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➤ ***ORAL PRESENTATION***

Life Cycle Assessment of Annual and Perennial Biomass Crops for Ethanol Production

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Abstract

The 20th century faces significant increases in the global population and fossil fuel consumption. There have been significant increases in the concentration of GHGs in the atmosphere from human activities. The GHGs build up in the atmosphere and cause the increase in earth's atmospheric temperature, which leads to many other changes around the world. In addition, increasing greenhouse gas emissions and decreasing fossil fuel sources has been posed new challenges to agriculture, which is agricultural feedstock production, especially due to fertilizer production. The purpose of this study is to investigate the life cycle of producing ethanol comparing an annual and perennial biomass crops, which are corn and switchgrass, respectively. This study employs the use of the full life-cycle model which is known as Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET 2021) model by Argonne National Laboratory to obtain the emission data. According to the results, total GHG emissions are around 0,012 kg N_2O/mm BTU; 0,0071 kg CH_4/mm BTU; 3,407 kg CO_2/mm BTU from the corn to ethanol production per year. However, total GHG emissions are around 0,133 kg N_2O/mm BTU; 0,093 kg CH_4/mm BTU; 41 kg CO_2/mm BTU from the switchgrass to ethanol production per its life time (approximately 15 years). We concluded that the various feedstocks, nutrients, and enzymes will affect the ethanol yield in the well-to-wheel analysis of ethanol production.

Keywords: ethanol production; corn; crop farming; switchgrass; life cycle assessment

INTRODUCTION

The human population has continued to grow at a significant rate and is expected to increase from 8 billion in 2022 to 9.7 billion by 2050 (Laurance and Engert 2022). This rapid increase in the population of humans and urban development since the mid-1970`s causes significant increase in energy consumption (Avtar et al. 2019). Meanwhile 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 et al. 2008). We already see the effects of global warming as higher sea levels, more severe storms, dirtier air, higher wildlife extinction rate, higher death rates, and so on (Singer 2006). Moreover, 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 predictions of the scientists, 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 (or bio-crops) have great potential to displace fossil fuel to lower net greenhouse emissions, and to diversify the ecosystems.

Ethanol (C_2H_6O) is presently the most well developed possible liquid fuel substitute for gasoline. It is an alcohol and a clean, renewable fuel that can be made from biomass. Bioethanol is an alcohol mainly produced from agricultural residues such as corn and sugarcane feedstocks. According to the 2015 statistics, USA at the top list of bioethanol producers with 56.05 mi m^3 from corn as main sources . Interestingly, even though Brazil is not a member contry of Organization for Economic Co-operation and Development (OECD), Brazil has the 2nd highest bioethanol producer country with 26.85 mi m^3 due to huge availability of sugarcane, a very productive biomass for ethanol production (Manochio et al. 2017). While annual bioenergy crops (such as oil palm, and corn) can be used successfully as feedstocks, perennial crops (such as miscanthus and switchgrass) can also be used and provide promising features such as higher productivity and low input requirements. Corn is one of the annual crops, which is also the most ubiquitous crop with the highest cultivation intensity due to optimum climate conditions. 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 et al. 2016). In addition, its fibrous structure and carbohydrate rates make it an interesting feedstock for biofuel production. On the other hand, switchgrass (*Panicum virgatum* L.) is a C_4 perennial sustainable bio-crop, which evolved in many different environments from cold northern to warm southern areas in the US with an average lifetime of 15-20 years. Switchgrass can cultivate in poor soil, drought, and flooded conditions, but it still needs to appropriate conditions to produce economical biomass yields and persist for several years. This study focuses on the potential environmental risk of producing ethanol using two biomass crops, which are corn and switchgrass. A comparison of these two crops will bring to light the differences when using a perennial and annual biomass crop and their effect on global warming and human health.

METHODOLOGY

Life cycle assessment (LCA) is a methodology, which is used to obtain GHG emission data to evaluate risk assessment based on corn and switchgrass to ethanol production. According to the International Organisation for Standardisation (ISO) in ISO 14040, LCA has four different stages including (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation. The first part of a LCA study generally starts with defining the goal of the study, its scope and functional unit (Rebitzer et al. 2004). The goal of the current study is to determine the environmental point of view using corn and ethanol crops to produce ethanol. 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 dry bio-crop. The initial boundaries of the system will be determined by the goal and the scope of the study. The system boundaries of biomass crops to ethanol for LCA are shown in Figure 1.

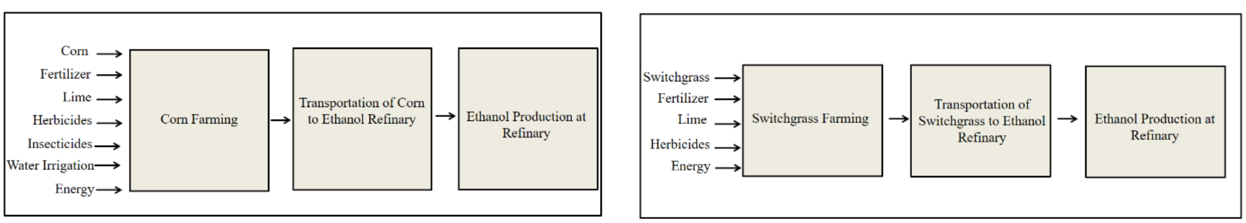

Figure 1. System boundary of corn and switchgrass feedstock to ethanol

Life cycle inventory (LCI) step involves the data collection and calculation input and output flows to complete the inventory (Hospido et al. 2004). 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 consider GHG emissions including nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) as the environmental impact at a problem level. This study employs the use of the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET^{TM}) model. The GREET model will estimate the greenhouse gas emission and butanol production for various input parameters. We used the GREET model to obtain emissions from the corn and switchgrass crops to generate ethanol in this study. While the main data source is the GREET model, input parameters pertaining to the farming operations include fertilizers, lime, pesticides, energy and also transportation of bio-crops to the refinary were used during ethanol production. Table 1 presents the key assumptions and GREET inputs for the corn and switchgrass crops.

Table 1. GREET Input Parameters for Corn and Switchgrass

Parameters	Corn	Switchgrass
Life span (years)	1	15
Yield (t/ha)	11	14,2
Energy use (Btu/mmbu)	47224,0	4361,863
Herbicide (g/bu)	5,85	53,10
Insecticide (g/bu)	0,01	0
Nitrogen (g/bu)	401,5	4877,4
P_2O_5 (g/bu)	150,6	2307,8
K_2O (g/bu)	152,3	32004
$CaCO_3$ (g/bu)	1457,0	5846,9

RESULTS AND DISCUSSION

The primary aim of this study is to evaluate the potential environmental risk of producing ethanol using corn and switchgrass. The main material inputs were listed in Table 1 as fertilizers, lime, pesticides, insecticides, energy, and etc. Then, using all inputs data the results were scaled as needed and summed up all outputs in the Greet model. 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). Therefore, the GHG emissions factor of input materials is calculated using Eq.1.

$$EF = E_{CO_2} + 25x\ E_{CH_4} + 298x\ E_{N_2O} \qquad (1)$$

Since the functional unit for the study was 1 tons of bio-crop, first we calculated the total GHG emissions for the both crops.Total CO_2 emission is 3,407 kg CO_2/mm BTU; N_2O emission is 12,319 kg N_2O/mm BTU; CH_4 emission is 7,129 kg CH_4/mm BTU from corn to ethanol production per year. Total GHG emission of 1-ton corn ethanol is calculated approximately as 0,0072 t CO_2 equivalents/ t ethanol. Nearly 50% of total GHG emissions come from N_2O emissions because of its highest effect on GWP, and over 90% 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 relase to the atmosphere from corn farming. On the other hand, total CO_2 emission is 41,866 kg CO_2/mm BTU; N_2O emission is 0,133 kg N_2O/mm BTU; CH_4 emission is 0,093 kg CH_4/mm BTU from the switchgrass to ethanol production per its life time. Total GHG emission of 1-ton switchgrass ethanol is calculated approximately as 0,083 t CO_2 equivalents/ t ethanol. According to GREET data, switchgrass farming seems to generate higher emissions rates, but its life span is 15 years, so in total corn farming produce more GHG emissions than switchgrass farming. These results provide that switchgrass would be a viable option for production of ethanol. However, the suitable environment conditions to grow switchgrass might be difficult, and should be considered.

Table 2. GHG Emissions from Corn and Switchgrass to Ethanol Production

Parameters (kg)	Corn	Switchgrass
CO_2	3407	41,866
N_2O	3,407	0,093
CH_4	7,129	0,133
Total GHG emissions	7,25	83,825

CONCLUSION

People want to produce biobutanol because of extensive consumption of fossil fuels and increasing GHG emission. However, GHG emissions increase because of feedstock production especially fertilizer production. Especially in developed countries biomass production is one of the major industries, so it is important to pay attention to the effects on human health and the environment. This study aimed to investigate the life cycle energy risk of producing ethanol using an annual and perennial biomass crop, which are corn and switchgrass, respectively. Even though switchgrass farming seems to generate higher emissions rates, its life span is 15 years, so in total corn farming produce more GHG emissions than switchgrass farming. These results provide an opinion about environmental effects of two crops, which is using of a perennial grass such as switchgrass would be a viable option for production of ethanol.

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➢ ***ORAL PRESENTATION***

A Risk Assessment Study for Corn Farming to Biobutanol Production

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Abstract

As a conclusion of growing global population and extensive fossil fuel consumption during the last century, the mass of greenhouse gases has been critically increased. Increasing greenhouse gas emissions and decreasing fossil fuel sources has been posed new challenges to agriculture, which is agricultural feedstock production. Because of the potential future effects of global climate change, people want to produce renewable fuel to reduce greenhouse gas emissions (GHG), but at the same time GHG emission increase because of feedstock production and fertilizer production. The purpose of this study is to investigate the life cycle energy and the potential risk of producing biobutanol from corn crop, which is one of the most used bio-crops all over the world. This study employs the use of the full life-cycle model GREET 2021 (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) to obtain the emission data for the corn crop farming stage. According to the results, total nitrous oxide emissions are around 2.73×10^{-3} t N_2O/t butanol per year from the corn farming. Also, the analysis of non-carcinogenic health risk of exposure to N_2O from the United States Environmental Protection Agency standards shows that adults are at considerable non-carcinogenic risk and there is no serious adverse health effect for adults at corn farming per hectare.

Keywords: Biobutanol production; corn; crop farming; risk assessment

INTRODUCTION

During the last two decades, approximately two billion people were added to the world population, and expected to increase to 9.7 billion by 2050 (Rubino et al. 2019; Laurance and Engert 2022). With this rapid increase in the population of humans cause to increase in energy consumption (Avtar et al. 2019). Extensive consumption of fossil energy resources has been associated with a significant increase in the mass of greenhouse gases (GHGs). Besides the adverse environmental and public health impacts of GHGs, the world faces an energy crisis since the global energy system is 85.5% dependent on fossil fuels right now (Ediger 2019). Due to 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. Nitrous oxide (N_2O) is one of the important anthropogenic GHG with tremendous global warming potential (GWP) (Wang and Sze 1980). The atmospheric concentration of N_2O has risen approximately 18% in the past two hundred years and continues to rise. Based on the current U.S. GHG Inventory, N_2O contributes approximately 6.5% to total GHG emissions (in CO_2 equivalents), and N_2O emissions from agricultural soils account for more than 50% of the global anthropogenic N_2O flux (Hénault et al. 2019; USEPA 2006; Reay et al. 2012). Increasing GHG emissions and decreasing fossil fuel sources have posed new challenges to agriculture (Fließbach et al. 2009). People want to produce renewable fuels because of the increasing N_2O emissions but increasing feedstock production will significantly increase N_2O emissions. In this context, feedstock production for biofuels production started to become a current challenge worldwide. 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 (Harvey and Meylemans 2011). Biobutanol, butanol produced from