Ecotoxicity Emissions of Corn Production

by

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Abstract

The population continuously rises throughout the world. As the that number continues to rise, so will the need for crops. The growth of the agricultural market will require an increase in herbicide, fertilizer, and irrigation, especially in the Midwest where higher yields are achieved with higher agrochemical application and irrigation. For an environmentally friendly increase in crops, it is important for farmers to identify and explore agricultural techniques that result in maximum yields with minimum impact. The Testing Ag Performance Solutions (TAPS) program allows for farmers to experiment with irrigation and farming practices while participating in a farm management competition.

This Honors Project analyzes the ecological toxicity impacts for corn production over 34 differently managed TAPS fields and assesses the inputs of herbicides and fertilizers. The impacts were assessed using USEtox characterization factors from TRACI 2.0 and the impact category analyzed was ecotoxicity, which is generally overlooked in corn production analyses. TAPS data was analyzed using a reference seed/seeding rate and variable seed/seeding rates determined by the farmer.

It was found that the ecotoxicity of corn production for agricultural soil ranged from 15.51 to 31.22 CTUeco/kg corn for reference seed/seeding rate and 13.54 to 37.02 CTUeco/kg corn for variable seed/seeding rate. Ecotoxicity for freshwater was generally higher, ranging from 49.39 to 99.37 CTUeco/kg corn for reference seed/seeding rate and 43.09 to 117.87 CTUeco/kg corn for variable seed/seeding rate. Finally, the ecotoxicity for air ranged from 19.09 to 38.43 CTUeco/kg corn for reference seed/seeding rate and 16.66 to 45.57 CTUeco/kg corn for variable seed/seeding rate. Results showed that the largest contributor to ecotoxicity was fertilizer for agricultural soil with 68%, herbicide for freshwater with 80%, and fertilizer for air with 93%. Results for irrigation vs yield showed that for 6 to 6.75 inches of total irrigation, the produced yield was very similar to that of 6.75 to 10 inches. Total ecotoxicity and nitrogen input did not show consistent trends.

This report shows that corn production can have significant ecotoxicity impacts, though usually overlooked within studies. Finding sustainable irrigation and farming practices can potentially reduce these impacts while keeping a desired yield.

Ecotoxicity Emissions of Corn Production: An Honors Report

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Executive Summary

The population continuously increases within the United States and throughout the world. As the number of people continues to rise, so will the need for crops including corn. The growth of the agricultural market will give way to an increase in needed herbicide, fertilizer, and irrigation, especially in the Midwest where higher yields are achieved with higher fertilizer application and irrigation. For an environmentally friendly increase in agricultural products, it is important for farmers to identify and explore irrigation and agricultural techniques that result in maximum yields with minimum agrochemicals and irrigation. The Testing Ag Performance Solutions (TAPS) program allows for farmers to experiment with irrigation and farming practices while participating in a farm management competition.

This study analyzes the ecological toxicity impacts for corn production over 34 differently managed TAPS program fields and assesses the inputs of various chemicals through herbicides and fertilizers. The impacts were assessed using USEtox characterization factors from TRACI 2.0 and the impact category analyzed is ecotoxicity to freshwater, agricultural soil, and air, an impact category generally overlooked during analysis of corn production. TAPS data was analyzed for 34 fields using a reference seed and seeding rate and 34 fields using variable seed and seeding rates determined by the farmer.

It was found that the ecotoxicity of corn production for agricultural soil ranged from 15.51 CTUeco/kg corn to 31.22 CTUeco/kg corn for reference seed and seeding rate and 13.54 CTUeco/kg to 37.02 CTUeco/kg for variable seed and seeding rate. Ecotoxicity for freshwater was generally higher, ranging from 49.39 CTUeco/kg corn to 99.37 CTUeco/kg corn for reference seed and seeding rate and 43.09 CTUeco/kg corn to 117.87 CTUeco/kg corn for variable seed and seeding rate. Finally, the ecotoxicity for air ranged from 19.09 CTUeco/kg corn to 38.43 CTUeco/kg corn for reference seed and seeding rate and 16.66 CTUeco/kg corn to 45.57 CTUeco/kg corn for variable seed and seeding rate. Results showed that the largest contributor to ecotoxicity was fertilizer with 68% for agricultural soil, herbicide with 80% for freshwater, and fertilizer for air with 93%. Results for irrigation vs yield showed that for 6 to 6.75 inches of total irrigation the produced yield was very similar to that of 6.75 to 10 inches of total irrigation. Total ecotoxicity and total nitrogen input did not show consistent trends. The ecotoxicity of corn production is dependent on the yield, which could fluctuate between blocks of land within fields.

This study shows that corn production can have significant ecotoxicity impacts, though usually overlooked within studies. Finding sustainable irrigation and farming practices can potentially reduce these impacts while keeping a desired yield.

1.0 Introduction and Background:

The population increases yearly within the United States and around the world. As this number consistently rises, it is imperative that crop yields rise with it. With an increase in crop yields, however, there is a potential increase in greenhouse gas emissions. Irrigation and fertilizer can present higher yields in Kansas, which is ranked eighth for corn production in the United States in 2023 (Dutton, 2020). As of 2012, corn was produced on virtually 50% of irrigated land in Kansas (Rogers & Lamm, 2012). Over the range of 1974 to 2008, the irrigated yield of corn showed an increased tread of 2.5 bushels/acre while the dryland yield of corn showed an increase of only 1.1 bushels/acre (Rogers & Lamm, 2012). This shows that irrigated field's yield increases more than double that of non-irrigated land. The common source of irrigation for land in Kansas is the Ogallala Aquifer, which has had a consistent decrease in water levels from 2018-2023 (Hanrahan, 2024). Most corn in Kansas is planted in cool soils with no tilling-cropping systems and show an increased yield with increased fertilizer application (Ciampitti et al., 2024).

In order to sustain this increase in crop yields, it is vital that farmers research and adopt sustainable and efficient agriculture practices. To advance this journey to sustainable agriculture, Kansas has participated in the Testing Ag Performance Solutions (TAPS). TAPS is a farm management competition that allows farmers to select a variety of variables, including seed variations, seeding rate, and crop insurance and make irrigation, fertilizer, and marketing decisions ("Testing Ag Performance Solutions (TAPS)," 2024). The purpose of this program is to encourage farmers to try new irrigation and agriculture management techniques on four test plots in Colby, Kansas in order to experiment new water management and farming practices.

This study uses life cycle assessment methods to analyze the potential ecotoxicity impacts to agricultural soil, freshwater, and air related to corn production, an impact rarely analyzed in most Life Cycle Assessments over corn production in the Midwest. The study will include ecotoxicity contributions from fertilizer application, herbicide application, and irrigation. The findings of this study are intended to be used for educational purposes for farmers or others who are curious about the environmental footprint of corn production and who are looking for ways to decrease it. This study will be released on the Kansas State University Honors Program website.

The study area under consideration here is the "Testing Ag Performance Solutions" (TAPS) program that is operated out of Colby, Kansas, United States. The system consists of 34 differently managed fields, with the function to produce the highest yield of corn while decreasing environmental impacts through fertilizer application, herbicide application, and irrigation techniques. The system includes agrochemicals in the form of fertilizer and herbicide as inputs and yield, emissions to rural air, emissions to water, and emissions to agricultural soil as outputs. The functional unit for this study, which is comparative in nature, will be one kg of corn.

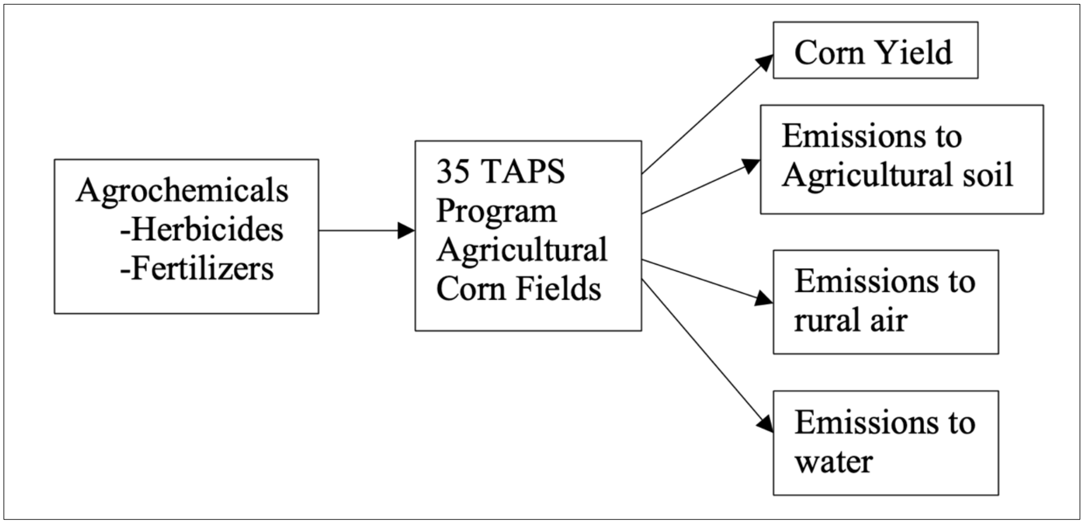

Figure 1. System Boundaries.

1.1 Literature Review:

Many life cycle assessment studies have been completed over the agricultural practices of corn production within the United States and throughout the Midwest. A majority of previous studies have focused on greenhouse gas emissions and the related global warming and climate change impacts. The studies have broken down the environmental impacts of corn production into two major categories: pre-field activities and in-field activities. Pre-field activities have been shown to encompass the production of agricultural necessities, including seed, energy, and fertilizer which occurs before the crop is planted and harvested (Koushki et al., 2020; Li et al., 2021). In-field activities can range from groundwater pumping, fertilizer application, tillage and planting, and harvesting (Koushki et al., 2020; Li et al., 2021). With these pre-field and in-field sources of GHG emissions, high GHG emission activities can be observed, and farmers can be directed towards more sustainable practices.

A study over the 2020 TAPS program in Oklahoma by Koushki et al. (2020) found that the GHG emissions from in-field activities such as groundwater pumping and fertilizer application represented the majority, 63%, of total GHG emission. The largest portion of those in-field GHG emission came from direct soil emissions in the form of nitrous oxide (N2O) (Koushki et al., 2020). This is consistent with the findings from a study over the life cycle and economic assessment of corn production practices in the U.S. corn belt. On-site soil emissions of N2O were found to have over 50% of the total GHG emissions for irrigated corn production in the panhandle of Nebraska (Li et al., 2021).

The herbicide application throughout the course of the TAPs program was a mixture of different herbicides and surfactants. Herbicide mixtures have modified properties and perform better than herbicides when used alone (Niedobová et al., 2019). These modified properties can make assessment of environmental impacts challenging because of the difference in behavior for single components, which are known, and mixtures, which are almost unknown (Krogh et al., 2002; Niedobová et al., 2019). For example, a study over the effects of herbicide and tank-mixing adjuvants on Pardosa spiders, a beneficial arthropod, showed that herbicide mixtures of glyphosate-based herbicides and surfactants notably decreased the predatory activity of Pardosa spiders (Niedobová et al., 2019). With that, research showed that non-mixture herbicide application did not show the same decrease in predatory activity (Niedobová et al., 2019). Beneficial insects help control agricultural pests, which is needed for supporting a healthy and balanced ecosystem (Gashler, 2024).

Previous studied have shown extensive research into the Global Warming Potential of corn production within the United States' Midwest. What has not been extensively studied are the ecotoxicity impacts related to corn production. This conclusion aligns with a US valuation exercise conducted by the National Institute of Standards and Technology (NIST), which showed that some impact categories receive more attention than others (Bare, 2012). Therefore, the purpose of this study will be to use TAPS program data over corn production in Kansas to expand light to an impact category that might not get as much attention, ecotoxicity.

Ecotoxicity is the potential of a compound or physical agent to cause harm to the environment and organisms (Gupta, 2022). Chemicals used within corn production agricultural practices could readily cause harm to the surrounding environment, so those impacts and potential opportunities to mitigate them through on-farm decision making will be highlighted using the TAPS Program data in this research paper. In the following sections I describe factors associated with ecotoxicity for a set of chemicals related to corn production.

1.2 Agrochemicals

1.2.1 Herbicides

There are nine components used within two different herbicide applications. These components are ammonium sulfate, valor, dicamba, atrazine, methylated seed oil (MSO), Resicore, atrazine, glyphosate, and nonionic surfactant. Each of these herbicides will be discussed to analyze their compositions and affinities to soil, air, and water.

1.2.1.1 Ammonia sulfate:

Ammonium sulfate is a versatile fertilizer that provides essential nitrogen and sulfur to a wide range of crops, commonly corn, wheat, and soybean, to enhance plant growth ("Ammonium sulfate fertilizer," 2024). The fertilizer, having the molecular formula $H_8N_2O_4S$, is a white, solid, inorganic sulfate salt created by the reaction of sulfuric acid and ammonia ("Ammonium Sulfate," 2024a). It is very soluble in water, which allows for plants to easily absorb the fertilizer, but is susceptible to leaching and runoff when excessively applied or during heavy rainfall ("Ammonium sulfate fertilizer," 2024).

1.2.1.2 Valor

Another herbicide used for control and suppression of weed growth in a variety of crops including corn, soybean, cotton is valor. Valor is a group 14 herbicide, which inhibits the ability for weeds to produce chlorophyll (Benajamin, 2024). According to the United States EPA, the active ingredient in valor is flumioxazin, having the chemical formula $C_{19}H_{15}FN_2O_4$, which is 51% of the herbicide ("VALOR Herbicide," 2018; "Flumioxazin," 2024g). The herbicide is toxic to non-target plants and aquatic invertebrates and is susceptible to drift or runoff into water when water levels are high ("VALOR Herbicide," 2018).

1.2.1.3 Dicamba

Dicamba, having the molecular formula $C_8H_6Cl_2O_3$, is an acidic herbicide in the benzoic acid group that can be used to control broadleaf weeds in agricultural and non-agricultural settings, with corn being one of the largest agricultural markets for the herbicide ("Dicamba," 2024b; Carbonari et al., 2022). Dicamba is a white solid when pure and is commonly dissolved in a liquid carrier, water ("Dicamba," 2024c). The herbicide has a low affinity to soil particles and is moderately volatile depending on amount applied, weather, and formulation of surface where it was applied (Carbonari et al., 2022). The herbicide is quickly biodegraded and is unlikely to leach into groundwater, but water contamination can occur by run-off during irrigation or heavy rainfall, spray drift, or vapor drift ("Dicamba – General Information," 2024).

1.2.1.4 Atrazine

One of the most commonly used herbicides in corn production that will be investigated in this article is atrazine. Atrazine, having the molecular formula $C_8H_{14}ClN_5$, is a chlorinated triazine systemic herbicide used primarily used on field corn, sweet corn, sorghum, and sugarcane to restrain the annual grasses and broadleaf weeds ("Atrazine," 2024). The herbicide is an odorless, white powder when pure, and is not very volatile, but dissolves in water. ("Atrazine," 2024b). The chemical properties of atrazine make the herbicide susceptible to leaching and runoff, especially during periods of excess rainfall, and it has a low affinity for soil particles (Ribaudo & Bouzaher, 2005; "Atrazine's Effect on Populations," 2023). According to a United States Environmental Protection Agency (EPA) chemical summary, atrazine degrades slowly when it enters water and is the most frequent detected pesticide in the U.S. Midwest Corn Belt region (2006).

1.2.1.5 Methylated Seed Oil

Another agrochemical used during corn production is methylated seed oil (MSO), also known as methyl esters. MSO is an adjuvant which maximizes the performance of post-emergent herbicides ("MSO," n.d.). MSO is produced from the esterification of vegetable oils with methanol to create fatty acid methyl esters (Seldes, 2023). According to the MSO safety data sheet, the adjuvant does not have any known ecotoxicity hazards, but large or frequent spills may have damaging effects ("Super Spread MSO," 2016).

1.2.1.6 Resicore

Resicore is an herbicide that is used in preplant, preemergence, postemergence in corn fields ("Resicore," 2024). The herbicide is made of a mixture of three herbicides which include acetochlor, clopyralid, and mesotrione and interferes with the normal germination and growth of many grass and broadleaf weeds ("Resicore," 2024). Resicore is toxic to non-target organisms and can adversely affect forage and habitats from spray drift ("Specimen label – Resicore," 2022). The herbicide is known to leach into soil and groundwater and has a high potential for reaching surface water from runoff water and sediment ("Specimen label – Resicore," 2022).

1.2.1.7 Glyphosate

Another commonly used herbicide for agricultural, residential, and commercial settings is glyphosate. Glyphosate, having the molecular formula C3H8NO5P, is an organophosphorus compound used for controlling broadleaf weeks and grasses ("Glyphosate," 2024b; "Glyphosate Contamination," n.d.). The herbicide is an odorless white powder when pure and is soluble in water, but not very volatile ("Glyphosate," 2024d). According to a public health goal report by the California EPA, glyphosate has an affinity to soil particles, and does not commonly move vertically into soil past the topmost layers (Ting, 2007). Glyphosate can enter water through three different methods: runoff due to irrigation or heavy rainfall, overspray, or spray drift into adjacent bodies of water (Ting, 2007; "Glyphosate Contamination," n.d.). The herbicide tends to remain in water systems as it does not readily break down ("Glyphosate Contamination," n.d.).

1.2.1.8 Nonionic Surfactant

Nonionic surfactants are used to improve pesticide efficiency by breaking the surface tension of water and increasing penetration and coverage of herbicides ("Nonionic Surfactants," n.d.). These surfactants have high soil adsorption and are easily degraded into soil, causing low environmental concentrations (Krogh et al., 2002). There is a possibility for low distance drift, but long-distance transport is not expected.

1.2.2 Fertilizers

Along with herbicides, fertilizers were also applied to the plots to enhance corn growth. These fertilizers were zinc sulfate, 12-40-0-10S 1Z Mesz, UAN 32%, Riser, and 10-34-0. Each of these fertilizers will be discussed to analyze their compositions and affinities to soil, air, and water.

1.2.2.1 Zinc sulfate

Zinc sulfate is an herbicide consisting of sulfur and zinc which is used for moss control in plants and agricultural crops (Boone et al., 2012). The herbicide binds to proteins or organic acids in plants, and with high concentrations can damage the cells of mosses and other plants, preventing growth (Boone et al., 2012). The herbicide is highly toxic to freshwater fish and invertebrates and can leach into groundwater where it is considered immobile due to binding with other substances (Boone et al., 2012; Seifi, 2022).

1.2.2.2 12-40-0-10S 1Z Mesz

12-40-0-10S 1Zn is a granular pre-plant fertilizer which contains and provides four nutrients to many crops, including corn. The nutrients nitrogen, phosphorus, sulfur, and zinc, which increase the phosphorus uptake in crops by up to 30% (“Crop nutrients,” 2024). The fertilizer is 75-85% soluble in water, so is likely to leach into soil and to water during times of large rainfall (“Safety Data Sheet – MicroEssentials SZ/MESZ,” 2020).

1.2.2.3 UAN 32%

A fertilizer used to provide nitrogen to crops is urea ammonium nitrate solution (UAN 32%). UAN 32% is a clear solution of ammonium nitrate and urea and is used to feed crops by supplying three forms of nitrogen: ammoniacal nitrogen, nitrate nitrogen, and urea nitrogen (“UAN-32,” n.d.). UAN32% is 100% soluble in water, and persists in water supplies (Law, 2015). The fertilizer is 35% urea and 45% ammonium nitrate (“Urea Ammonia Nitrate,” 2021).

1.2.2.4 Riser

Riser is a fertilizer that provides phosphate and micronutrients to help with growth and metabolism in many crops (“Every Crop Starts with Riser,” n.d.). The fertilizer is derived from UAN, ammonium polyphosphate, potassium acetate, zinc oxide, anhydrous ammonia, copper EDTA, iron HEDTA, manganese EDTA, and zinc EDTA (“Riser,” n.d.). According to a Riser safety data sheet, the fertilizer is a toxic hazard to fish and release to watercourses should be avoided (“Safety Data Sheet Riser,” 2015).

1.2.2.5 10-34-0

The last fertilizer used throughout the TAPS plots is 10-34-0, or liquid ammonium phosphate. The fertilizer is usually green in color and contains 10% nitrogen and 34% phosphate ("1-0-34-0 Liquid Ammonium Phosphate," n.d.). The fertilizer allows for the uptake of micronutrients in plants, supports root development, and prevents the growth of bluegrass ("1-0-34-0 Liquid Ammonium Phosphate," n.d.; "10-34-0 Ammonium Polyphosphate," n.d.). The solution is 100% soluble in water, so it is likely to leach into soil and enter water ways during times of high rainfall.

2.0 Inventory

The inputs and yield inventory for this study were obtained through the Testing Ag Performance Solutions (TAPS) program. The inventory data shows the yields from the plots as well as inputs of herbicides and fertilizers, some of which were kept constant while others were at the discretion of the farmers. Along with that, there is inventory data for a reference seed, Brevant B0rZ92AM, and seeding rate and for the farmers' choice of seed and seeding rate.

In order to find the potential ecotoxicity impacts of the herbicides and fertilizers, the inventory input data was converted from lbs/acre to kg/acre. The yield data was converted from bushels per acre to lbs/acre using the assumption that there are 56 lbs per bushel of corn on average (Luke, 2020). The yield was then converted to kg/acre.

3.0 Methods

3.1 Databases and ecotoxicity methods

3.1.1 TRACI 2.1

The TRACI 2.1, or "the Tool for the Reduction and Assessment of Chemical and other environmental Impacts," method was used to determine characterization factors to conduct impact assessment on the corn production in Kansas using the TAPS program inventory data. TRACI 2.1 is an impact assessment software tool developed by the United States Environmental Protection Agency (EPA) to assess environmental impacts using the best applicable methodologies (Bare, 2012).

TRACI 2.1's underlying methodologies use the amount of chemical emission and an estimated potency to determine the potential impacts of the emission (Bare, 2012). The estimated potency is determined by using specific models for specific impact categories (Bare, 2012). Characterization factors can be site specific, depending on the location of the emission, or global, not depending on the location of the emission (Bare, 2012). There are many impact categories that TRACI 2.1 provides, each chosen to encompass existing regulations and policies, recognized importance, and modelling ability (Bare, 2012). The impact category of focus in this research paper is ecotoxicity, which will use the non-site-specific model, Equation 1.

$I^i = \sum_{xm} CF^i{}_{xm} \times M_{xm}$..Equation 1

Where I^i is the potential impact of all chemicals, x, for a specific impact category i, $CF^i{}_{xm}$ is the characterization factor of chemical x emitted to media m for impact category i, and M_{xms} is the mass of chemical x emitted to media m at site s (Bare, 2012).

For ecotoxicity, TRACI 2.1 provides characterization factors for six different medias. These medias are: urban air, nonurban air, freshwater, seawater, natural soil, and agricultural soil (Bijster et al., 2017). The medias that were analyzed in this paper are: agricultural soil, freshwater, and rural air.

3.1.2 USEtox Model

The TRACI 2.1 method uses the USEtox model for ecotoxicity impact assessments. USEtox is a consensus model created by various multimedia model developers under the Life Cycle Initiative of the United Nations Environmental Program (UNEP) and Society of Environmental Toxicology and Chemistry (SETAC) (Bijster et al., 2017). The model is constructed to calculate characterization factors for human health and freshwater ecotoxicity (Bijster et al., 2017). The model uses a combination of fate factors (FF) from multimedia fate models, exposure factors (XF) from multi-pathway exposure models, and effect factors (EF) to calculate the characterization factors (Bijster et al., 2017). The equation used is Equation 2.

$CF^i{}_x = FF^i{}_x XF^i{}_x EF^i{}_x$..Equation 2

Where CF is the characterization factor for a chemical x in media i, FF is the fate factor for a chemical x in media i, XF is the exposure factor for a chemical x in media i, and EF is the effect factor for a chemical x in media i (Bijster et al., 2017).

With this calculation of characterization factor the impact score can be determined, or potential impact, for ecotoxicity expressed at a midpoint level in terms of potentially affected fraction (PAF) of freshwater species integrated over exposed volume and time (Bijster et al., 2017). The endpoint potential impact can be derived using Equation 3 in terms of potentially disappearing fraction (PDF) of freshwater species and with units of CDU_e.
$PDF = 0.5 \times PAF$..Equation 3

The framework for the USEtox model can be seen in Figure 2.

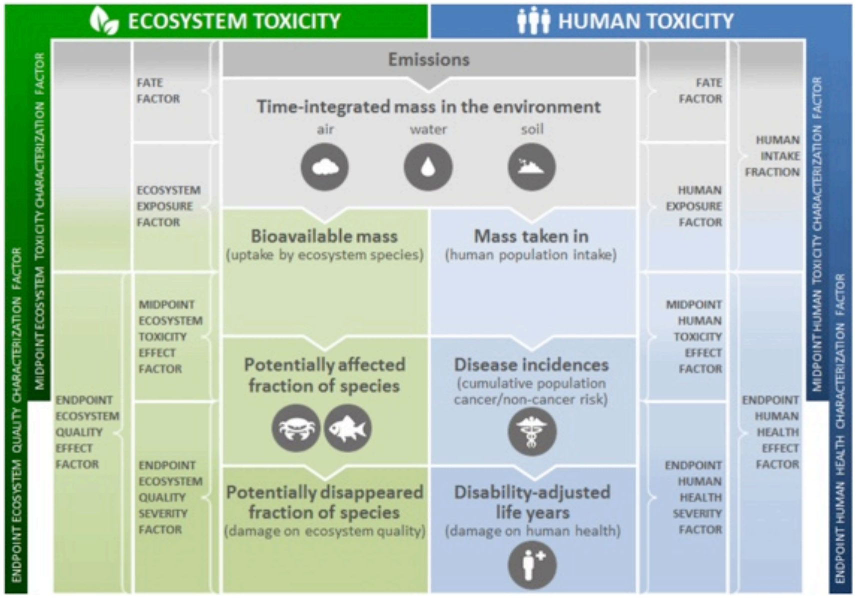

Figure 2. Framework for USEtox Model in TRACI 2.0.

Source: Adapted from Bijsteret al., 2017.

3.2 Life Cycle Ecotoxicity Emissions:

Ecotoxicity emissions for each field were determined by compiling the amount and composition of agrochemicals used in each field unit in the 2024 Kansas TAPS program. Due to lack of characterization factors within the ECOtox model, assumptions were made to determine the potential emissions.

3.2.1 Herbicides

<u>3.2.1.1 Pre-Emergence Herbicide</u>

The Pre-Emergency herbicide, which was used in uniform amount across all fields, consisted of valor, dicamba, atrazine, and methylated seed oil (MSO). The mixture, as per the TAPS data, was ammonium sulfate, 2.5 ounces/acre valor, 16 ounces/acre dicamba, 32 ounces/acre atrazine, and 128 gallons of MSO per 100 gallons of solution. To find the ecotoxicity of the pre-emergency herbicide, the fraction of each component was found by dividing the volume of that component by the total volume of the mixture, emitting MSO. The resulting compositions can be seen in Table 1.

Table 1. Component Mass Fractions for Pre-Emergence Herbicide.

Component	Mass Fraction
Valor	0.0495
Dicamba	0.3168
Atrazine	0.6334
MSO	N/A

The mass fraction was then multiplied by the total mass of herbicide used and by the characterization factor. A summation of those values resulted in the total ecotoxicity for the herbicide.

3.2.1.2 2nd Application Herbicide

The 2nd application herbicide, which was also spread uniformly across all plots of land, was a mixture of resicore, atrazine, glyphosate, and nonionic surfactant (NIS). The composition of the mixture was 2.5 qt/acre resicore, 32oz/acre atrazine, 32 oz/acre glyphosate, and 1 qt/gallons of water. Resicore was found to have a composition of 31% acetochlor, 3.3% mesotrione, and 2.7% clopyralid MEA salt (Baxter, 2016).

To find the overall ecotoxicity of the resicore portion of the herbicide, the mass of product was multiplied by the mass fraction of the resicore in the mixture, the mass fraction of the chemical within the resicore, and finally by the characterization factor. To find the overall ecotoxicity of the other chemicals, the same method as 2.3.1.1 was used. The results from this analysis can be seen in Table 2.

Table 2. Component Mass Fractions for 2nd Application Herbicide.

Component	Mass Fraction
Resicore	0.556
Acetochlor	0.031
Mesotrione	0.033
Clopyralid MEA salt	0.027
Atrazine	0.222
Glyphosate	0.222
NIS	N/A

3.2.2 Nitrogen Fertilizer

3.2.2.1 Dry Phosphorous Blend

The dry phosphorous blend, spread uniformly across all fields, was a mixture of zinc sulfate and 12-40-0-10S 1Z Mesz. The mixture is said to be 11.75 lbs/acre of zinc sulfate and 101.76 lbs/acre 12-40-0-10S 1Z Mesz. The analysis of the data showed that there was 12 lbs/acre of nitrogen, 40 lbs/acre of phosphorus, 10 lbs/acre of sulfur, and 5 lbs/acre of zinc.

In order to find the ecotoxicity of the fertilizer, the mass fractions of each chemical were found and then multiplied by the amount of fertilizer and the characterization factors for that chemical. The analysis of mass fractions can be seen in Table 3.

Table 3. Component Mass Fractions for Dry Phosphorous Blend.

Component	Mass Fraction
Nitrogen	0.1791
Phosphorus	0.5970
Sulfur	0.1493
Zinc	0.0746

3.2.2.2 Pre-Plant Nitrogen

The pre-plant nitrogen, which was spread across the fields at the farmers' discretion, consists of UAN 32%. UAN 32% is a mixture of water, urea, and ammonium nitrate. The composition of UAN 32% can be seen in Table 4.

Table 4. Component Mass Fractions for Pre-Plant Nitrogen.

Component	Mass Fraction
Urea	0.35
Ammonium Nitrate	0.45
Water	0.2

The same method as before was used and the total ecotoxicity was found by multiplying the mass of added fertilizer by the mass fraction of urea and then by the characterization factors for urea.

3.2.2.3 Side Dress

The side dress, which was applied in amounts chosen by the farmers, was UAN 32%. The same values and method as 2.3.2.2 were used to find the total ecotoxicity for this fertilizer.

3.2.2.4 Fertigation

There were four fertigations throughout the course of the TAPS program, each of which allowed farmers to add additional UAN 32% up to 30 lbs/acre. The same method as 2.3.2.2 and 2.3.2.3 was utilized to find the ecotoxicity of these fertigations.

3.2.2.5 Starter Fertilizer

The starter fertilizer, which was applied to the field in uniform amounts, consisted of 2 gallons/acre of Riser, 2 gallons/acre 10-34-0, and 4 gallons/acre water. The analysis of the data showed that there were 7.25 lbs/acre nitrogen, 23 lbs/acre phosphorus, 1.2 lbs/acre potassium, 0.3 lbs/acre copper, 0.08 lbs/acre iron, 0.02 lbs/acre manganese, and 0.38 lbs/acre zinc. To assess the ecotoxicity of the chemicals, the same analysis was completed as before by calculating the mass fraction of each component within the mixture. The results from the analysis can be seen in Table 5.

Table 5. Component Mass Fractions for Starter Fertilizer.

Component	Mass Fraction
Nitrogen	0.2249
Phosphate	0.7136
Potassium	0.0372
Copper	0.0093
Iron	0.0025
Manganese	0.0006
Zinc	0.0118

3.2.2.6 At-Planting Fertilizer

The at-planting fertilizer, which was applied at the farmers discretion, is UAN 32%. The same method as completed for 2.3.2.2, 2.3.2.3, 2.3.2.4 was used.

3.3 Irrigation

To analyze the relationship between total irrigation and yield, the average yield per field was plotted alongside total irrigation for greater than Q stable depth and less than Q stable depth. The

Q stable depth for this region is 7.65 inches, and it represents a rate of irrigation withdraw from the regional aquifer that would result in stabilized aquifer levels as opposed continued decline (Butler et al., 2016) . It was assumed that total irrigation was constant for the reference seed and seeding rate and varying seed and seeing rate.

4.0 Results and Discussion

4.1 USEtox Characterization Factors

Characterization factors for the set of chemical constituents that were found to comprise herbicide and fertilizer treatments applied during the 2024 Kansas TAPS program are presented in Table 6.

Table 6. Characterization Factors for Agrochemicals.

	Chemical constituent	**Ecotox. CF [CTUeco/kg], Em.airC, freshwater**	**Ecotox. CF [CTUeco/kg], Em.fr.waterC, freshwater**	**Ecotox. CF [CTUeco/kg], Em.agr.soilC, freshwater**
Herbicide	Ammonium Sulfate	N/A	N/A	N/A
	Valor	N/A	N/A	N/A
	Dicamba	3.39E+02	1.89E+03	4.76E+02
	Atrazine	3.29E+03	8.77E+04	1.14E+04
	Methylated Seed Oil	N/A	N/A	N/A
	Glyphosate	1.34E+01	3.21E+02	1.04E+02
	Nonionic Surfactant	N/A	N/A	N/A
	Acetochlor	1.37E+03	6.78E+04	7.61E+03
	Mesotrione	N/A	N/A	N/A
	Clopyralid MEA Salt	N/A	N/A	N/A
Fertilizer	Nitrogen	N/A	N/A	N/A
	Phosphorus	N/A	N/A	N/a
	Sulfur	N/A	N/A	N/A
	Zinc	3.86E+04	1.69E+04	2.11E+04
	Iron	N/A	N/A	N/A
	Urea	2.26805147	10.2429235	3.04863294
	Water	N/A	N/A	N/A
	Ammonium Nitrate	N/A	N/A	N/A
	Potassium	N/A	N/A	N/A
	Copper	2.33E+04	5.52E+04	2.92E+04
	Manganese	N/A	N/A	N/A

As seen in Table 6, there are many chemicals within the herbicides and fertilizers that did not have USEtox characterization factors. Therefore, the impacts associated with those chemicals were assumed to be negligible and were not included within the total ecotoxicity values.

4.2 Ecotoxicity Results

Once the ecotoxicity of each added herbicide and fertilizer were calculated in CTUeco/acre, the values were related to the yield by dividing the ecotoxicity per acre by the yield in kg/acre to have a final ecotoxicity result of CTUeco/kg corn. Yields for each field unit were determined as the arithmetic mean of yields for each of the 4 to 5 subplots that comprised a field unit. The ecotoxicity results can be seen in Table 7 for the reference hybrid seed and constant seeding rate.

Table 7. Ecotoxicity for Reference Seed and Constant Seeing Rate.

Field Unit	Agricultural Soil	Freshwater	Air
	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn
1	17.365	55.285	21.367
2	16.982	54.066	20.896
3	17.739	56.473	21.834
4	31.215	99.370	38.431
5	16.353	52.062	20.123
6	21.949	69.877	27.014
7	20.758	66.086	25.543
8	19.571	62.306	24.089
9	19.506	62.099	24.006
10	16.730	53.262	20.591
11	20.339	64.752	25.031
12	17.910	57.0171	22.041
13	17.958	57.171	22.098
14	20.314	64.670	25.000
15	15.532	49.448	19.115
16	20.149	64.147	24.793
17	17.595	56.017	21.651
18	16.833	53.589	20.716
19	17.352	55.243	21.353
20	19.124	60.884	23.538
21	31.096	98.996	38.274
22	18.143	57.759	22.327
23	18.657	59.396	22.960
24	18.131	57.721	22.311
25	19.154	60.979	23.571
26	17.533	55.818	21.577
27	16.230	51.672	19.970
28	20.148	64.143	24.793
29	23.485	74.768	28.899
30	15.986	50.891	19.676
31	15.514	49.391	19.093
32	20.603	65.589	25.360
33	20.729	65.991	25.516
34	17.123	54.512	21.074

The same analysis was completed for the variable seed and seeding rate, chosen by the farmer. The total ecotoxicity results can be seen in Table 8.

Table 8. Ecotoxicity for Farmers Choice of Seed and Seeding Rate.

Field Unit	Agricultural Soil	Freshwater	Air
	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn
1	17.615	56.081	21.674
2	17.338	55.199	21.335
3	19.081	60.745	23.487
4	35.893	114.26	44.192
5	16.674	53.083	20.518
6	21.140	67.299	26.019
7	19.398	61.757	23.871
8	20.215	64.355	24.882
9	19.165	61.013	23.588
10	15.886	50.573	19.552
11	20.675	65.821	25.446
12	18.545	59.038	22.823
13	17.870	56.893	21.992
14	23.208	73.883	28.563
15	15.728	50.070	19.356
16	21.646	68.912	26.636
17	18.083	57.570	22.253
18	17.740	56.475	21.833
19	17.971	57.213	22.116
20	18.930	60.265	23.300
21	37.024	117.87	45.573
22	19.725	62.798	24.276
23	17.756	56.528	21.853
24	15.685	49.933	19.302
25	19.610	62.429	24.133
26	17.099	54.438	21.045
27	16.208	51.601	19.944
28	20.954	66.709	25.786
29	25.847	82.286	31.807
30	15.542	49.478	19.131
31	13.535	43.088	16.657
32	21.480	68.382	26.441
33	20.125	64.068	24.773
34	17.737	56.466	21.830

The ecotoxicity was graphed alongside the yield to show the relationship between herbicide usage, fertilizer usage, and yield for both reference and variable seed and seeding rate. The results for the reference seed and seeding rate can be seen in Figure 3 and the results for the variable seed and seeding rate can be seen in Figure 4.

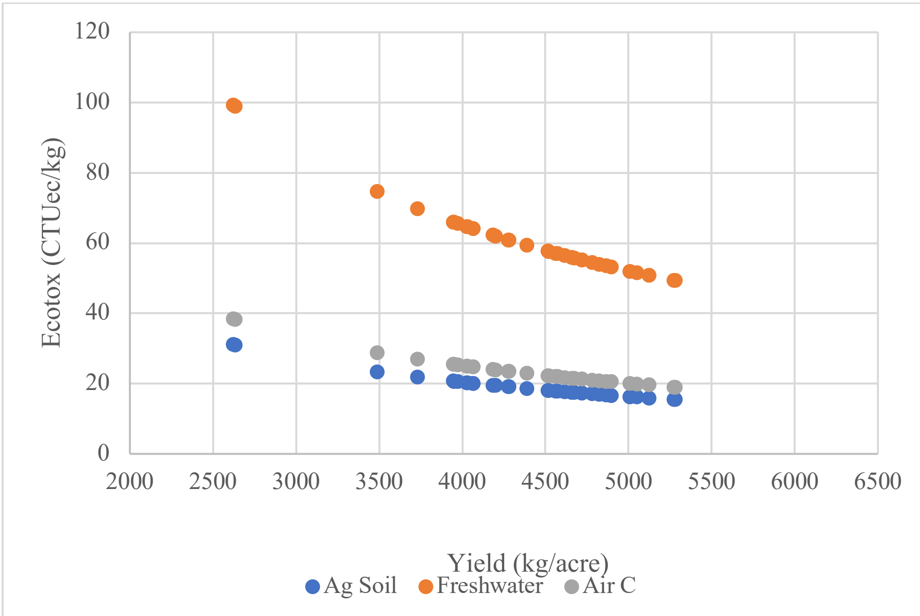

Figure 3. Ecotoxicity vs Yield for Reference Seed and Seeding Rate.

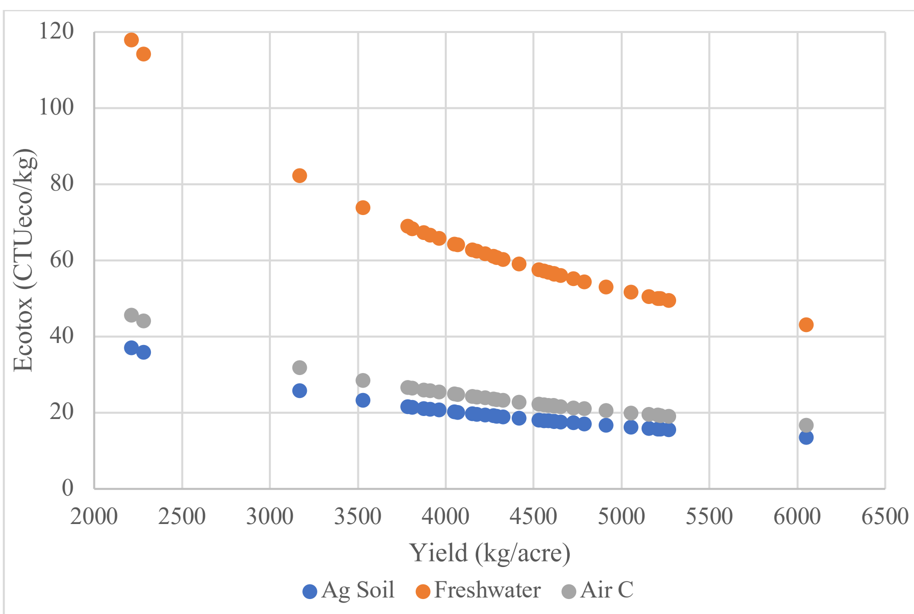

Figure 4. Ecotoxicity vs Yield for Variable Seed and Seeding Rate.

As expected, the total ecotoxicity for agricultural soil, freshwater, and air decreased with yield for both conditions. This does not necessarily show that there are less emissions for these fields, but that there are less emissions per kg of corn, the reference unit. As seen in the figures, there is a large difference between the total ecotoxicity of freshwater when compared to that of agricultural soil and air for all fields. This increase makes sense due to the values of characterization factors. As seen in Table 6, the characterization factors for freshwater are much larger than agricultural soil and air, which are similar in value. Many of the inputted chemicals were soluble in water, which could be the cause for these high characterization factors.

Along with total ecotoxicity vs yield, the total nitrogen content from nitrogen fertilizers was plotted vs average yield data for both constant and variable seed and seeding rate to analyze the relationship between fertilizer intake and yield. The results can be seen in Figure 5 and Figure 6.

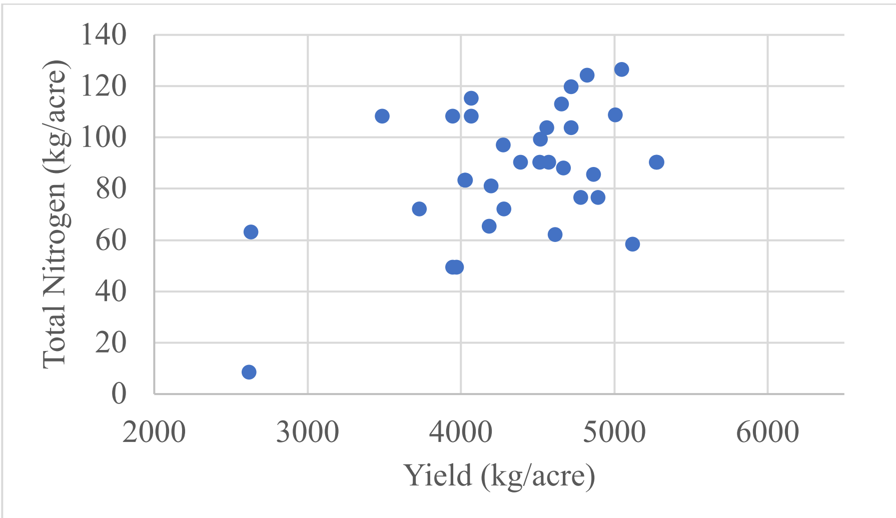

Figure 5. Total Nitrogen vs Yield for Reference Seed and Seeding Rate.

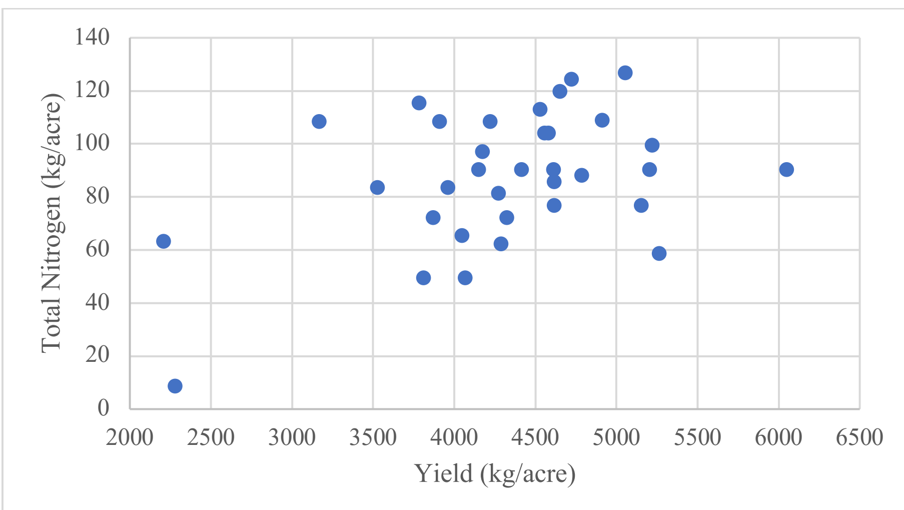

Figure 6. Total Nitrogen vs Yield for Variable Seed and Seeding Rate.

As seen from Figures 5 and 6, there does not seem to be any direct trends between increase in nitrogen fertilizer and yield, which is interesting. Aside from the outlier with 10 kg/acre of total nitrogen, the rest of the yield data is grouped around the same range in total nitrogen intake and does not have any strong trends. The highest yielding fields for both conditions have the same nitrogen intake as other, less yielding fields. This shows that there should be more research related to nitrogen intake vs yield to find the lowest total nitrogen intake that produces the highest yield.

To further analyze the total nitrogen intake, the ecotoxicity vs total nitrogen was graphed for both constant and variable seed and seeding rate to see if there was a relationship between nitrogen intake and total ecotoxicity. The analysis can be seen in Figure 7 and Figure 8.

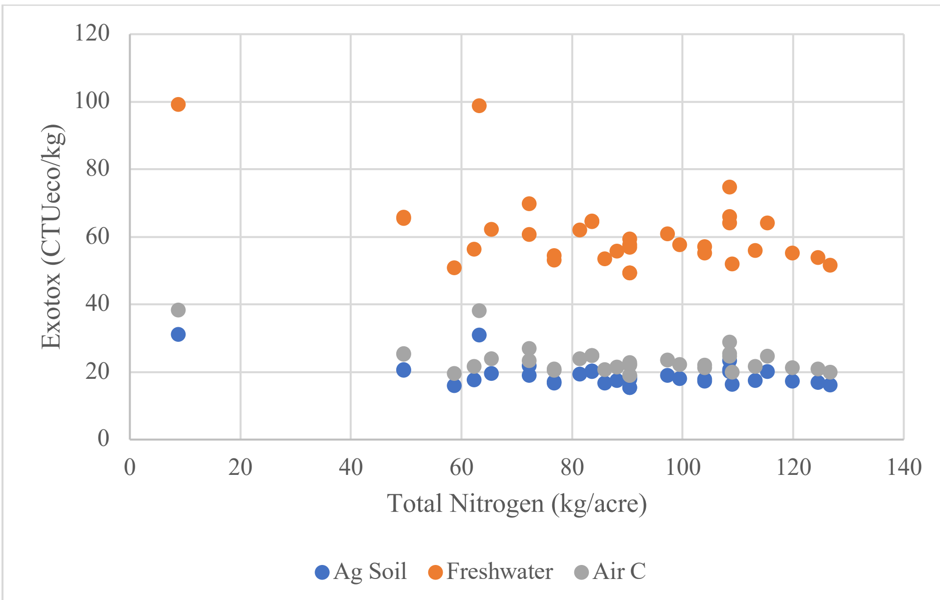

Figure 7. Ecotoxicity vs Total Nitrogen for Reference Seed and Seeding Rate.

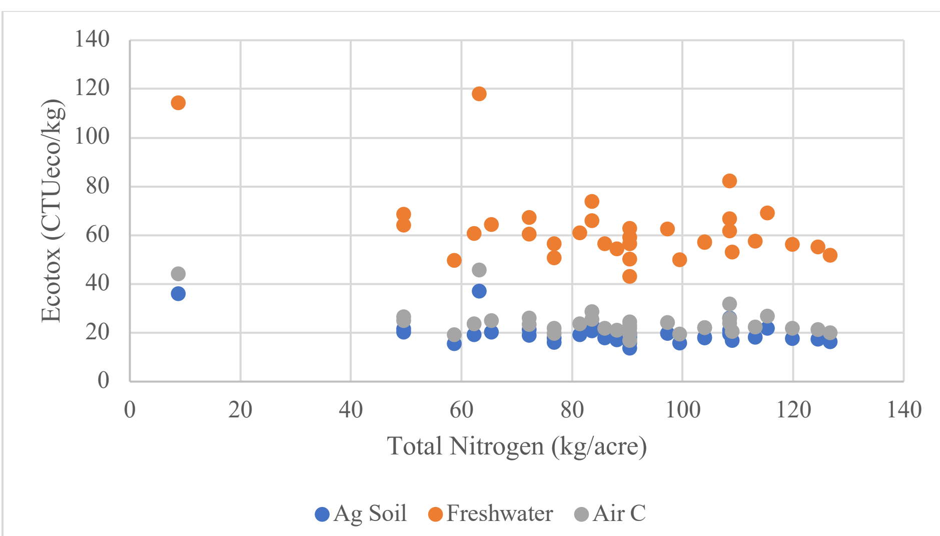

Figure 8. Ecotoxicity vs Total Nitrogen for Varying Seed and Seeding Rate.

As seen in the figures, excluding the outliers at 62 kg/acre, there does not seem to be a trend between total ecotoxicity and total nitrogen. Considering herbicide application was constant throughout, this indicates that all fields had around the same ecotoxicity values. This could be due to the large characterization factors present for the chemicals applied. Because the characterization factors were well above the amount applied, all values would be around the same. There were two outliers, however, at around 10 kg/acre and 62 kg/acre of nitrogen fertilizer. At these points the total ecotoxicity was considerably higher the other values with similar total nitrogen intake. This would suggest that these fields had considerably lower yields, resulting in higher ecotoxicity per unit of corn.

4.3 Irrigation

To analyze how yield was affected by water intake, the total irrigation vs yield was plotted in two sets of data: <Q stable depth and >Q stable depth for both constant and variable seed and seeding rate. The results can be seen in Figure 9 and Figure 10.

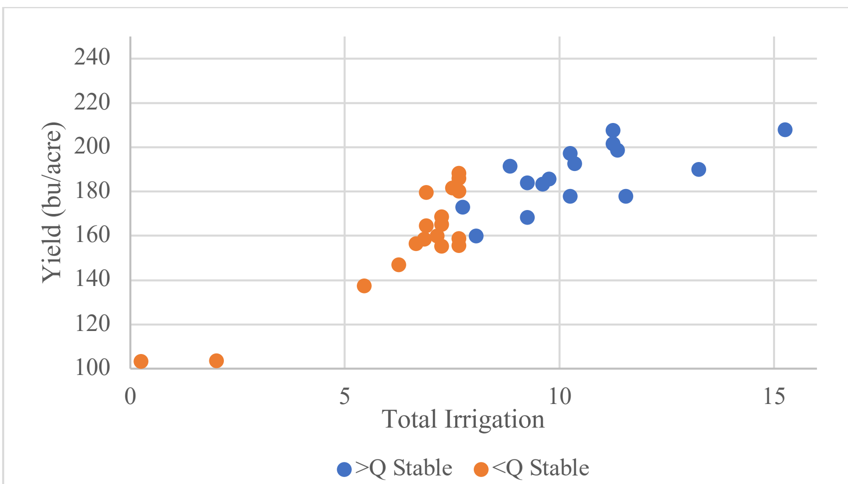

Figure 9. Yield vs Total Irrigation for Reference Seed and Seeding Rate.

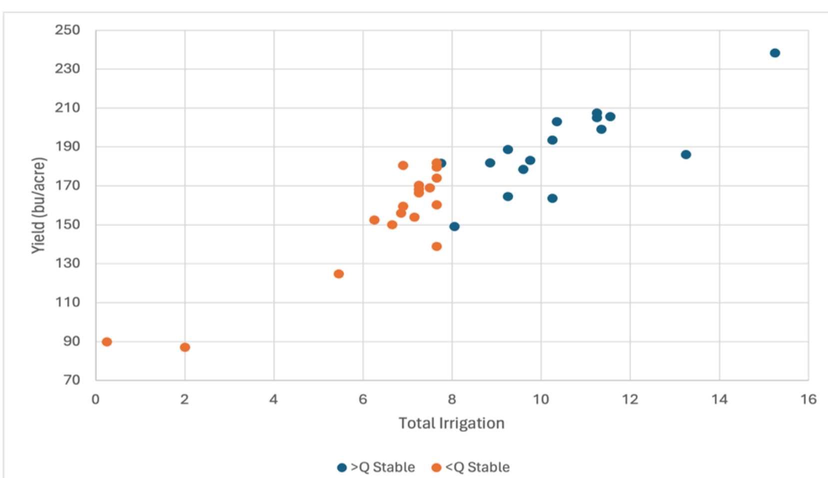

Figure 10. Yield vs Total Irrigation for Variable Seed and Seeding Rate.

As expected, the yield increases linearly with increase in water intake overall. However, in the six to ten range of total irrigation there is >Q stable data which has higher yield than some <Q stable data. This section shows that there is a range of total irrigation where the yield is still high while staying in the Q stable range, which is desired. At the low end of total irrigation, the trend stays consistent. The field that had almost zero total irrigation had significantly lower yield than other fields.

At the high end of total irrigation, there were some differences between constant and variable seed and seeding rate. For constant seed and seeding rate, the largest total irrigation, which was over two times the Q stable limit, did not have an extreme increase in yield. This could show that the reference seed has a cap of total irrigation, at which point the yield no longer increases linearly. On the other hand, for variable seed and seeding rate, the largest total irrigation had yield of around 30 bu/acre higher than the next highest field. This could imply that the yield for some seed choices continue to increase with total irrigation increases.

As total ecotoxicity decreased with yield due to normalization with the reference unit, kg of corn, the ecotoxicity would also decrease with increase in irrigation due to the same factors.

4.4 Nitrogen vs Fertilizer Intake

Along with analysis of ecotoxicity vs yield, the ecotoxicity for herbicide and fertilizer for agricultural soil, freshwater, and air were analyzed. An average of herbicide and fertilizer application across the 34 fields was taken to glimpse into the impacts of the agrochemicals for different categories. The results of the analyses can be seen in Figure 16, Figure 17, and Figure 18.

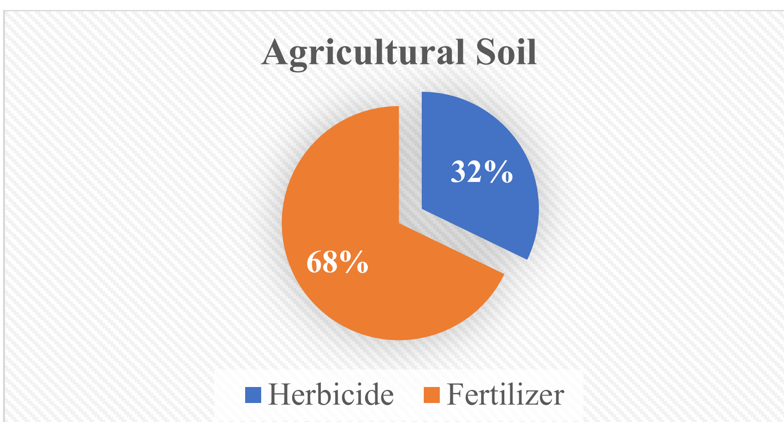

Figure 11. Average Herbicide vs Fertilizer Ecotoxicity for Agricultural Soil, Ref. Seed/Seeding.

Figure 16 shows that fertilizer has the largest contribution to the total ecotoxicity for emissions to agricultural soil. Table 6 shows larger characterization factors for fertilizer for emission to agricultural soil, suggesting higher emissions. This correlates to the nature of the fertilizers with which characterization factors were found, which are likely to leach into soil.

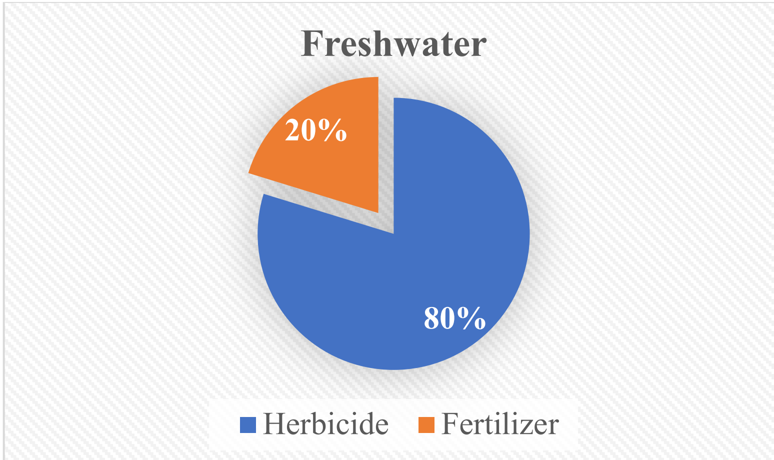

Figure 12. Average Herbicide vs Fertilizer Ecotoxicity for Freshwater, Ref. Seed/Seeding.

As seen in Figure 17, herbicide shows the largest contribution to total ecotoxicity for emissions to freshwater. As seen in the agrochemicals review, many of the chemicals applied to the fields are soluble in water and can enter bodies of water during times of high rainfall. Therefore, the large contribution from herbicide is likely due to the identified characterization factors for the chemicals. As seen in Table 6, the characterization factors for herbicide chemicals are larger than those for fertilizer, making the contribution larger.

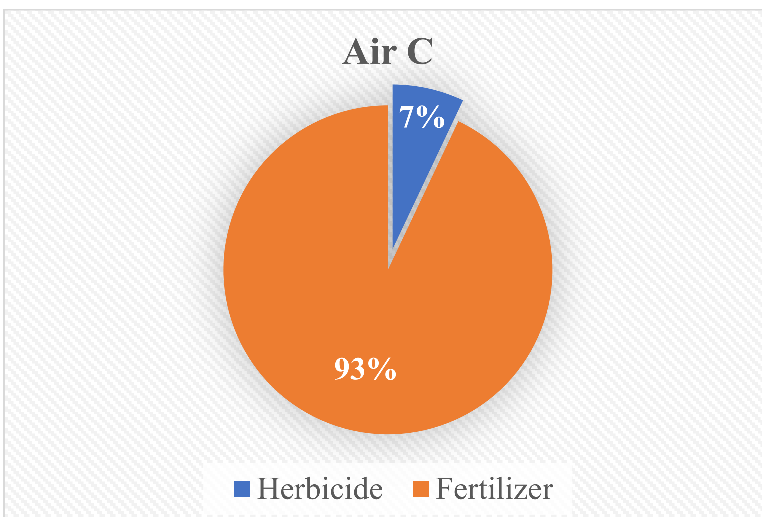

Figure 13. Average Herbicide vs Fertilizer Ecotoxicity for Air, Ref. Seed/Seeding.

Figure 18 shows that the largest contribution to total ecotoxicity emissions to air is from fertilizer. There was not a lot of research covering the emissions of fertilizer and herbicide chemicals into the air, so the difference in contribution can be directed to the identified characterization factors. Table 6 suggests that the chemicals in fertilizer have larger characterization factors, and therefore larger contribution to the total ecotoxicity.

4.5 Quantified Uncertainty

Uncertainty within the total ecotoxicity would lie in the fact that average yield was used instead of yield for each section of the field. To quantify this uncertainty, the total ecotoxicity per yield was calculated for the lowest and highest yields for each field for both constant and variable seed and seeding rate. The results of the total ecotoxicity can be seen in Tables 11 and 12 in the appendix, and the increase/decrease from using the average can be seen in Tables 9 and 10.

Table 9. Percent Changes in Total Ecotoxicity for Reference Seed and Seeding Rate.

Field Unit	Percent Change Lowest Yield	Percent Change Highest Yield
1	20.21	-16.26
2	6.35	-7.90
3	4.44	-4.85
4	40.92	-33.58
5	7.81	-10.63
6	12.44	-20.15
7	21.94	-16.47
8	14.53	-15.79
9	16.62	-14.75
10	20.60	-18.38
11	20.46	-14.33
12	15.88	-12.39
13	9.19	-13.36
14	13.01	-30.13
15	2.59	-3.34
16	25.97	-13.71
17	14.79	-11.01
18	24.61	-15.71
19	26.28	-15.57
20	17.98	-17.20
21	43.84	-44.07
22	7.40	-8.43
23	16.48	-11.58
24	18.49	-21.69
25	21.18	-14.54
26	20.36	-10.98
27	7.70	-9.06
28	11.27	-17.27
29	9.59	-8.34
30	5.45	-7.99
31	10.95	-10.23
32	14.12	-21.38
33	13.85	-8.23
34	8.46	-7.89

Table 10. Percent Changes in Total Ecotoxicity for Variable Seed and Seeding Rate.

Field Unit	Percent Change Lowest Yield	Percent Change Highest Yield
	%	%
1	19.73	-23.22
2	9.45	-13.31
3	5.97	-6.05
4	29.82	-43.15
5	5.56	-12.90
6	10.94	-18.24
7	17.55	-17.89
8	9.63	-11.85
9	14.19	-13.02
10	11.60	-8.38
11	8.85	-13.13
12	30.84	-15.90
13	18.25	-17.08
14	24.25	-26.88
15	5.60	-6.72
16	11.98	-10.93
17	18.77	-16.14
18	34.65	-15.51
19	17.44	-13.02
20	23.17	-29.56
21	34.50	-55.88
22	23.63	-29.63
23	14.37	-6.37
24	15.97	-17.05
25	30.35	-14.00
26	11.89	-8.78
27	18.98	-25.79
28	12.23	-19.89
29	16.78	-8.67
30	6.98	-15.86
31	6.63	-9.23
32	18.37	-19.78
33	10.25	-8.50
34	7.25	-6.74

As seen from Tables 9 and 10, using the lowest yield to calculate total ecotoxicity increased the value as much as 43.84% for constant seed and seeding rate and 34.65% for variable seed and seeding rate. With that, using the highest yielding block decreased the total ecotoxicity by as much as 44.07% for constant seed and seeding rate and 55.88% for variable seed and seeding rate. This shows that there is indeed uncertainty with the yield value that is used to calculate total ecotoxicity. Field 21 showed the highest variation between yield values between blocks, but all fields had some variation between values. A better estimation for total ecotoxicity could be found by assessing each individual block.

5.0 Conclusions

The ecotoxicity assessment results for the reference seed and seeding rate show that the total ecotoxicity for agricultural soil, freshwater, and air ranged from 15.51 CTUeco/kg corn to 31.22 CTUeco/kg corn, 49.39 CTUeco/kg corn to 99.37 CTUeco/kg corn, and 19.09 CTUeco/kg corn to 38.43 CTUeco/kg corn, respectively. The results for variable seed and seeding rates showed that the total ecotoxicity for agricultural soil, freshwater, and air ranged from 13.54 CTUeco/kg corn to 37.02 CTUeco/kg corn, 43.09 CTUeco/kg corn to 117.87 CTUeco/kg corn, and 16.66 CTUeco/kg corn to 45.57 CTUeco/kg corn, respectively. Total ecotoxicity decreased with yield, which was to be expected due to the functional unit. Total ecotoxicity versus total nitrogen and total nitrogen versus yield did not show any consistent trends, while irrigation vs yield showed an overall upwards trend. Ranges were found where yield did not increase significantly with increased total nitrogen and total irrigation, showing favorable inputs. Uncertainty was found when using the average yield to calculate total ecotoxicity. When the lowest yielding block within the fields were used, the ecotoxicity increased as much as 43.84% for reference seed and seeding rate and 34.65% for variable seed and seeding rate. When the highest yielding block within the fields were utilized, the total ecotoxicity decreased by as much as 44.07% for reference seed and seeding rate and 55.88% for variable seed and seeding rate.

There were many limitations of this study, namely the lack of characterization factors for all components within the herbicides and fertilizers, the use of average yield values for total ecotoxicity values, and the use of constant total irrigation for analyses. Estimation techniques utilized to quantify the total ecotoxicity could have caused some uncertainty with the results. With that, this study only included the ecotoxicity values related to herbicide and fertilizer application, while prior studies have explored additional impacts related to farming equipment, seed manufacturing and transportation, and other factors. These additional inputs could have influenced the results of the study immensely. The results of this study could potentially educate farmers and influence the exploration of sustainable irrigation and farming techniques to decrease the ecotoxicity impacts while obtaining desired yields.

Further studies over the ecotoxicity of corn production would be essential for analyzing the overall impacts. Having additional characterization factors for agrochemicals and using field specific yield and irrigation values are recommendations for further studies for a comprehensive analysis of ecotoxicity.

6.0 Appendix

Calculation excel: 

Table 11. Total Ecotoxicity for Highest and Lowest Yield for Ref. Seed/ Seeding.

Field Unit	Lowest Yield			Highest Yield		
	Agricultural Soil	Freshwater	Air	Agricultural Soil	Freshwater	Air
	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn
1	21.765	69.292	26.781	14.936	47.551	18.378
2	18.134	57.732	22.312	15.739	50.108	19.366
3	18.564	59.098	22.849	16.919	53.863	20.825
4	52.832	168.187	65.046	23.368	74.391	28.770
5	17.738	56.470	21.827	14.781	47.058	18.189
6	25.069	79.807	30.854	18.268	58.158	22.484
7	26.594	84.665	32.725	17.823	56.743	21.932
8	22.898	72.896	28.183	16.902	53.808	20.803
9	23.394	74.478	28.792	16.998	54.115	20.920
10	21.072	67.085	25.934	14.132	44.992	17.393
11	25.570	81.405	31.469	17.789	56.634	21.893
12	21.291	67.783	26.202	15.935	50.729	19.610
13	19.774	62.955	24.334	15.841	50.432	19.493
14	23.352	74.344	28.739	15.610	49.697	19.212
15	15.945	50.764	19.623	15.030	47.848	18.496
16	27.216	86.647	33.489	17.719	56.413	21.804
17	20.650	65.742	25.410	15.850	50.462	19.504
18	22.327	71.081	27.478	14.547	46.313	17.903
19	23.539	74.940	28.966	15.014	47.799	18.476
20	23.318	74.234	28.699	16.318	51.948	20.083
21	55.367	176.264	68.147	21.584	68.714	26.566
22	19.592	62.374	24.111	16.732	53.267	20.591
23	22.337	71.112	27.489	16.721	53.233	20.578
24	22.243	70.814	27.372	14.900	47.435	18.335
25	24.302	77.368	29.906	16.722	53.237	20.578
26	22.016	70.089	27.094	15.799	50.297	19.443
27	17.585	55.985	21.637	14.882	47.379	18.311
28	22.708	72.293	27.943	17.181	54.699	21.142
29	25.975	82.696	31.964	21.676	69.010	26.673
30	16.907	53.823	20.810	14.802	47.124	18.220
31	17.421	55.462	21.439	14.074	44.806	17.320
32	23.991	76.374	29.530	16.974	54.038	20.894
33	24.061	76.599	29.617	19.153	60.974	23.576
34	18.705	59.548	23.021	15.871	50.527	19.533

Table 12. Total Ecotoxicity for Highest and Lowest Yield for Variable Seed/Seeding.

Field Unit	Lowest Yield			Highest Yield		
	Agricultural Soil	Freshwater	Air	Agricultural Soil	Freshwater	Air
	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn	CTUeco/kg corn
1	21.945	69.864	27.001	14.295	45.512	17.589
2	19.148	60.960	23.561	15.302	48.715	18.829
3	20.292	64.600	24.977	17.992	57.279	22.147
4	51.145	162.815	62.971	25.073	79.817	30.871
5	17.656	56.210	21.727	14.768	47.017	18.174
6	23.736	75.565	29.215	17.878	56.916	22.005
7	23.527	74.901	28.952	16.455	52.385	20.249
8	22.369	71.211	27.533	18.074	57.538	22.246
9	22.333	71.100	27.487	16.957	53.983	20.870
10	17.969	57.206	22.117	14.657	46.662	18.040
11	22.682	72.209	27.916	18.275	58.181	22.493
12	26.813	85.362	32.999	16.001	50.941	19.693
13	21.859	69.590	26.900	15.263	48.592	18.783
14	30.638	97.537	37.707	18.291	58.232	22.512
15	16.660	53.038	20.503	14.737	46.917	18.137
16	24.591	78.289	30.260	19.512	62.120	24.011
17	22.261	70.871	27.394	15.571	49.571	19.161
18	27.146	86.421	33.410	15.358	48.894	18.902
19	21.767	69.297	26.787	15.901	50.622	19.568
20	24.639	78.439	30.326	14.611	46.516	17.984
21	56.527	179.955	69.578	23.752	75.617	29.236
22	25.827	82.224	31.786	15.217	48.446	18.728
23	20.736	66.016	25.520	16.693	53.142	20.544
24	18.666	59.425	22.971	13.399	42.658	16.490
25	28.155	89.635	34.650	17.202	54.763	21.169
26	19.407	61.784	23.885	15.719	50.042	19.345
27	20.004	63.687	24.615	12.885	41.022	15.855
28	23.873	76.002	29.378	17.478	55.644	21.509
29	31.058	98.876	38.219	23.785	75.722	29.269
30	16.707	53.188	20.565	13.415	42.706	16.512
31	14.495	46.146	17.839	12.390	39.446	15.249
32	26.314	83.771	32.392	17.933	57.091	22.075
33	22.422	71.381	27.601	18.548	59.047	22.832
34	19.123	60.880	23.537	16.617	52.903	20.453

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