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INVESTIGATION OF THE GREENHOUSE GAS EMISSIONS OF BIOFUEL PRODUCTION FROM CORN FARMING AND MITIGATION STRATEGIES

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ABSTRACT

Extensive consumption of fossil energy resources including coal, oil, gas has risen as a result of the growing world population, so the mass of greenhouse gases (carbon dioxide, nitrous oxide, water vapor, methane, ozone, etc.) has been significantly increased. People want to produce renewable fuel because of the increasing greenhouse gases (GHG) emissions. However, increasing feedstock production and fertilizer production, which are required for producing renewable fuel, GHG emission increase. Even though we use fossil fuels as the main energy source, there is great potential for it to be produced using biomass. Corn is one of the annual crops, which is one of the most important feedstock for biofuel production because of its availability and production rate. However, especially the corn farming stage in the system boundary has caused great concern because of the potential yields, nutrients and effect on land, which directly effect GHG emissions. The main purpose of this study is to demonstrate the importance of GHG emissions, GHG emissions mitigation technologies in agriculture, several human health, and environmental effects. In this study, we used Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model to obtain emission data for cron production. Basically, the GREET model will calculate the consumption of total energy, GHG emission, and air criteria pollutants. The results show that the highest part of GHG emissions came from nitrogen fertilizer, urea, and lime productions. Especially, 93% of N_2O emissions came from nitrogen fertilizer in corn farming stage. Also, 36% of CO_2 emissions came from corn farming fertilizer usage. In addition, decision-makers need to develop the potential of mitigation strategies to quantify and address the uncertainty of GHG emissions. Therefore, the correct strategies to mitigate GHG emissions from agricultural systems can be found and this can help to productivity, crop quality, economic returns, and reduce negative environmental risks.

Keywords: Greenhouse gas, corn production, biofuel, life cycle assessment

INTRODUCTION

Approximately two billion people were added to the world's population over the past two decades (Rubino, Etheridge et al. 2019). With this rapid increase in the population of humans and also urban development since the mid-1970`s, there has been a significant increase in energy consumption (Avtar, Tripathi et al. 2019). Extensive consumption of fossil energy resources has been associated with a significant increase in the mass of greenhouse gases (GHG), which are known to inhibit long-wavelength radiation from escaping into space, into the atmosphere (Smithson 2002, Galloway, Townsend et al. 2008). The effects of global warming has been already observed as higher sea levels, more severe storms, dirtier air, higher wildlife extinction rate, higher death rates, and so on (Singer 2006). Besides the adverse environmental and public health impacts, the world faces an energy crisis since the demand for fossil fuels such as coal, oil, natural gas, is growing in most countries in the world. According to the 2019 Annual Energy Outlook, crude oil reserves will run out by 2052, natural gas will run out by 2060, and coal will run out by 2090 if the fossil fuels's consumptions continue at the present rate (Agency 2020). The global energy system is 85.5% dependent on fossil fuels right now, and US, China, and India are the most fossil fuel dependent countries (Ediger 2019). According to the US Department of Energy in 2010, the US consumed on average 19.1 million barrels per day and imported 11.8 million barrels per day of petroleum products (EIA 2011). With increasing strain between the US and its foreign oil suppliers it has become imperative that the US becomes less reliant on international suppliers. Because of the potential future effects of using fossil fuels, people want to produce renewable fuel to eliminate the adverse impacts, so biomass crops have great potential to displace fossil fuel to lower net greenhouse emissions, and to diversify the ecosystems. Corn is one of the annual crops, which has the potential to have high yields. Because of its availability and production rate at the required amount for industry scale, corn is one of the most important feedstocks for biofuel production (Woiciechowski, Medeiros et al. 2016). In addition, its fibrous structure and carbohydrate rates (make it an interesting feedstock for biofuel production. Butanol has become a fuel of interest because of its ability to be easily incorporated into the fuel market. Currently, butanol is mainly produced using fossil fuels but there is great potential for it to be produced using biomass. Biobutanol, butanol produced from biomass, has a higher energy density than ethanol and thus would be a more advantageous fuel to substitute gasoline (Ranjan and Moholkar 2012). Biobutanol is less corrosive and has a lower water solubility than gasoline but it can be blended or used pure (100%) with existing engines without replacement. Although the energy density of butanol is lower than gasoline, his Buick averaged 3 mpg higher with pure butanol as fuel than gasoline. The lower GHG emission potential also makes biobutanol a more attractive option. This study focuses on the potential environmental risk of producing biobutanol from corn crop and how to eliminate the emissions with mitigation strategies.

METHODOLOGY

Life cycle assessment (LCA) methodology is used to obtain GHG emission data to evaluate risk assessment based on corn farming. LCA is a methodology that investigates the environmental impacts of a product or process instead of the other technologies. LCA has four different stages including (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation according to the International Organisation for Standardisation (ISO) in ISO 14040. The first part of a LCA study generally starts with defining the goal of the study, its scope and functional unit (Rebitzer, Ekvall et al. 2004). The goal of the current study is to determine the environmental point of view using corn crops produce butanol. The intended audience of the study will be the researchers and technical experts in the area of environmental sciences especially environmental impacts of agriculture. Once the goal and the scope of the study are chosen, the next step is to set the functional unit, which should be chosen based on the goal of the study. The functional unit for the study was 1 ton of corn. The initial boundaries of the system will be determined by the goal and the scope of the study. The system boundaries of biomass crops farming for LCA are shown in Figure 1.

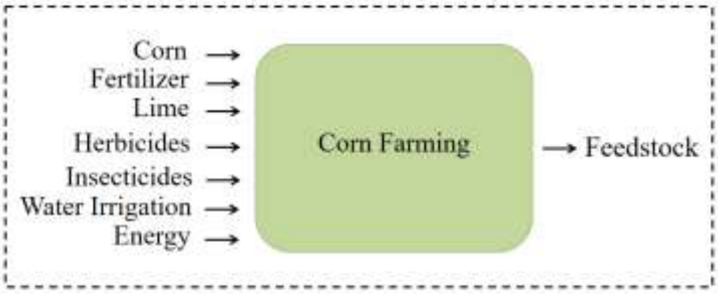

Figure 1. System boundary of corn feedstock production

Life cycle inventory (LCI) step involves the data collection and calculation input and output flows to complete the inventory (Hospido, Moreira et al. 2004). LCA studies sometimes can face the problems related to data availability and/or quality problems within this phase. In our study, the preliminary inventory data is collected from previous studies in the literature and/or LCA databases. In addition, background information (e.g. chemicals production processes) is normally provided by free LCI databases such as Agribalyse, USDA, NEEDS, ELCD, bioenergiedat, USLCI. In an LCA, an important aspect is the selection of the appropriate impact categories, which is in life cycle impact assessment (LCIA) stage. In this study, we only consider Global Warming Potential (GWP) as the environmental impact at a problem level (de Haes, Jolliet et al. 1999). After the impact category is selected, the inventory data are classified to the selected category, which is essential to define characterization factor. This study employs the use of the Greenhouse gases, Regulated Emissions, and Energy use in

Transportation (GREET™) model. The GREET model will estimate the green house gas emission and butanol production for various input parameters. We used the GREET model to obtain emissions from the corn and miscanthus crops to generate butanol in this study. While the main data source is the GREET model, input parameters pertaining to the farming operations include fertilizers, lime, pesticides and energy were used during feedstock production. Table 1 presents the key assumptions and GREET inputs for the corn crops.

Table I GREET Input Parameters for Corn

Parameters (kg)	Per dry ton
Nitrogen	16.06
P_2O_5	6.024
K_2O	6.092
$CaCO_3$	58.25
Herbicide	0.234
Insecticide	0.0004

RESULTS AND DISCUSSION

The primary aim of this study is to evaluate the potential environmental risk of producing butanol using corn, which is based on crop farming shown in Figure 2. The main material inputs were listed in Table 1 as crop seed, fertilizers, lime, pesticides, machinery, electricity, and etc. Therefore, using all inputs data the results were scaled as needed and summed up all outputs in the Greet model. The results indicate wide dispersion of the effects between selected emissions depending on material input, electricity usage, and emissions produced that occurred for each process. The emissions (N_2O, CO_2 and CH_4), which can be presented as CO_2 equivalents, using GWP factors from the Intergovernmental Panel on Climate Change (IPCC)'s report (GWP for CH_4 = 25, GWP for N_2O = 298). Since the functional unit for the study was 1 tons of biomass production, first we calculated the total GHG emissions for corn. Total CO_2 emission is 3,407 g/bu; N_2O emission is 12.319 g/bu; CH_4 emission is 7.129 g/bu from corn farming and total emissions of 1-ton corn butanol is calculated as 0.755 t CO_2 / t butanol; $2.73x10^{-3}$ t N_2O / t butanol; and $1.58x10^{-3}$ t CH_4 / t butanol. Total GHG emission of 1-ton corn butanol is calculated as 1.608 t CO_2 equivalents/ t butanol. Nearly 50% of total GHG emissions come from N_2O emissions, and 93% of N_2O emissions are derived from nitrogen fertilizer. Since 11-ton corn can be produced per hectare area, total N_2O emissions is around $5.412x10^{-3}$ t N_2O/ha from corn farming, which equals to total around $2.73x10^{-3}$ t N_2O/t butanol per year per hectare. The results show that the predominant contributor of total GHG emissions for corn production is ammonia nitrate, which is commonly used in agriculture as a high nitrogen fertilizer. The results also show that decision-makers need to develop the potential of mitigation strategies to quantify and address the uncertainty of N_2O emissions, so the correct strategies to mitigate N_2O emissions (e.g. using of nitrification inhibitors (such as 3,4-dimethyl pyrazole phosphate (DMPP)); changing nitrogen source, and application rate; fertilizer reduction; banded fertilization; wetland restoration, etc.) from agricultural systems can be found (Adler, Del Grosso et al. 2012). However, in practical application nitrogen fertilization is the limiting factor for crop growth, this is often a reason for lower crop yields in farming, but also a reason for lower emissions (Fließbach, Mäder et al. 2009). On the other hand, using an extensive amount of nitrogen fertilizer to getting higher crop yields may lead to higher GHG emissions, which creates a paradox.

CONCLUSION

People want to produce biobutanol because of extensive consumption of fossil fuels and increasing N_2O emission. However, GHG emissions increase because of feedstock and fertilizer production at the same time. Especially in developing countries agriculture is one of the major industries, so it is important to pay attention to the effects on human health besides the environment. This study aimed to investigate the life cycle energy of producing biobutanol using corn as s biomass crop. The results show that the highest part of GHG emissions came from N_2O emissions and the sources are nitrogen fertilizer, urea, and lime productions.

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