Impacts of Emissions of Nitrous Oxide Due to Land Use Changes

Abstract

The emissions of nitrous oxide have dramatically increased due to human activities. In this paper, we assessed the impacts of land use conversions to the nitrous oxide emissions. We collected the data from 40 studies and analyzed them based on three conversion groups: forest to degraded forest, forest to crop, and forest to pasture. We generated regression lines and found that the logarithmic model best fits the conversion from forest to degraded forest with $R^2 = 0.396$; the Frechet Distribution best fits the conversion from forest to crop with $R^2 = 0.241$; the Frechet Distribution best fits the conversion from forest to pasture with $R^2 = 0.397$. The trends of nitrous oxide emissions are similar to the study done by Lent, Hergoulach, and Verchot. Lent’s Model. In order to more accurately assess the impacts of nitrous oxide emissions, we need to collect more data in different regions to eliminate the gaps of data measurements due to temperature, light intensity, and soil types.

Introduction

Nitrous oxide (N$_2$O) is one of the major greenhouse gases (GHG) (Moorer et al. 2016). The concentration of N$_2$O is increasing at the rate of 0.8 ppbv y$^{-1}$ (Boorman et al. 1993) and has increased 16% from 1750 (Dahl et al. 2003). Despite the small amount of increase, it has caused great concern regarding the issue of global warming. Compared to CO$_2$, the radiative forcing of N$_2$O is 265 times greater with a long life time residence of 170 yrs. in the atmosphere (Dahl et al. 2003; Beauchamp et al. 1997). Of all N$_2$O in the globe, 65% is emitted from microbial processes in soil through nitrification and denitrification (Smith et al. 2004; Van Lent et al. 2015).

The rate of nitrous oxide emissions is highly spatially variable and is affected by both biotic and anthropogenic activities such as rainfall, temperature, soil type, and the use of N fertilizers (Mosier et al. 1998; Beauchamp et al. 1997). The N$_2$O production increases with increasing soil moisture and decreases with increasing temperature (Maug et al. 1996). In addition, the N$_2$O emissions increase due to the application of N fertilizers (Boorman et al. 1993).

Different types of land use impact soil quality such as the water content, soil pH, etc. (Islam et al. 2000). Subsequently, it affects the local ecosystem and has an impact to the climate (Islam et al. 2000). Therefore, the types of land use are an important contributor to N$_2$O emissions. Due to human activities, more than half of the global land surface has been impacted (Harris et al. 2015). Since 1980, more than half of the new agricultural land is converted from intact forests and another 25% are from deforested forests (Lambin et al. 2011). It is estimated that 7% to 18% of the total anthropogenic GHG emissions are contributed by land use conversions (LUC) (Van Lent et al. 2015; Houghton et al. 2003). With the increasing demands for wood, crops, and lands, the globe is experiencing deforestation with a high loss rate (Achard et al. 2014). Hence, it is important to know how LUC would change nitrous oxide emissions and further impact the globe.

Our research aims to assess how the emissions of N$_2$O have been affected by LUC. We used online resources to find all possible peer-reviewed studies to collect the data. Then, we used Fréchet distribution to analyze the data and find trends of N$_2$O emissions based on different land conversion types.

Materials and Methods

We took three steps to examine how N$_2$O emissions are affected by land use conversions: 1) compiling all N$_2$O emission data with the corresponding land type changes on an Excel sheet; 2) fitting the data based on their land conversions; 3) analyzing the magnitude of emission change due to land use conversions.

Data Collection

Online databases (e.g., Science Direct) and search engines (e.g., Google Scholar) were used to collect N$_2$O emission data related to the land use change. The keywords such as ‘N$_2$O emission’ and ‘land conversion’ were used in the search queries. There was not much research done to test the impact of land conversion on N$_2$O emissions. We used the database from J. van Lent et al. (2015) as the base of our research. We extracted 23 studies, which have the N$_2$O emission data with the land type conversions. Then, we expanded the database by finding additional 17 studies. In total, we collected data from 40 studies. We grouped the same land conversion types together (converted from forest to crop land; from forest to pasture; from forest to degraded forest) to visualize the change of N$_2$O emissions using graphs. We selected three groups of emission data due to insufficient information for the conversions from grassland, arable land, and crops (Harris et al. 2015; Mosier et al. 1997; Wu et al. 2017). After we graphed the data for each conversion, there are two more groups of data that are excluded for the conversions from forest to crop and forest to pasture (Malajnen et al. 2003; Keller et al. 1993). The emission data collected by Malajnen et al. (2003) is higher than others, which may be due to the regional and seasonal variation. The study done by Keller et al. (1993) used a high conversion rate, which results in high emission values.

Statistical Analysis

For each conversion, different types of regression lines were used to find the trend that best fit our data models including linear regression, exponential regression, polynomial regression, and Frechet Distribution. R$^2$ values were calculated for each regression line: the higher the R$^2$, the better the regression line.

Fréchet Distribution:

$$f(x) = \frac{1}{\Gamma(a)b^a} \exp(-\frac{x}{b}) \left(\frac{x}{b}\right)^{a-1}$$

(Pindado et al., 2017).

We tested different equations, and we found that Fréchet Distribution is the best fit to our data.

Results

Data Overview

Most of the cases are studied in South America and Asia. Similar numbers of cases were collected for each of the land conversion types. The conversion from forest to crop is presented by the most cases.

Discussion

Data Set and Future Research Directions

There is minimal research done related to N$_2$O emissions from land conversions. The database mostly represents the emission data in South America and Asia. The emissions from other biogeographic areas such as Africa, North America, Australia, and Europe are underrepresented. Most of the research on LUC and N$_2$O emissions were conducted in tropics area and it lacks of data in other areas of the globe. More studies should be conducted in area other than tropics and sub-tropics to better improve the database. We did not specify the effects of nitrogen fertilizers on N$_2$O emissions because only two studies in our data set provided relevant information (Verchot et al., 2016; Veldkamp et al., 2008). There was a dominance of research done on the land conversion from forest to other types. The conversion from other land types such as grassland should be further investigated. Further studies should work on different land conversion types including the conversion to fertilized lands. In addition, further research should test the LUC and N$_2$O emissions in the area other than South America and Asia. Patterns of N$_2$O Emissions for LUCs

Forest to Degraded Forest

The logarithmic regression line best fits our data set with the highest R$^2 = 0.396$. The N$_2$O emission gradually decreased after the land conversion.

Forest to Cropland

The Frechet Distribution best fits our data set with the highest R$^2 = 0.241$. The N$_2$O emissions increased and reached to the peak after three years of cropland conversion. Then, the emissions gradually decreased overtime. The trend of N$_2$O emissions we assessed is similar with the study done by Lent, Hergoulach, and Verchot. Lent’s Model has an increase of emissions approximately until the third year, and decreased afterward.

Forest to Pasture

The Frechet Distribution best fits our data set with the highest R$^2 = 0.197$. The N$_2$O emissions increased until year one and gradually dropped down overtime. This trend is also similar with Lent and Verchot’s study.

Our calculations are greatly affected by the emission rates derived from each studies, from which the different measurements and application errors might lead to misleading conclusions.

Conclusions

For all of land conversion groups, the emission rate first increased and then gradually dropped down. The emission rate of the conversion from forest to pasture reduced in the first year, which is earlier than other two groups that reduced their emission in the third year. This research increased the data pool of the past data analysis. In order to attain more accurate emission trends, more studies are needed to minimize the data collection errors from studies.