.78 | $2.29 | $0.00 |
| Water (kg) | $0.00 | $0.00 | $0.00 |
| Superb HC (kg) | $6.89 | $0.28 | $0.00 |
| Fungicide application* (ha) | $19.76 | $1.50 | $0.00 |
| Diesel use tractor (L) | $0.62 | $0.99 | $1.06 |
| Diesel use combine (L) | $0.62 | $0.64 | $0.68 |
| Field work (ha) | $70.64 | $5.38 | $5.75 |
| Machinery Cost (ha) | $175.90 | $13.39 | $14.32 |
| Land Lease (ha) | $419.90 | $31.96 | $34.19 |
| Total | | $96.12 | $98.44 |

* **Note:** Application rates include the equipment, fuel and labor costs for application of herbicide and fungicide.

## 7. Data Sources

### *7.1. Environmental:*

The environmental impacts for the production of the two 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 customer supplied data. 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 4.

**Table 4:** Summary of eco-profiles used the eco-efficiency analysis

| Eco-Profile | Source, Year | Comments |
|---|---|---|
| Headline® | | |
| Pyraclostrobin (A.I. in Headline) | 2006 | BASF Internal |
| Naphtha (Solvent carrier) | 1996 | Boustead database[6] |
| Crop Oil | GB Avg., 1996 | Boustead database[6] |
| Water | BASF well data, 1995 | Boustead database[6] |
| Glyphosate | 1997 | Boustead database[6] |
| Acetochlor | DE Avg., 1997<br>BASF, 2006 | Boustead database[6] |
| Atrazine | DE avg., 1997 | Boustead database[6] |
| Urea Fertilizer | Agrium, 2005 | Boustead database[6] |
| DAP Fertilizer | U of Minnesota., 2002 | |
| K-Fertilizer | DE Avg., 1997 | Boustead database[6] |
| Diesel Use - US | US Avg., 1996 | Boustead database[6] |
| Jet A diesel | US Avg., 1999 | Boustead database[6] |
| | | |
| | | |
| 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:*

The data sources for the amounts and costs of the individual components were obtained from the BASF Agricultural Products Division. A summary of the source of this data is provided in Table 5. The reference materials for this information can be found in Appendix A.

**Table 5:** Summary of data sources for amounts and costs

| Corn Characteristics | Data Source: |
|---|---|
| Variety - DKC60-19 | Dekalb Genetics Seed Company |
| Yield (grain) | BASF Corp. - Based on Iowa State University trials |
| Amount of corn seed | Iowa State University |
| Plant protection | |
| N-fertilizer | USDA & Iowa State University |
| P-fertilizer | USDA & Iowa State University |
| K-fertilizer | USDA & Iowa State University |
| Herbicide 1 - Harness Xtra | Monsanto Company |
| Herbicide 2 - Roundup | Monsanto Company |
| Water amounts | BASF Corp. |
| Fungicide 1 - Headline® | BASF Corp. |
| Water | BASF Corp. |
| Herbicide Application 1 | Iowa State University |
| Fungicide Application 1 | Iowa State University |
| Other additves | |
| Additive 1 - Superb® HC (Crop Oil) | Agriliance, LLC |
| Energy | |
| Diesel use tractor | Iowa State University |
| Diesel use combine | Iowa State University |
| Fuel use of aircraft(Jet A diesel) | BASF Corp. |
| Field work | Iowa State University |
| Machinery cost | Iowa State University |
| Land Lease | Iowa State University |

## 8. Eco-efficiency Analysis Results and Discussion

*8.1. Environmental Impact Results*: The environmental impact results for the Headline® Fungicide EEA are generated as defined in Section 6 of the BASF EEA methodology. The results discussed in Section 8.1.1 through 8.3 (depicted in Figures 5 through 22) are for the Base Case only and do not represent any of the Scenarios.

*8.1.1. Primary energy consumption*: The Headline® fungicide alternative is slightly lower for energy consumption compared to the conventional corn production. Figure 6 shows that the key drivers for the raw material energy consumption. Energy use is dominated by the production of fertilizers. More than 60 g of fertilizer (N, P, K) are used per kg of corn (>60 kg per CB). With an average energy balance of about 30 MJ/kg of fertilizer this is the dominating effect in the whole process (almost 2000 MJ/CB). Field work / diesel use only results in approximately 120 MJ per CB.

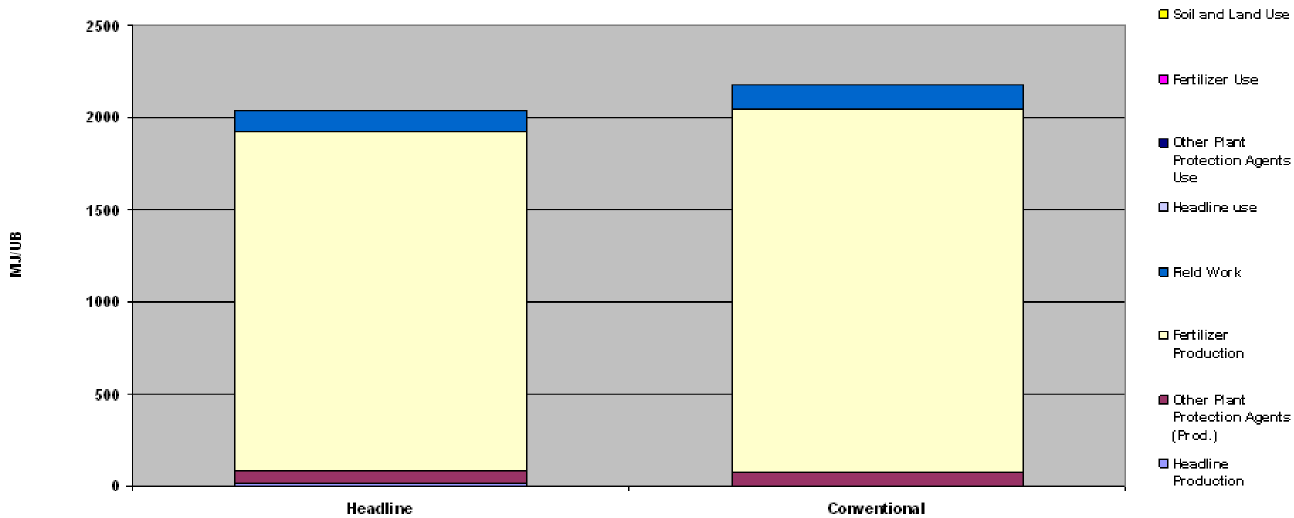



**Figure 6.** Primary energy consumption.

*8.1.2. Raw material consumption*: Figure 7 shows that the key driver for the raw material or resource consumption is dominated by the production of fertilizers and the relevant energy carriers. More than 60 g of fertilizer (N, P, K) are used per kg of corn (>60 kg per CB).

Per the BASF EEA 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. Phosphorous is the main resource that dominates raw material consumption (apart from energy carriers like coal, lignite, oil and gas). Within the different resources assessed Phosphorous is weighted highly since it is scarce. Figure 8 shows the overall use of individual raw materials for the production of corn with and without the use of Headline® fungicide.

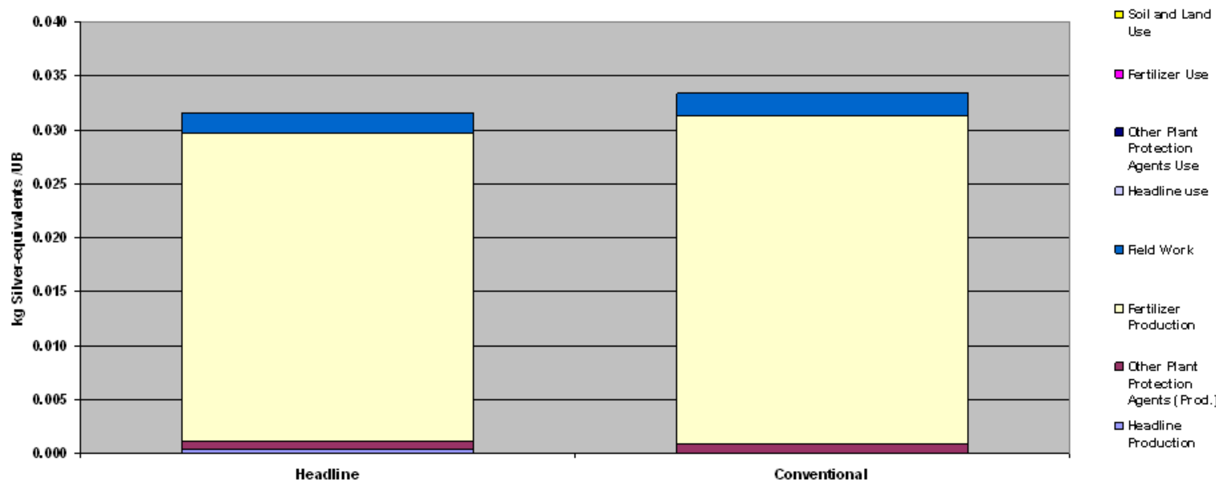



**Figure 7.** Raw Material consumption by Module.

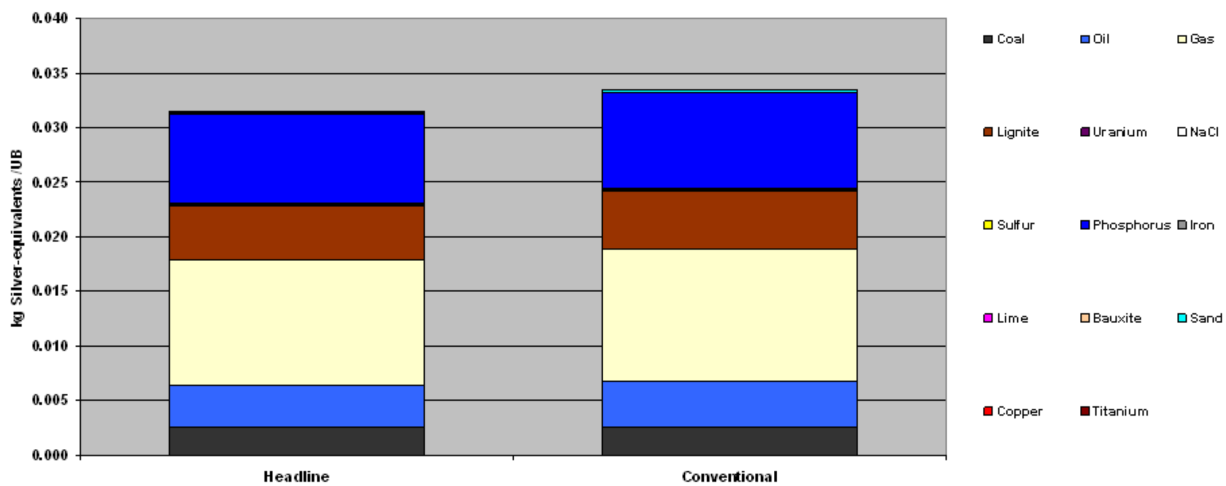



**Figure 8.** Raw Material consumption by Type.

*8.1.3. Air Emissions*:

*8.1.3.1. Green House Gases (GHG)*: Green House Gases is equivalent and also known as the Global Warming Potential (GWP), GHG is the cause and GWP is the affect. The highest carbon footprint occurred in soil and land use. With field emissions of 8 kg $N_2O$-N per ha a year (IPCC 2006[7]) from crops this is the dominant factor. Other important sources for green house gas emissions are $N_2O$-emissions from N-fertilizers (1% of fertilizer N directly and 0.325% of fertilizer N indirectly through volatilization and leaching; IPCC 2006[8]) as well as $CO_2$-emission from urea (worst case: 20% of urea is being emitted as $CO_2$). Emissions in fertilizer production are mainly due to the use of fossil energy. Figure 9 shows the overall GHG emission for production of corn with and without the use of Headline® fungicide.

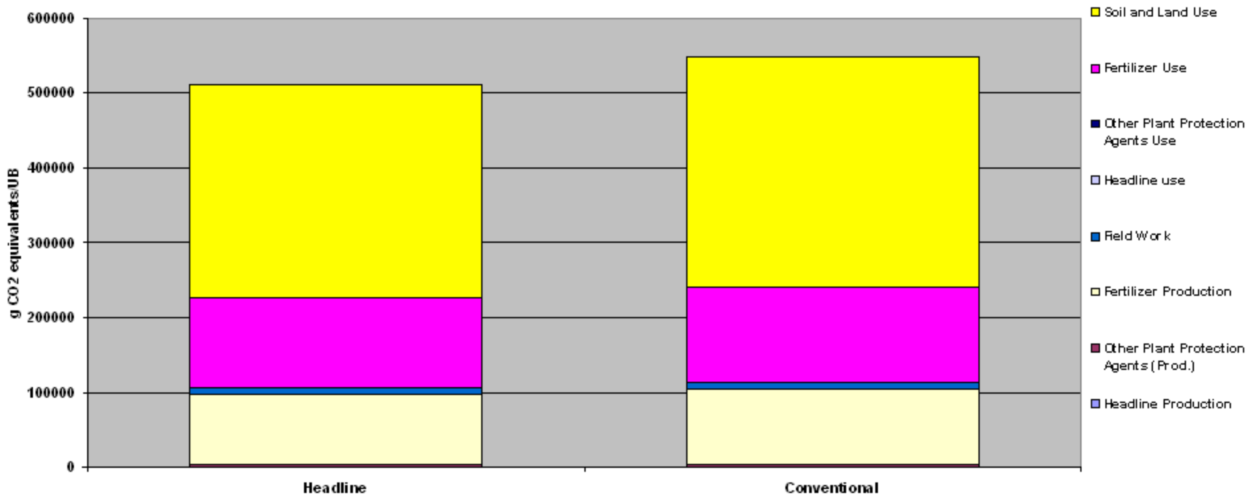



**Figure 9.** Green House Gas Emissions.

*8.1.3.2. Photochemical ozone creation potential (POCP, smog)*: Emissions with Photochemical Ozone Creation Potential are dominated by fossil fuel use (field work and fertilizer production). This environmental category has a very minor influence and the results are shown in Figure 10.

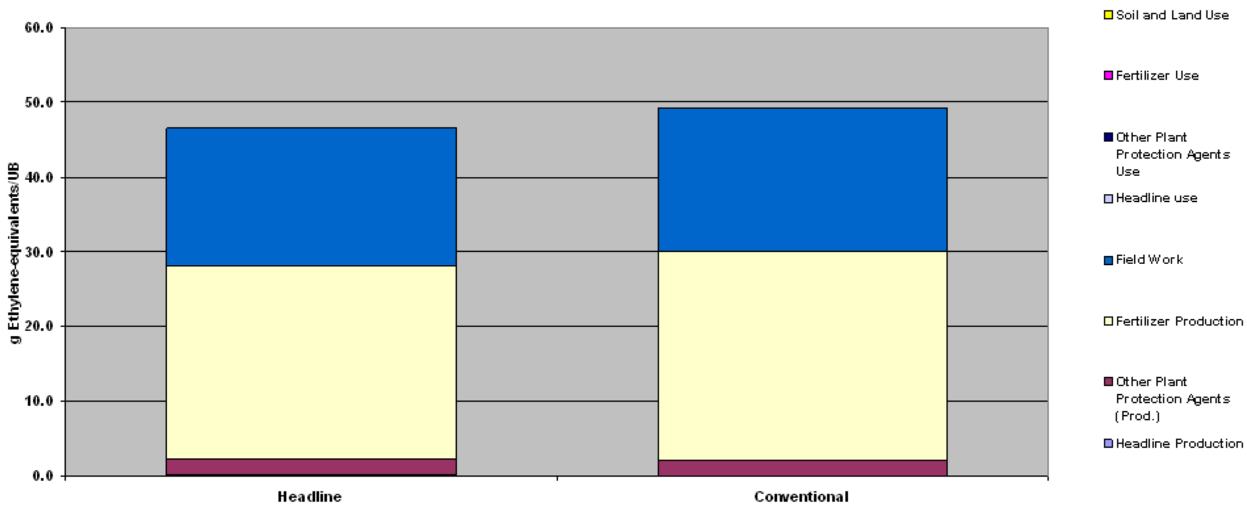



**Figure 10.** Photochemical ozone creation potential.

*8.1.3.3. Ozone depletion potential (ODP)*: Overall, the ODP emissions are very small and are dominated by the production of other plant protection agents (halogenated hydrocarbons) and from fertilizer production. The plant protection agents are the herbicides and additives. This environmental category has a very minor influence also and the results are shown in Figure 11.

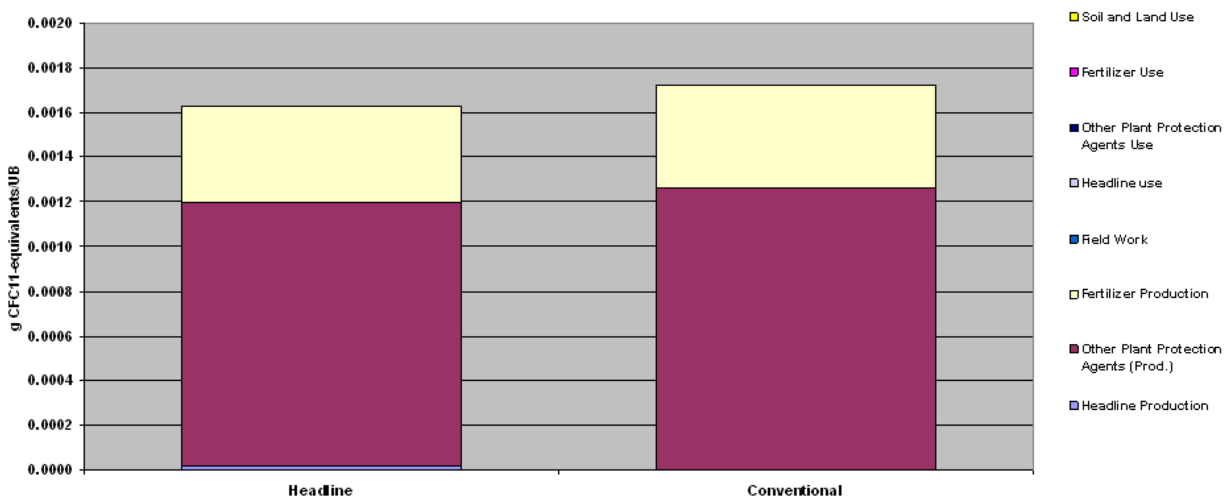



**Figure 11.** Ozone depletion potential.

*8.1.3.4. Acidification potential (AP)*: It can be seen in Figure 12 that overall, $NH_3$- and NOx emissions from fertilizer use are dominant. According to literature[9], 2% of N-fertilizers are emitted as $NH_3$ and 2% as NOx respectively. Another important fraction comes from fossil energy use for fertilizer production and field work (diesel and oil use / burning).

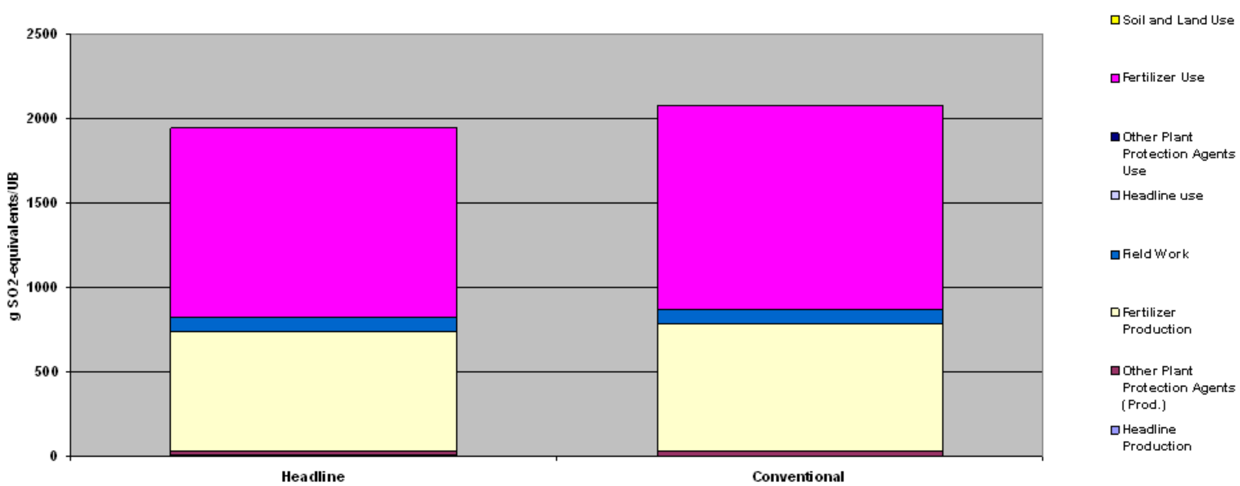



**Figure 12.** Acidification potential.

Figure 13 below, shows the relative impacts of the four air emissions: GHG, AP, POCP and ODP. These values are normalized and weighted based on the calculation factors (see Figure 32 for the calculation factor percentage). The calculation factor is a calculation of the relative environmental factors and the social weighting factors.

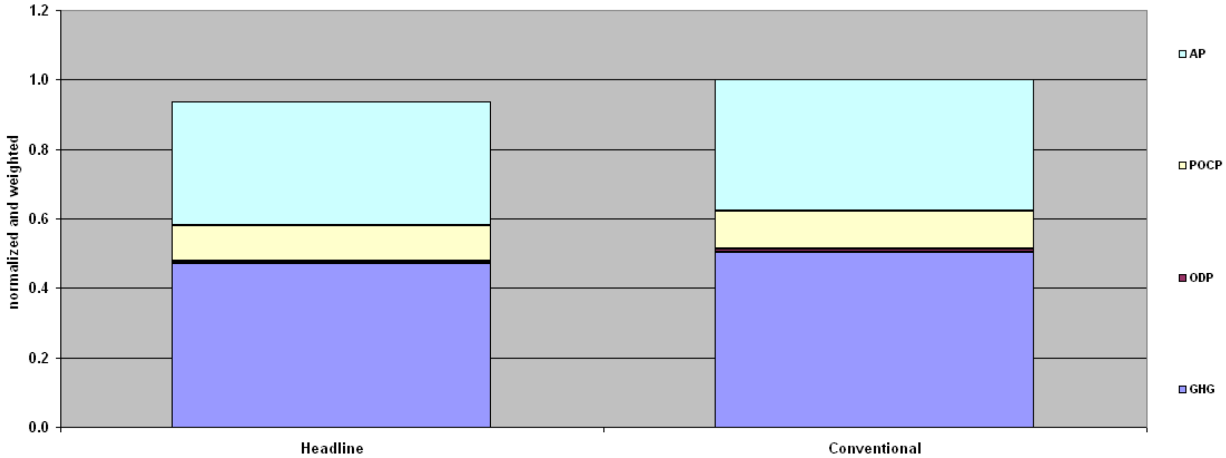



**Figure 13.** Overall Air Emissions

### *8.1.4. Water emissions*:

Figure 14 displays that water emissions are dominated by fertilizer use and plant protection agent use. The main substances emitted are heavy metals from fertilizers and carbon compounds (plant protection agents) causing chemical oxygen demand (COD). According to literature sources[10] mineral fertilizers contain a substantial amount of heavy metals (up to 2 g per kg). A worst case scenario was used here. Up to 10% of fertilizer N (depending on climate and region) ends up as a water emission. Since this number is highly variable, N-water-emissions and P-water-emissions were not included in the base case. In a scenario however 10% leaching of fertilizer N was assumed[11], this is plausible and shall at least be considered in a scenario (Scenario #5).

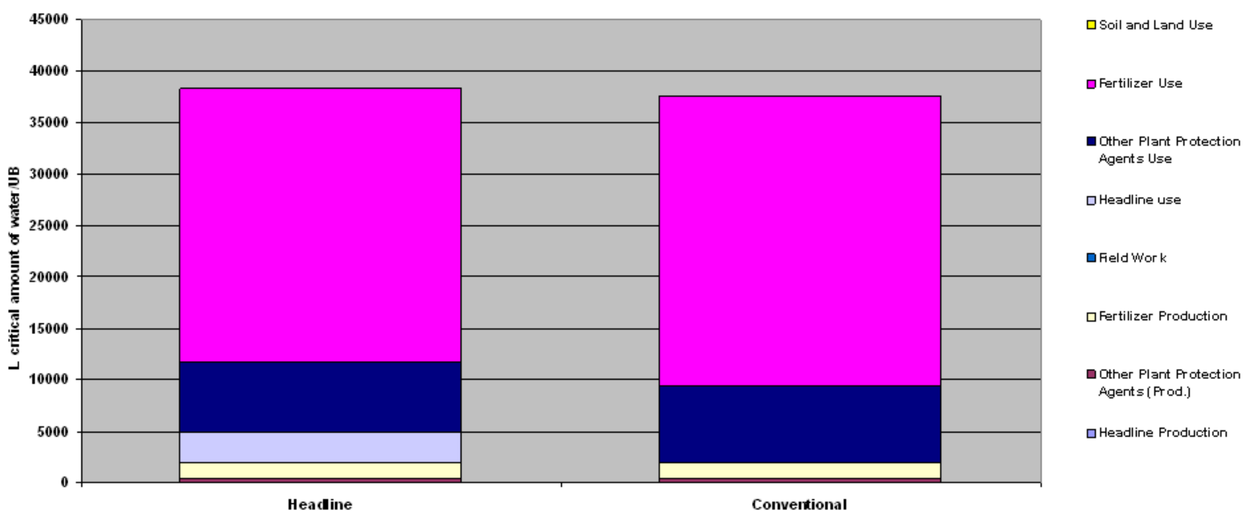



**Figure 14.** Water emissions.

### *8.1.5 Solid waste generation*:

Solid waste emissions have minor influence on the overall result. Solid wastes (chemicals) generated in fertilizer (and plant protection agent) production are dominating factor. These waste values include municipal, hazardous and mining waste. Hazardous waste is generated from production of pesticides, fertilizers and diesel. Figure 15 displays the solid waste emissions for the two alternatives.

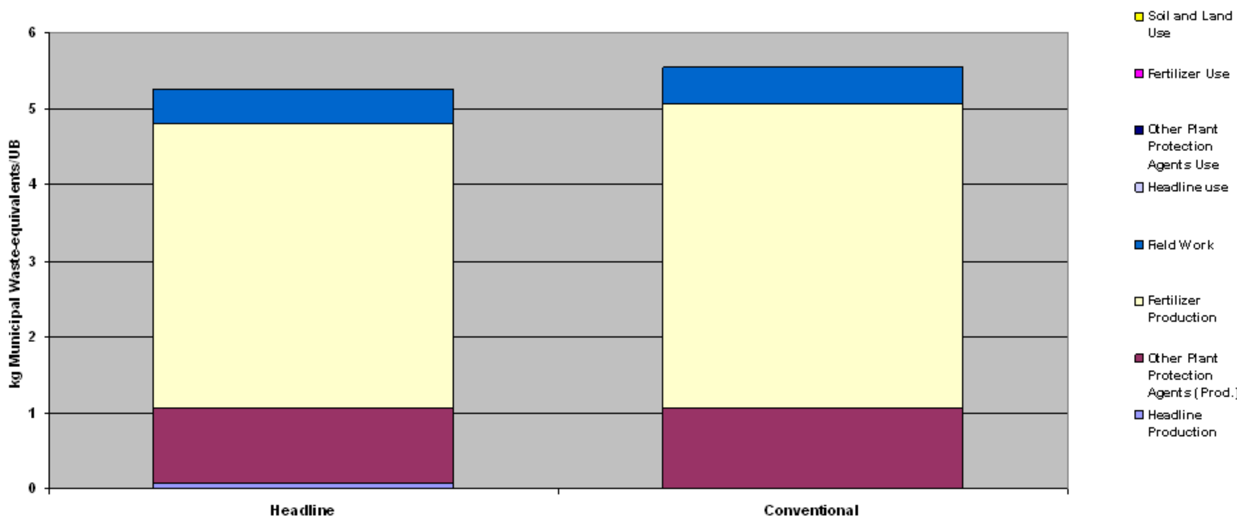



**Figure 15.** Solid waste generation.

### *8.1.6 Land use*:

As displayed in Figure 16, land use is one of the most important environmental categories for agricultural processes assessed with eco-efficiency analysis. The standard assessment is based on the so called hemeroby concept. This concept is a European approach and is a measurement of the total effects of human activities on the past and current land use. Different kinds of area use are weighted differently according to how much the use differs from “untouched land”. The BASF process evaluates land use as pasture, fallow, bio-agriculture, conventional agriculture, sealed land, roads, tracks, and canals. The end result showed that developed arable land (conventional agriculture) or farm land used is the dominant factor. All the other land use added together is less that 0.5 % of the total land use. Land use for production of chemical additives used is the next highest and this amount is negligible. Since the Headline® alternative produces more corn less land is needed than in the conventional alternative. These values are also normalized and weighted and 40 $m^2$ more land is needed to be transformed for the conventional alternative.

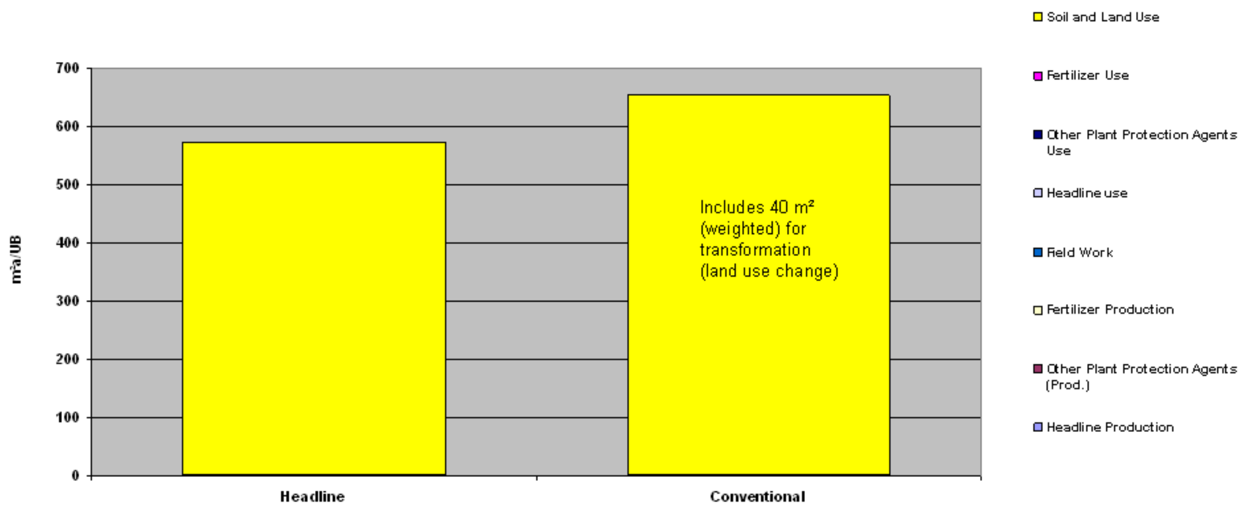



**Figure 16.** Land use – standard assessment.

### *8.1.7 Toxicity potential*:

The toxicity potential for the corn production with and without using the Headline® fungicide was analyzed for the production and use phases of their respective life cycles. For the production phase, not only were the final products considered but the entire pre-chain of chemicals required to manufacture the products were considered as well. Human health impact potential in the use phase consists of the material applications (e.g. application of fertilizers and the affect of these). Ecotoxicity was also evaluated for the use phase since the fertilizers and pesticides are sprayed on the soil. This study does look at the total toxicity based on the amount used for the one year growing season. The application of the Headline® fungicide is applied to the corn plant in the VT to R2 stage and most of the absorption of the fungicide is through the plant. There may be some over spray that gets to the soil and this was evaluated in the eco-toxicity analysis. As for the resistant of the fungi to the Headline® fungicide over time, this is reduced due to crop rotation as previously mentioned.

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.

Inventories of all relevant materials were quantified for two of the life cycle stages (production and use). Consistent with the methodology's approach for assessing the human health impact of these materials (ref. Section 6.8 of Part A submittal), a detailed scoring table was developed for each alternative broken down per life cycle stage. This scoring table with all relevant material quantities considered as well as their R-phrase and pre-chain toxicity potential scores[12] were provided to NSF International as part of the EEA model which was submitted as part of this verification. Figure 17 shows the human toxicity potential for both the Production and Use phase for each alternative. The values have been normalized and weighted. Human toxicity potential is decreased since it is strongly influenced by the amount of fertilizers used. Due to the higher yield, less fertilizer is used per ton of corn grown with Headline®.

Headline® use increases slightly the ecotoxicity potential of the Headline® alternative. As to be expected the application of the materials (fertilizer, herbicides and fungicide materials) as well as the higher weighting placed on the exposure during the Use phase contributed the largest amount to the ecotoxicity potential for each alternative. As the materials themselves are identical, the main difference between the alternatives is thus the application and use of Headline®. Figure 18 shows the ecotoxicity of the two alternatives.

The active ingredient in Headline® is pyraclostrobin and the toxicity of this material is roughly twice that of glyphosate, acetochlor and atrazine, the active ingredients in the herbicides. This statement is based on the scoring, which an example can be found in Section 6.8.2 of Part A submittal. However the amount used of the active ingredient in the herbicides is 10 to 20 times more than the amount used of the active ingredient in Headline®. Therefore there are benefits in toxicity with the use of Headline® due to the increase in yield and less fertilizer and less herbicide needed to produce 1 metric ton. From toxicity point of view, any increase in yield greater than 2% when using Headline® out weighs the toxicity of the use and application of the Headline®. Without the increase in yield, there would be no advantage of the Headline® for any of the environmental parameters.

Figure 19 shows the overall toxicity potential score for each alternative and how the scoring is distributed across the life cycle stages. The values have been normalized and weighted. For the weighting, the human health toxicity was weighted as 70% of the total toxicity potential with the Use phase making up 78% of this total and Production phase making up 22% of this total. The eco-toxicity made up the other 30% of the total toxicity potential with all of this being the Use phase. Consistent with the discussion above, the Use phase is the most significant and disposal was not evaluated. A high safety standard was assumed for the manufacturing processes for the raw materials. For the Use phase, an allowance was made to take into consideration the open nature of the application process. For the normalization, the highest toxicity potential alternative was set to a value of 1 and the other alternative was proportioned to this value.

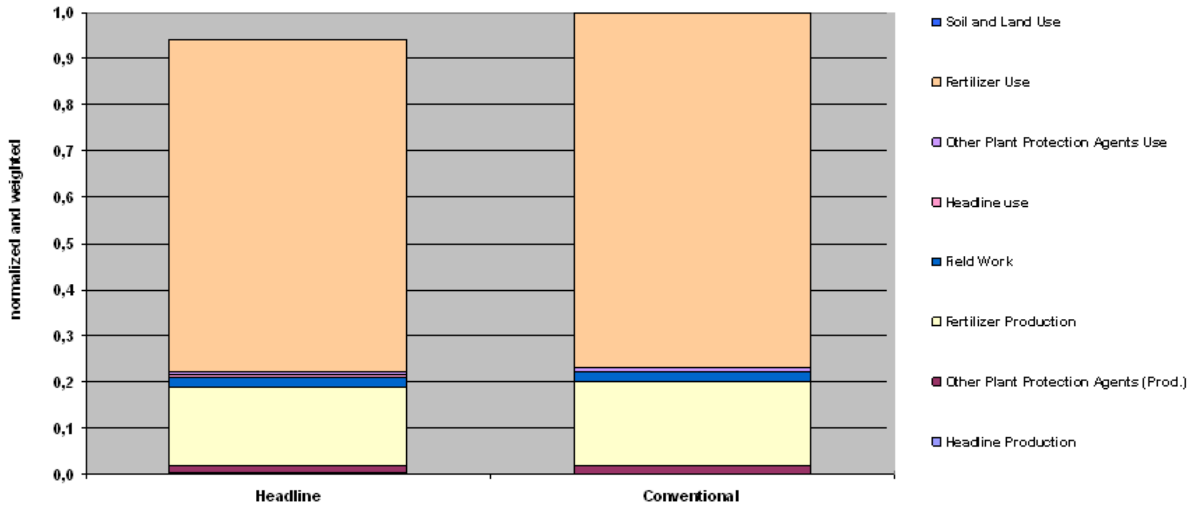



**Figure 17.** Human Toxicity potential

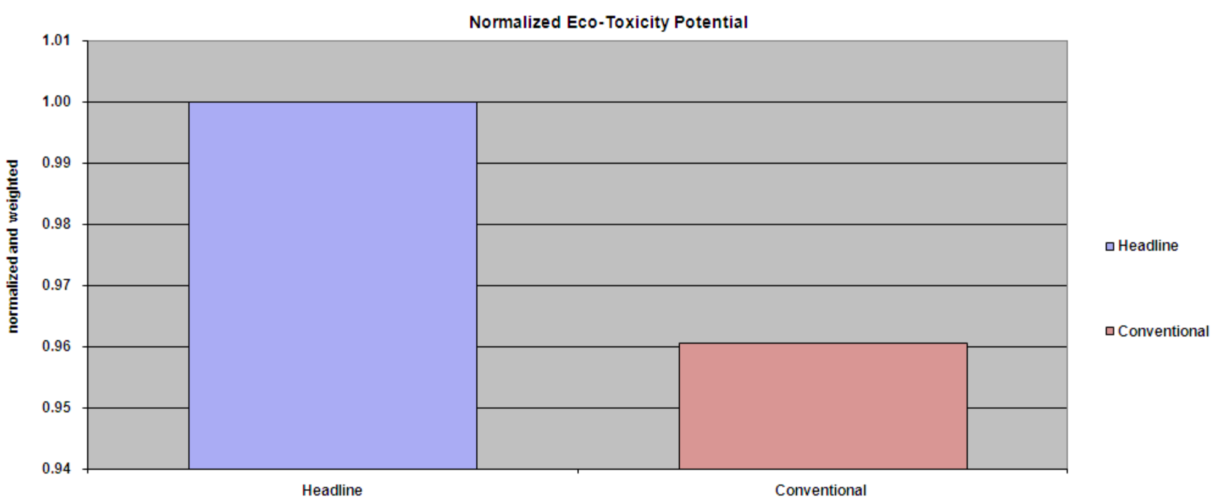
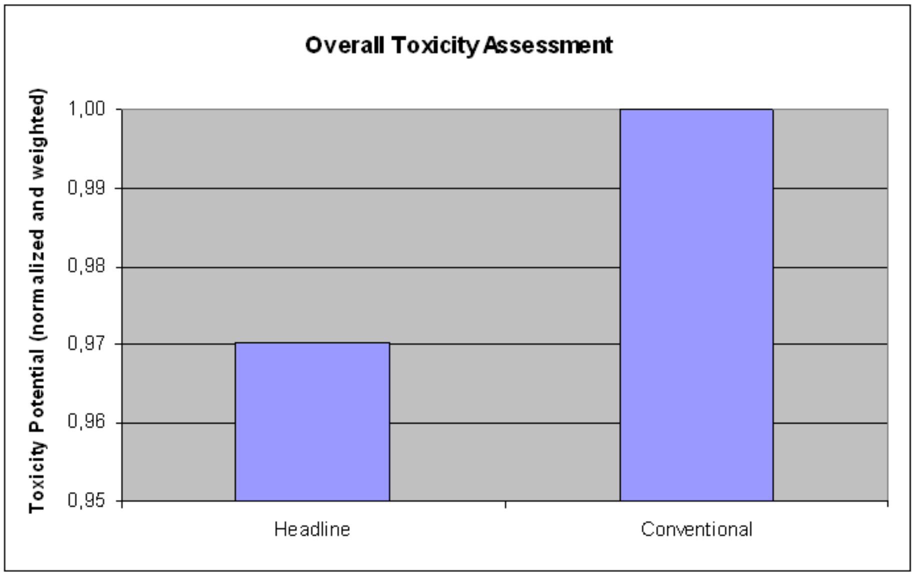



**Figure 18.** Eco-toxicity potential



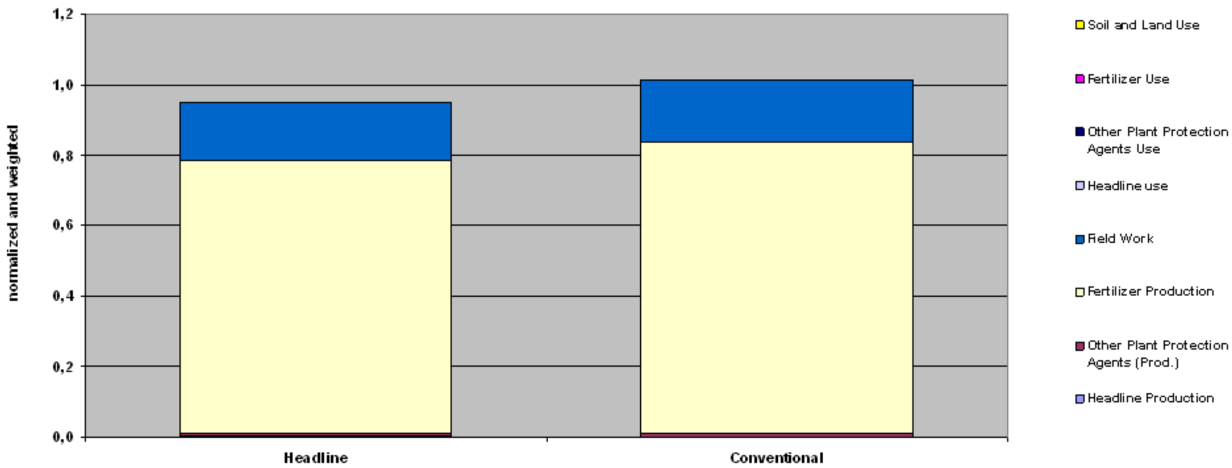

* Societal factor for toxicity assessment in the US is 19%. 70% were granted to human toxicity (78% use phase, 22% production phase, no disposal phase), 30% to ecotoxicity in the use phase.

**Figure 19.** Overall Toxicity potential - Life Cycle Phases

#### *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.

In Figure 20, the greatest Occupational Illnesses and Accident potential occurs in the production of fertilizers. The field work also contributes to the risk potential for occupational illnesses and accidents, but this does not include the cultivation process.




The cultivation process as such was not assessed. The higher chemical input (mostly fertilizer) for the conventional cultivation leads to a higher amount of accidents and occupational diseases.

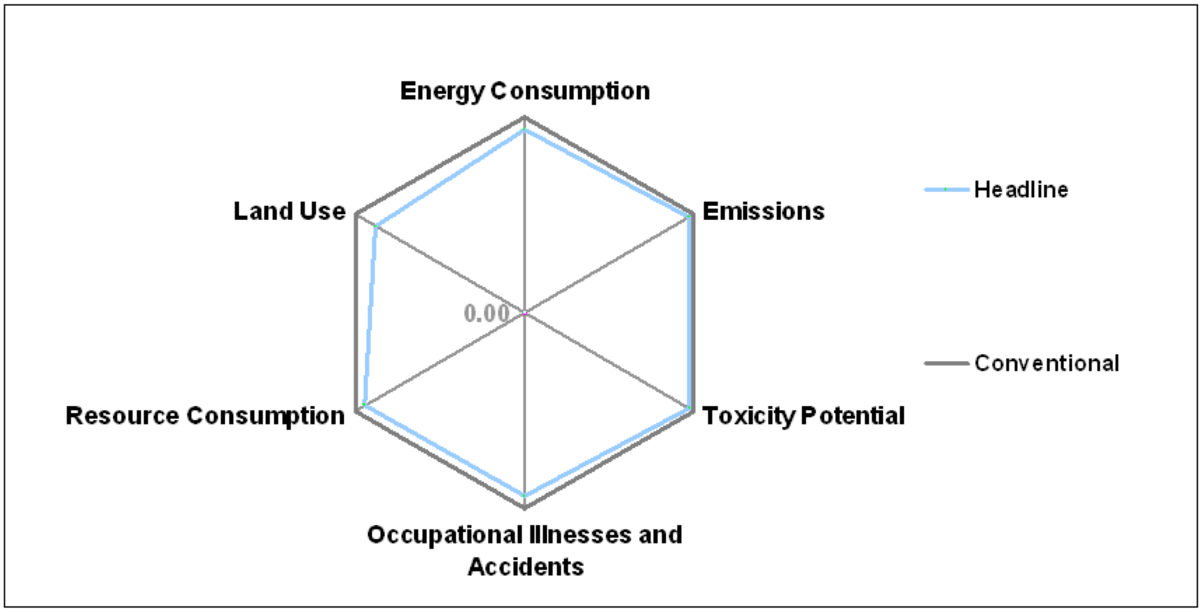
**Figure 20.** Occupational Illnesses and Accidents

### *8.1.9 Environmental fingerprint*:

Following different environmental impact categories in a normalized style and normalized and weighted with regards to emissions. The relative impact for all six of the environmental categories each alternative is shown in the environmental fingerprint (Figure 21). A value of 1 represents the alternative with the highest impact in the concerning category, all other alternatives are rated in relation to 1.

The conventional production of corn has the highest environmental impact in all categories, due to greater amount need to produce 1 metric ton of corn. Headline® fungicide performs the best in all categories due to requiring the least amount of material over the life-cycle. Due to the increased yield implied with using Headline® its advantages can be noticed in the following categories:

Resource consumption
Land use
Energy use
Occupationals diseases and working accidents




- A value of 1 represents the highest impact per category
- A value of 0 represents no impact

**Figure 21.** Environmental fingerprint.

## 8.2 *Economic Cost Results*:

The life cycle cost data for Headline® Fungicide EEA 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 Headline® Fungicide alternative has the lowest life cycle costs, even including the cost of Headline® and application. This again is due to the increased in yield when using Headline®. See Table 3 in section 6.2 above for production of 1 metric ton (1,000 kg or 2,204 lbs) of corn for each alternative. Figure 22 represents the graph of the costs for each of the alternatives based on the individual components.

The cost analysis is based on data from a "point in time" mainly from data supplied from 2009 to early 2010. Although this cost data may vary throughout the year, the input data is the same for both alternatives, but the amount will vary based on the yield increase. Because of both of these variables, the economic data may vary slightly depending on market prices and yield response.

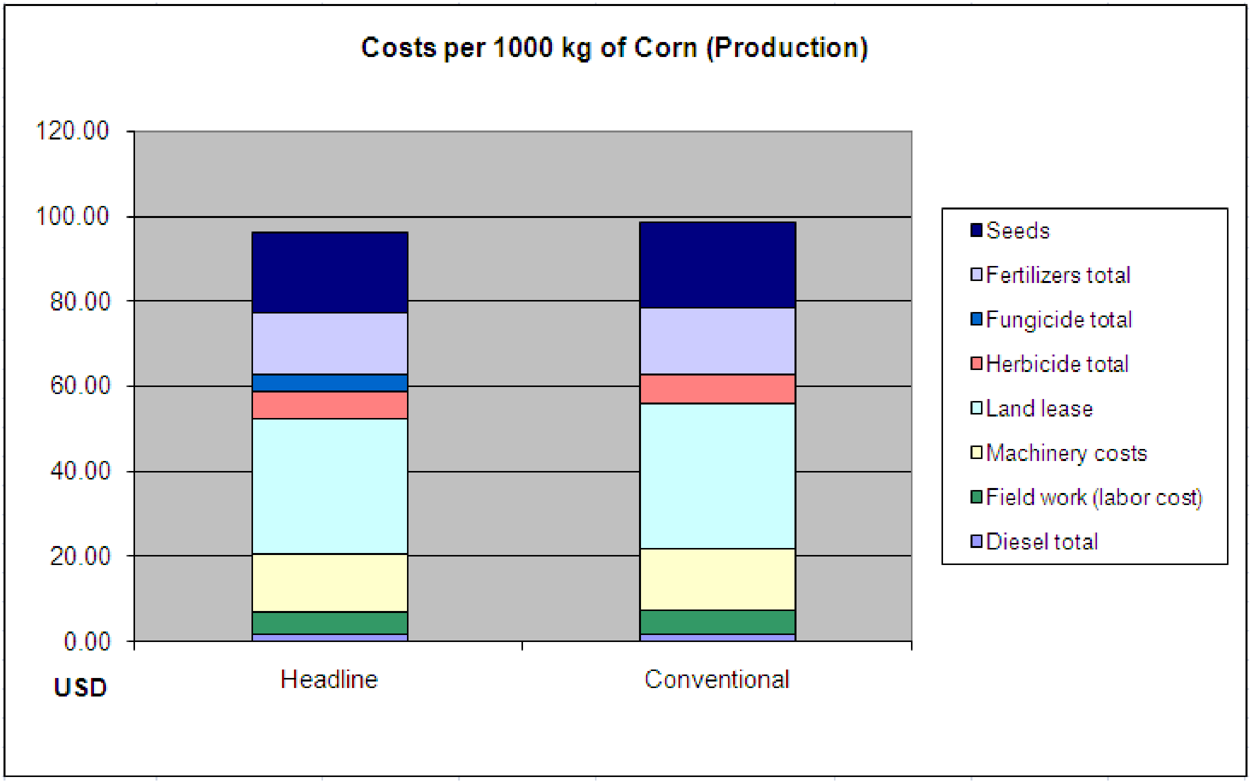



**Figure 22.** Life cycle costs – modules

## 8.3 *Eco-Efficiency Analysis Portfolio*:

The Eco-efficiency analysis portfolio for the Headline® Fungicide 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 2007 and the social weighting factors were recently updated in 2009 by an external, qualified 3rd party.

Figure 23 displays the Base Case (BC) eco-efficiency portfolio, which shows the results when all six 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 and the results from this study find that Headline® Fungicide is the more eco-efficient alternative due to its combination of lower environmental burden and having the lowest life cycle cost.

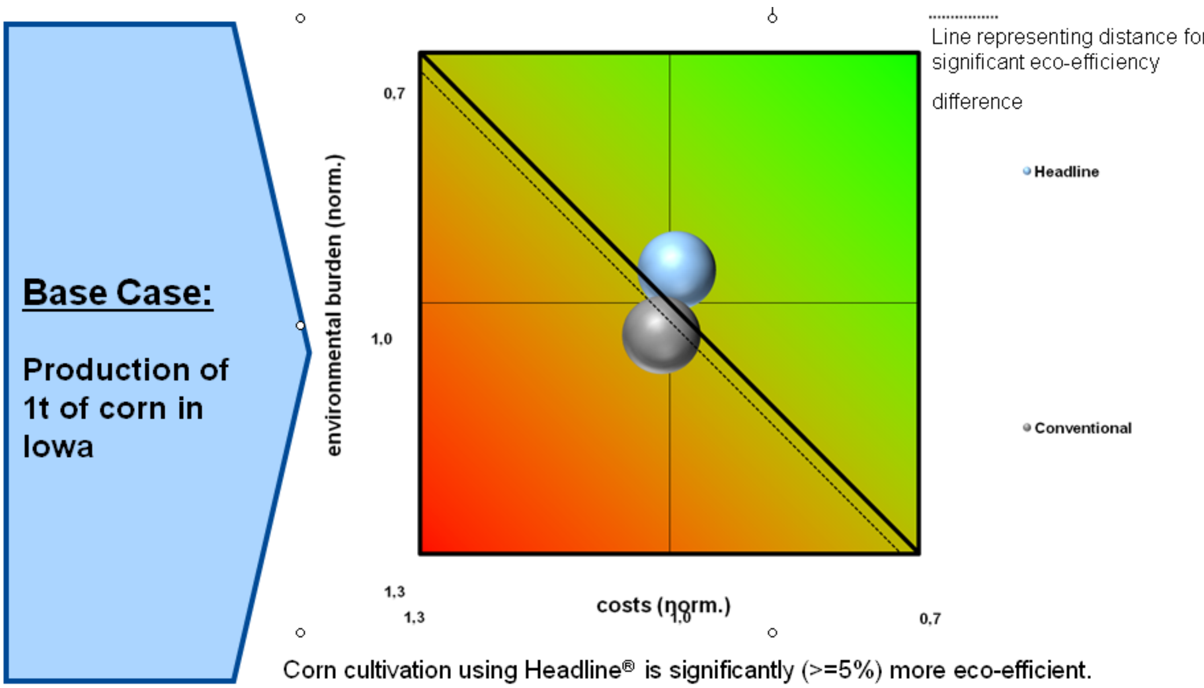



**Figure 23** Eco-Efficiency Portfolio Base Case – Headline® Fungicide – Corn Production

### *8.4 Scenario Analysis:*

#### *8.4.1. Scenario #1: 5% Increase in yield for corn in Headline® application (12% total yield increase over conventional corn production)*

As expected for this scenario analysis, a 5% increase in yield response with Headline®, further moves the Headline® in a sustainable direction and the conventional corn production moves further away from Headline®. There was an increase in the difference between the two alternatives of 5.4% in the environmental burden portion and a 5.1% increase in the difference for the costs in this scenario. With this study the environmental impacts and costs are clearly dependant on the yield production. An increase in yield greatly impacts the Eco-Efficiency Portfolio. Figure 24 shows the results of Scenario #1. It is reasonable to conclude that Headline® fungicide will maintain its preferable eco-efficiency relative to conventional corn production if yield is greater.

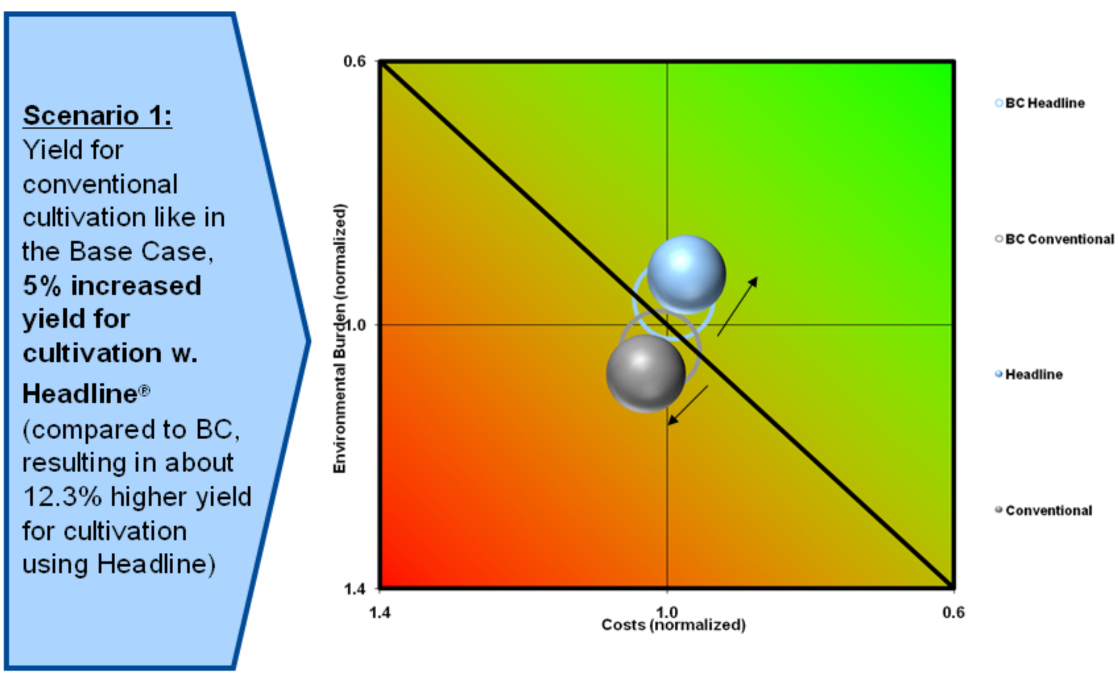



**Figure 24.** Scenario #1: 5% Increased Yield for Headline®

### *8.4.2. Scenario #2: 4% Decrease in yield for corn in Headline® application (3% total yield increase over conventional corn production)*

As expected for this scenario analysis, a 4% decrease in yield response with Headline®, moves the Headline® and the conventional corn production closer together. There was a decrease in the difference between the two alternatives of 4.3% in the environmental burden portion and a 4.1% decrease in the difference for the costs in this scenario. With this study, this scenario clearly emphasizes the effect on the environmental impacts and costs when yield production is decreased for Headline®. A decrease in yield greatly impacts the Eco-Efficiency Portfolio. Figure 25 shows the results of Scenario #2. Again, Headline® fungicide will maintain its preferable eco-efficiency relative to conventional corn production if yield is greater.

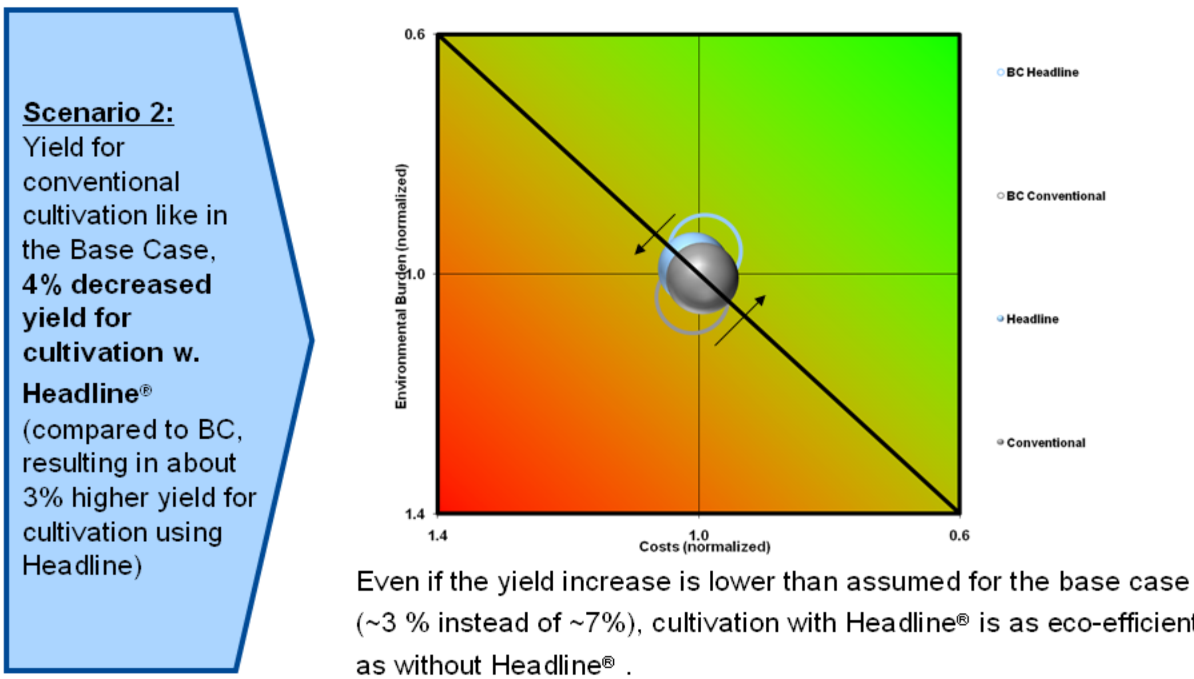



**Figure 25.** Scenario #2: 4% Decrease Yield for Headline®

### *8.4.3. Scenario #3: 6.5% Decrease in yield for corn in Headline® application (Yields similar)*

As expected for this scenario analysis, a 6.5% decrease in yield response with Headline®, moves the Headline® away from a sustainable direction and the conventional corn production becomes slightly more sustainable. Figure 26 shows the results of Scenario #3. Headline® fungicide does not maintain its preferable eco-efficiency relative to conventional corn production when yield is similar. There was a decrease in the difference between the two alternatives of 8.3% in the environmental burden portion and a 6.1% decrease in the difference for the costs in this scenario. The Headline® eco-efficiency is still within the 5% significance as shown in Figure 26 by the diagram with the dotted line. This shows that even with the similar yields, there is no significant difference between the two alternative.

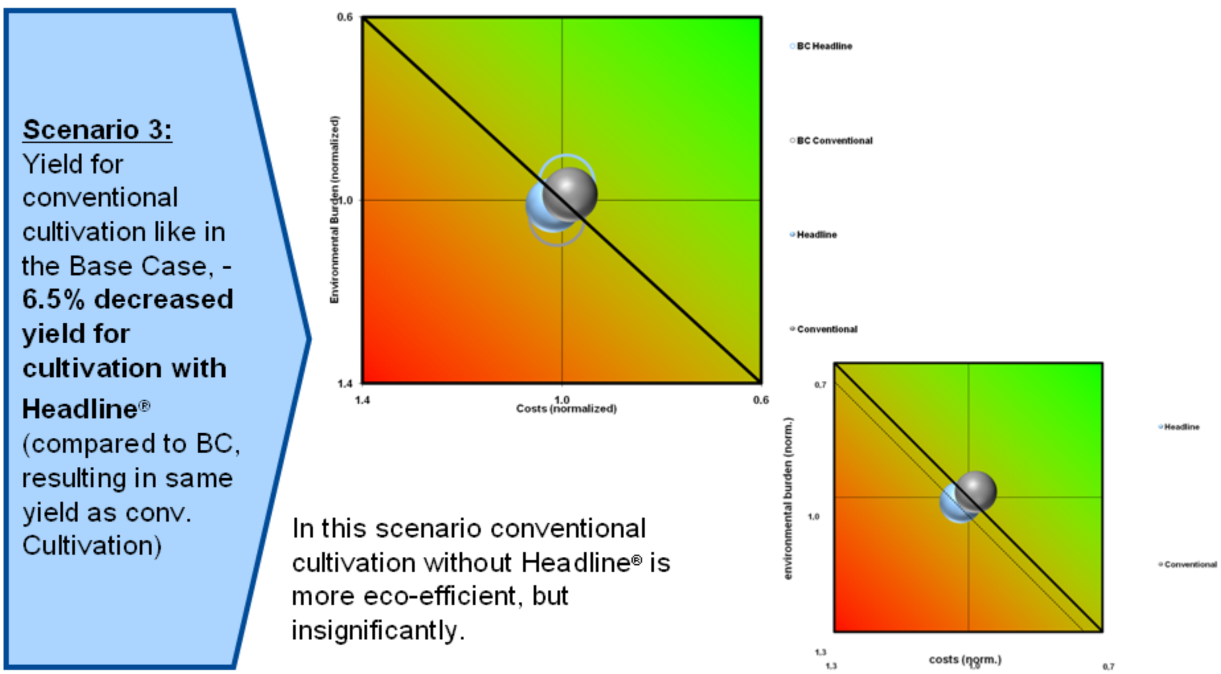



**Figure 26.** Scenario #3: 6.5% Decrease Yield for Headline®

### 8.4.4. *Scenario #4: $N_2O$-Emission from crop soils (8 kg $N_2O$-N per ha and year according to IPCC) not considered*

Scenario #4 shows the affect of not considering the $N_2O$-Emission from crop soils. The soil will emit $N_2O$ based on the N fertilizer used in the production of the corn. When this emission is not considered, there is no eco-efficiency difference between the two alternatives from the base case. There was no change to the difference between the two alternatives from the base case in this scenario. Figure 27 shows the results of Scenario #4. Headline® Fungicide was still the more eco-efficient alternative.

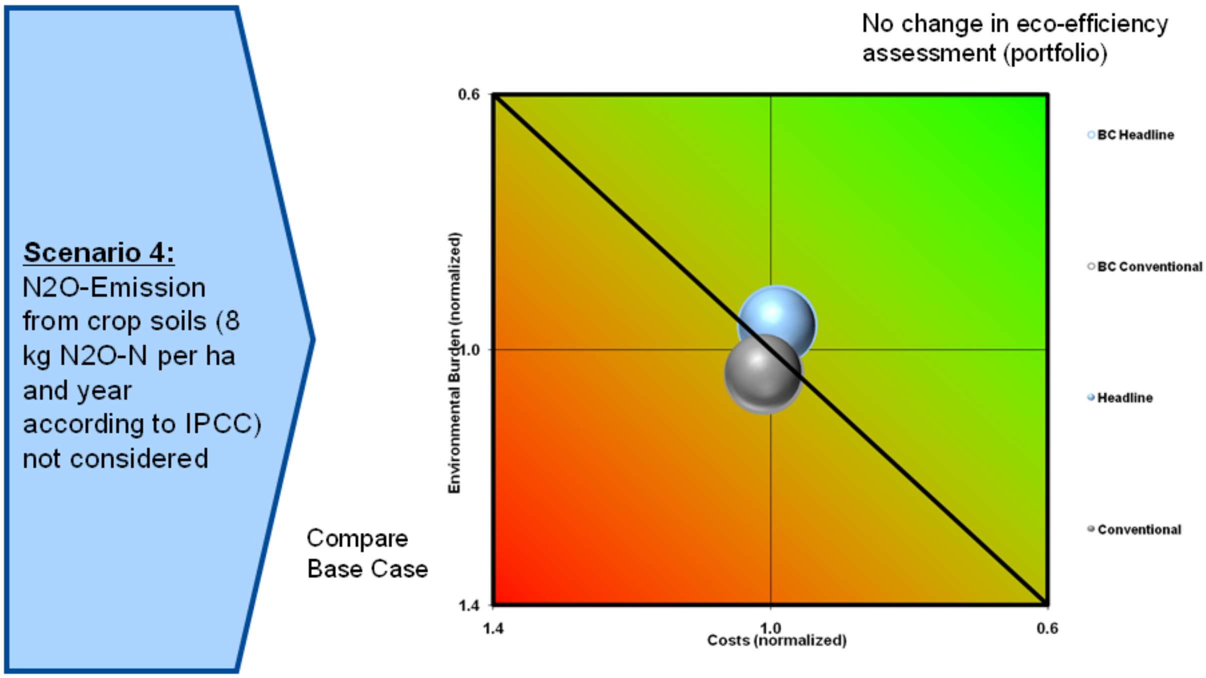



**Figure 27.** Scenario #4: $N_2O$ emission from crop soils not considered

### *8.4.5. Scenario #5: Water emissions (N) 10% of fertilizer N (base case: no N-water-emissions from fertilizer-N not considered)*

In Scenario #5, the water emissions from the use of the fertilizers are evaluated whereas in the base case these were not evaluated. Water emissions are now dominated by N-emissions of fertilizers and overall water emissions for Headline® alternative are smaller. As shown in Figure 28, the Headline® alternative is more eco-efficient; eco-efficiency difference becomes a little greater than in the base case. There was a decrease in the difference between the two alternatives of 0.15% in the environmental burden portion and a no change in for the costs in this scenario. Water emissions play a bigger role (calculation factor 21%) in environmental assessment. The Headline® Fungicide is more eco-efficient alternative in this scenario.

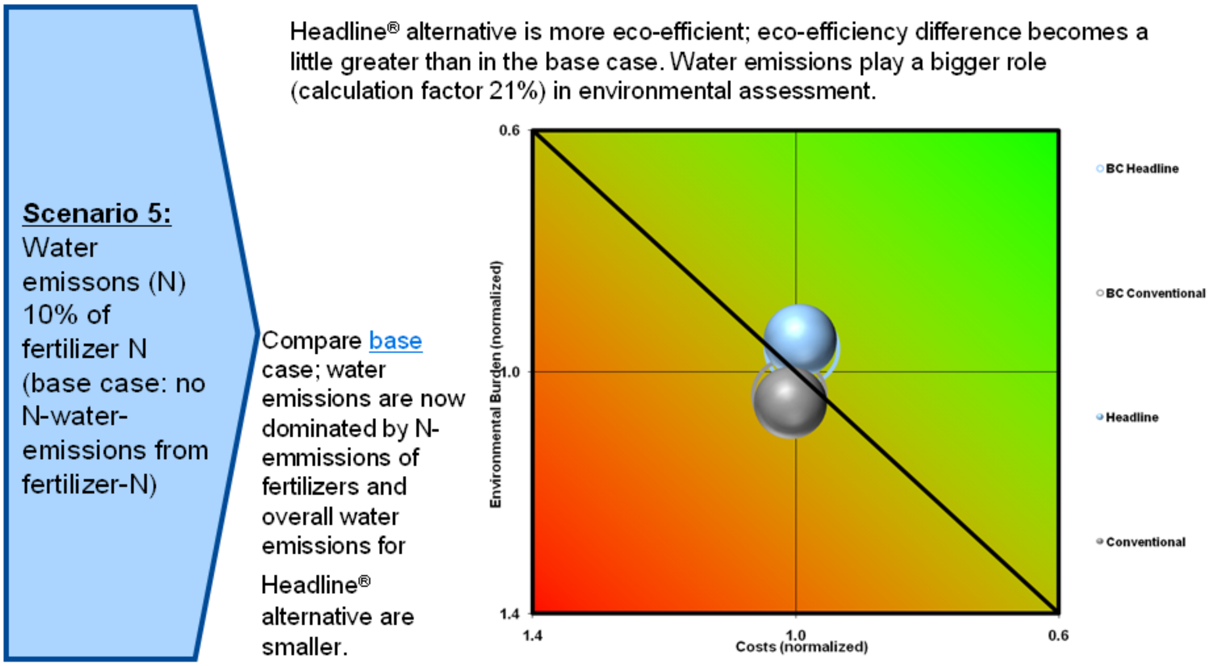



**Figure 28.** Scenario #5: Water emissions from N fertilizers

### *8.4.6. Scenario #6: Evaluation based on one hectare, with yield results equal.*

The base case and first five scenarios kept the customer benefit equal at 1000 kg corn, and modified the amount of inputs required per CB based on changes in crop yields. In Scenario #6, the input variables were all the same and based on one hectare. The yield results for both of the alternative were also equal. The only difference between the two alternatives was that the Headline® alternative had the use and application of the Headline® and the environmental and cost associated with the Headline® use and application. This scenario shows the impact of the use of Headline® for environmental and cost.

As shown in Figure 29, the Headline® alternative is shifted and is not as eco-efficient as the Conventional alternative. This shift is due to the environmental and cost affects of the Headline® only since every other input is equal. There was a decrease in the difference between the two alternatives of 8.3% in the environmental burden portion and a 6.1% decrease in the difference for the costs in this scenario. This figure also shows that the Headline® alternative is within the 5% significance, so the difference is minor and is not significant. This scenario shows that the use of the Headline® has minimal impact and cost impact when there is no increase in yield. If the impact from the extra yield was added, this would be equal to the Base Case. This scenario again shows the dependence of the yield on the significant difference between the two alternatives.

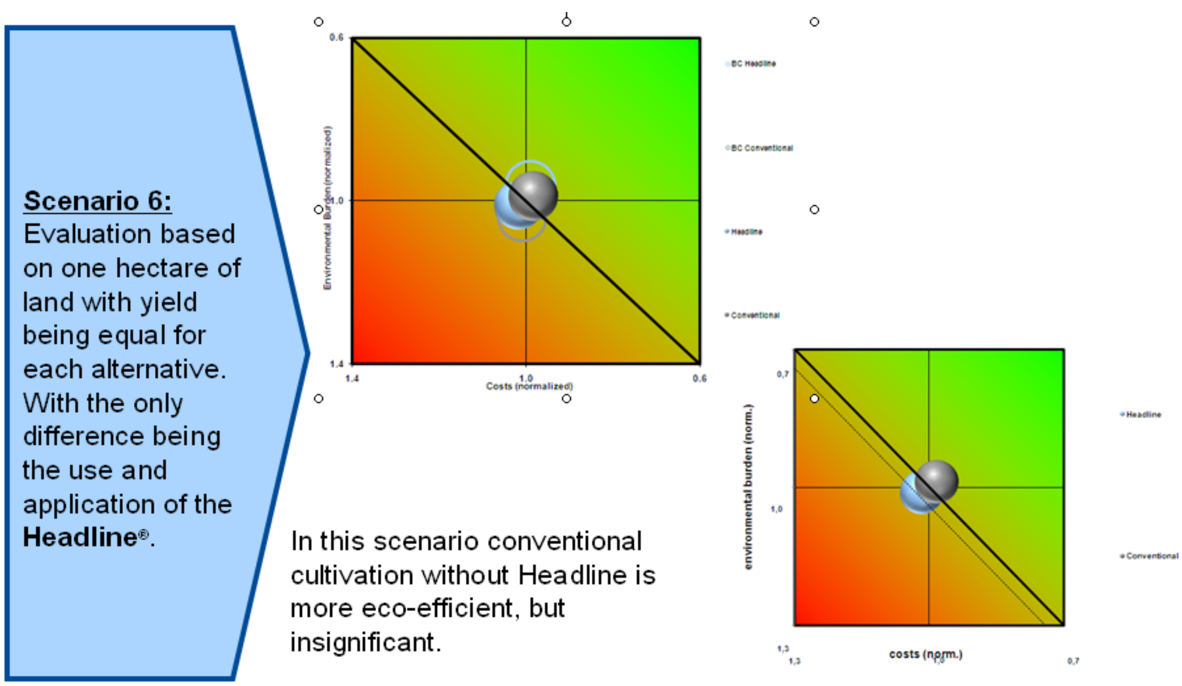



**Figure 29 .** Scenario #6: Evaluation based on one hectare, with equal yields

Figure 30 shows the environmental impacts of this scenario, shown in the environmental fingerprint for this scenario. The main environmental difference between the two alternatives in this scenario is the toxicity and the emissions from the use and application of the Headline®. This difference is minimal and there is only a slight shift in the diagram.

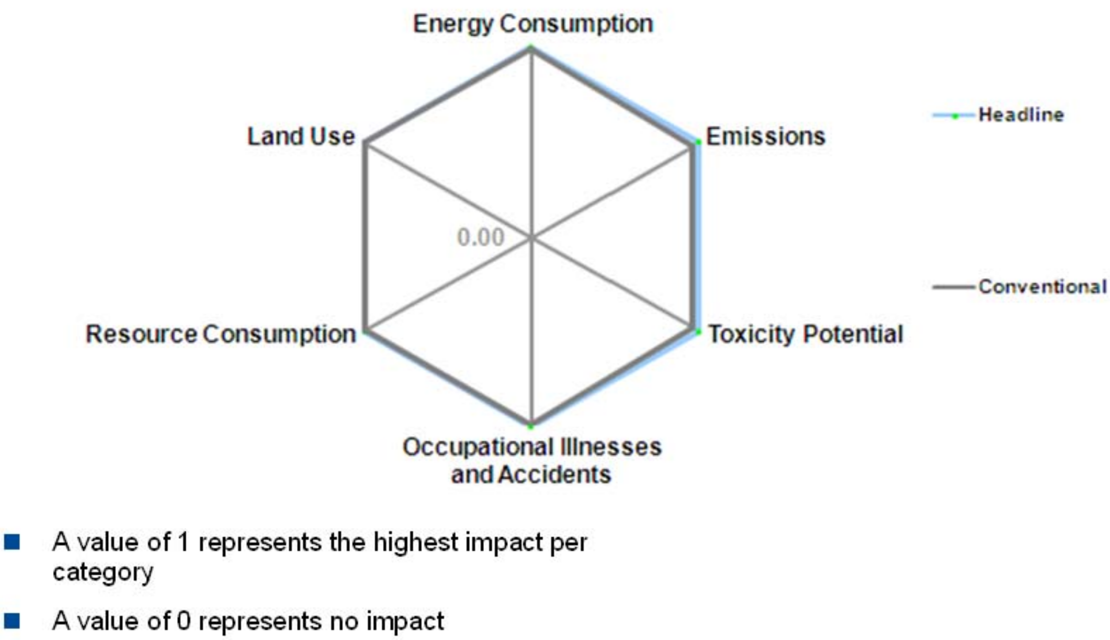



**Figure 30 .** Scenario #6: Environmental fingerprint based on one hectare, with equal yields

## 9. Data Quality Assessment

*9.1. Data Quality Statement*: The data used for parameterization of the EEA 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. The data is from agricultural production of corn in the state of Iowa and most of the data is from 2009 and 2010 sources. There are a few sources with data before 2009, see Appendix A for data sources and years. Table 6 provides a summary of the data quality for the EEA.

**Table 6:** Data quality evaluation for EEA parameters.

| Parameter | Quality Statement | Comments |
|---|---|---|
| Seed Parameter | | |
| Yield | High | Field trials at over 2,400 sites in the last 6 years. |
| Amount of corn seed planted | High | Iowa State University data. |
| Plant Protection | | |
| N-P-K Fertilizers | Mod.-High | USDA & Iowa State University. |
| Herbicides | High | Monsanto Company |
| Fungicide | High | BASF Agricultural Products data. |
| Application rates | High | BASF Agricultural Products data from field trials. |
| Crop Oil | Moderate | Agriliance, LLC. |
| Energy | | |
| Diesel Use Tractor | High | Iowa State University data. |
| Diesel Use Combine | High | Iowa State University data. |
| Fuel use aircraft | Mod.-High | BASF Agricultural Products data. |
| Field Work | Mod-High | Iowa State University data. |
| Machinery cost | Mod.-High | Iowa State University data. |
| Lease of Equipment | Mod.-High | Iowa State University data. |
| Lease of aircraft | Mod.-High | BASF Agricultural Products data. |
| | | |

## 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 BIP Relevance (or GDP-Relevance) factor calculated for the study. The BIP 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 BIP 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 BIP Relevance calculation). The main assumptions and data related to environmental impacts were:

- Yield
- Emissions
- Fertilizer Application 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. A closer look at the analysis (see Figure 31) indicates that the impact with the highest environmental relevance was land use, followed by emissions and toxicity potential. This is to be expected, as the study dealt with the production of a crop and the use of fertilizers. Air emissions were the most important in the emissions category. More specifically, GHG and AP are considered the two most important air emissions. The calculation factors (Figure 32), which considers both the social weighting factors and the environmental relevance factors, indicate which environmental impact categories were having the largest affect on the final outcome. Calculation factors are utilized in converting the environmental fingerprint results (Figure 21) into the final, single environmental score as reflected in our portfolio (Figure 23). The impacts with the highest calculation factors were similar to the environmental relevance factors, with regards to the six main impact categories. The emissions factor was slightly higher than the land use in the calculation factors. 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.

The input parameters for this study were mainly taken from research done at Iowa State University, which these would be considered highly credible. The production of corn is an annual process and crops are usually rotated year after year. In this study, the evaluation was done for one growing season and it was assumed that an alternative crop would be plant the next year

The benefit of using the Headline® fungicide to reduce the fungi amount or the elimination of the fungi or reduction effects of the fungi in other crops was not evaluated in this study. In this study the environmental effects of the fungicide over several years was evaluated in the Toxicity evaluation, based on the amount used for the one year growing season. BASF does have some data that shows less fertilizer and less water is needed when the fungicide is applied due to a healthier plant, but this was not evaluated in this study. This data was not used in the study because it is preliminary data and BASF wanted to compare known data from University trials.

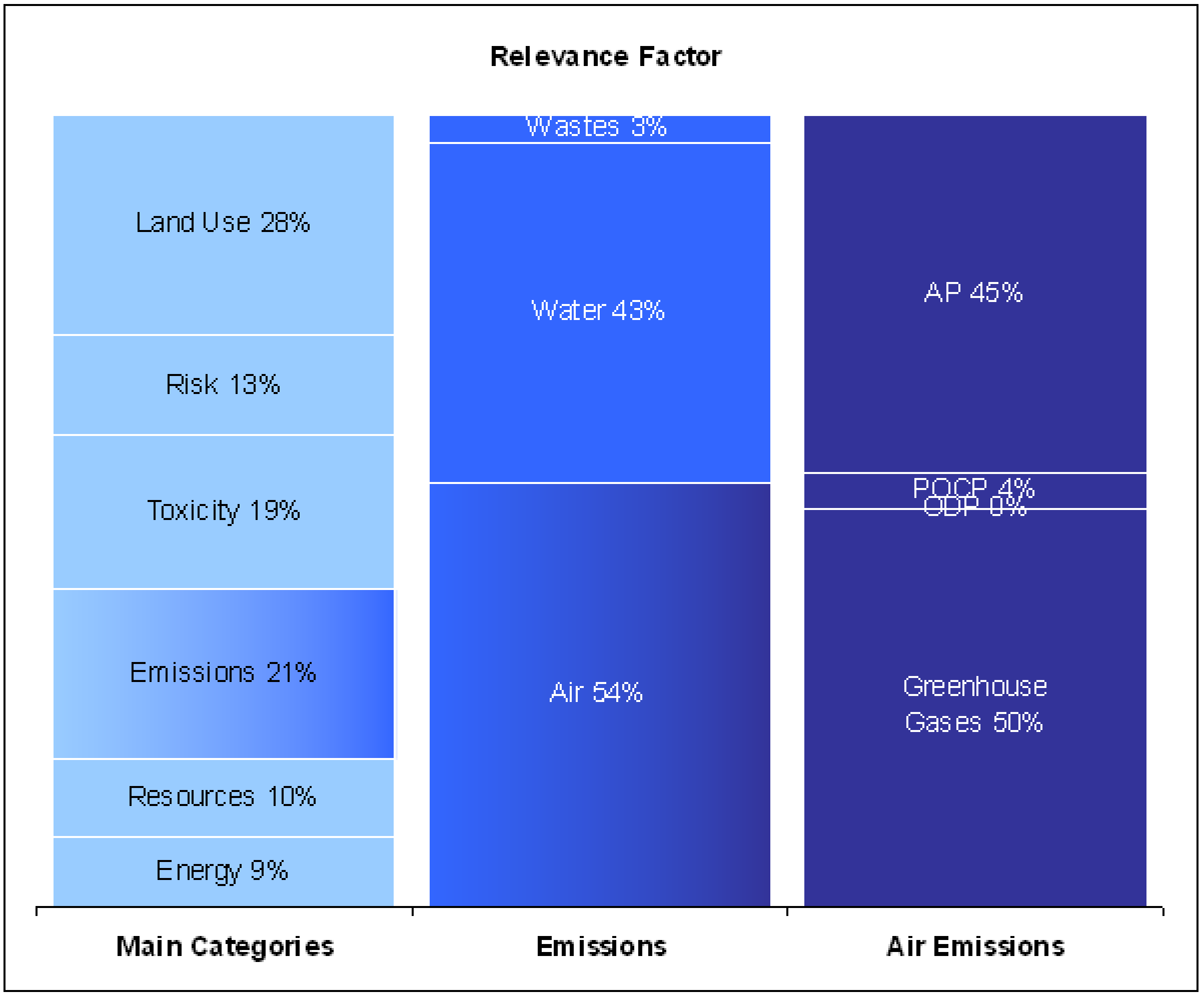



**Figure 31.** Environmental Relevance factors that are used in the sensitivity and uncertainty analyses.

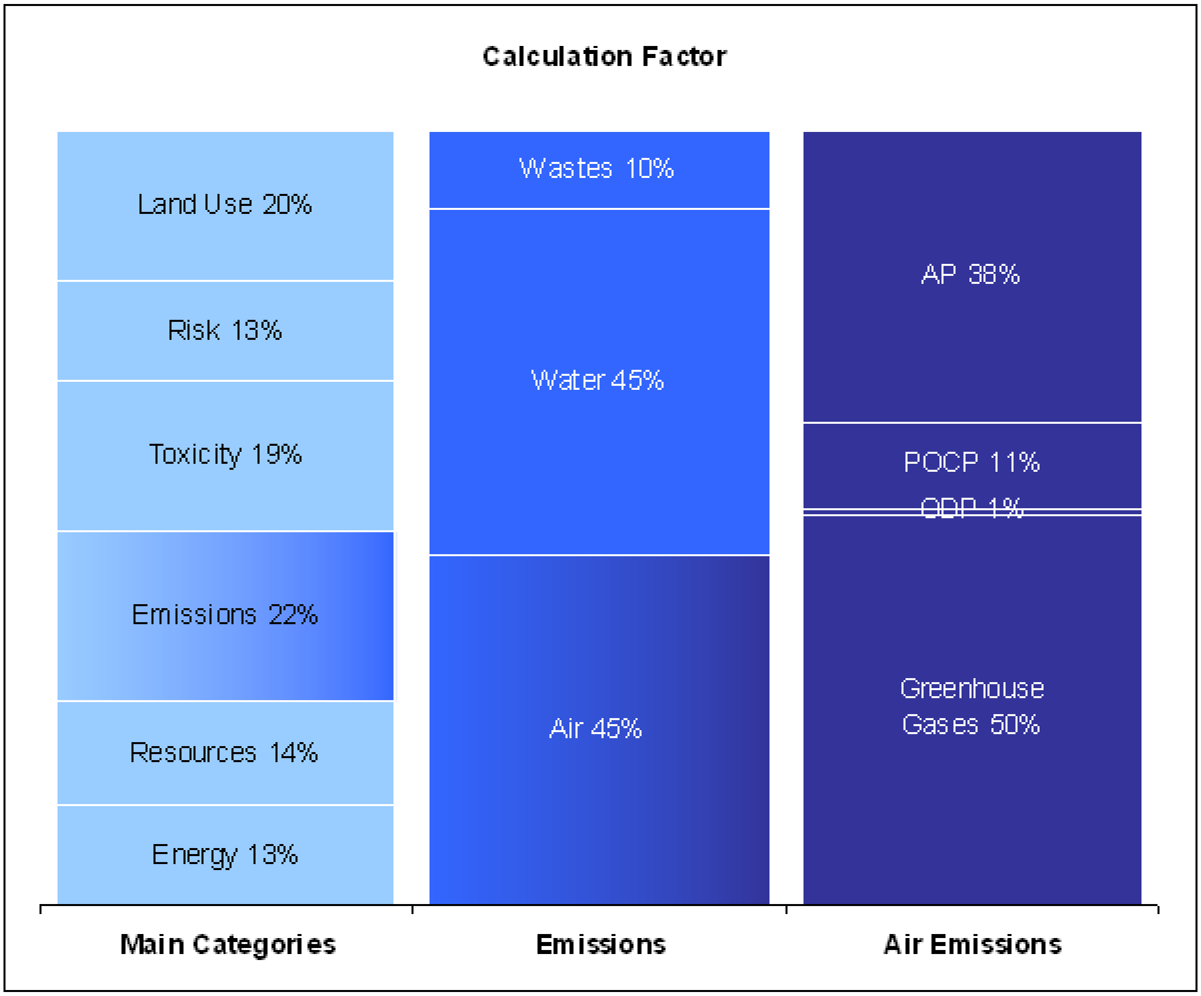



**Figure 32.** Calculation factors that are used in the sensitivity and uncertainty analyses.

### *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 EEA Study Results

### *11.1. Limitations*:

These 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. BASF Corporation, 2009 *Headline® Corn Yield Slides* Presentation, slides 9-10 average yield from Iowa State University trials (16 trials) from 2008 & 2009, January 2010.

2. BASF Corporation, *Headline® Fungicide Corn* Technical Information Bulletin, 2008.

3. BASF Corporation, *Safety data sheet HEADLINE*, Version 4.1, January 4, 2008.

4. Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, Chapter 11: N20 Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application, Table 11.1, page 11.11, 2006.

5. BASF Corporation, 2009 *Headline® Corn Yield Slides* Presentation, slides 9-10 average yield from Iowa State University trials (16 trials) from 2008 & 2009, January 2010.

6. Boustead Consulting Ltd UK, The Boustead Model 5.1.2600.2180 LCA database.

7. Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, *Chapter 11: N20 Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application*, Table 11.1, page 11.11, 2006.

8. Intergovernmental Panel on Climate Change, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, Chapter 11: N20 Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application, Table 11.3, page 11.24, 2006.

9. Klöpffer,W.; Department of the Environment/Federal Environment Agency Austria: Life Cycle Assessment of Genetically Engineered Products based on Comprehensive Assessment of Possible Environmental Impacts, internal BASF Ref.-ID 3411, 1999.

10. 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

11. 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

12. Landsiedel R, Saling P: Assessment of toxicological Risks for Life Cycle Assessment and Eco-Efficiency Analysis, Int J LCA 7(5) 262-268, 2002.

# Appendix A:

## Data Sources used for input data:

**Corn Seed:**

- Iowa State University - University Extension, *Corn Planting Guide,* pages 1-8, (Sept. 2001)
- 2010 Seed Resource Guide, Asgrow®, DEKALB® and Deltapine®, pages 14-39, 2010.

**N-P-K Fertilizer:**

- Iowa State University - University Extension, *Nitrogen Fertilizer Recommendations for Corn in Iowa,* pages 1-2, (May 1997)
- Iowa State University - University Extension, *A General Guide for Crop Nutrient and Limestone Recommendations in Iowa,* pages 1-21, (Sept. 2008)
- United States Department of Agriculture (USDA) Economic Research Service Website – http://www.ers.usda.gov/Data/FertilizerUse/ERS/USDS data, *U.S. Fertilizer Use and Price,* Tables 7, 8, 10, 12, 14, (Feb. 2010)

**Harness® Xtra:**

- Harness® Xtra Herbicide Label, Monsanto Company, pages 1-11, 2008
- Harness® Xtra Herbicide Safety Data Sheet, Monsanto Company, Version 2.0, pages 1-13, Sept. 2007.

**Roundup PowerMax®:**

- Roundup PowerMax® Herbicide Label, Monsanto Company, pages 1-51, 2007.
- Roundup PowerMax® Herbicide Safety Data Sheet, Monsanto Company, Version 3.0, pages 1-9, Dec. 2007.

**Headline:**

- Headline® Fungicide Safety Data Sheet, BASF Corporation, Version 4.1, pages 1-8, Jan. 2008.

**Superb HC:**

- Superb® HC Label, Agriliance, LLC, pages 1-2.
- Superb® HC Safety Data Sheet, Agriliance, LLC, pages 1-4, June 1999.

**Application rates:**

- Iowa State University - University Extension, *2009 Iowa Farm Custom Rate Survey,* pages 1-2, (March 2009)

**Diesel use tractor/combine:**

- Iowa State University - University Extension, *Machinery Management-Fuel Required for Field Operations,* pages 1-2, (April 2001)
- Official Nebraska Government Website – http://www.neo.ne.gov.statshtml/187.htm, *Agricultural Prices for Bulk Delivery of Diesel Fuel in the Northern Plains,* pages 1-2, (May 2009)

**Fuel Use of aircraft:**

- BASF supplied information from trials

**Field work:**

- Iowa State University - University Extension, *Estimated Costs of Crop Production in Iowa-2010,* pages 1-7, (Dec. 2009)

**Machinery Cost:**

- Iowa State University - University Extension, *Estimated Costs of Crop Production in Iowa-2010,* pages 1-7, (Dec. 2009)
- Iowa State University - University Extension, *Estimating Farm Machinery Costs,* pages 1-8, (Nov. 2009)

**Land Lease:**

- 2008 Cash Rent: Cropland and Pasture, Iowa by County.