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PARAMETER SENSITIVITY ASSESSMENT OF DNDC (DENITRIFICATION - DECOMPOSITION: DECOMPOSITION - DENITRIFICATION) MODEL WHEN CALCULATING N_2O GREENHOUSE GAS EMISSIONS FROM MAIZE CULTIVATION

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Abstract

This paper presents the results of the parameter sensitivity assessment of the DNDC (Denitrification - Decomposition: Decomposition - Denitrification) model when calculating N_2O greenhouse gas emissions from maize cultivation. The research results show that water Conductivity, moisture saturation, ammonium concentration, nitrate concentration and soil salinity index are not affected; radiation quantity, wind regime, microbial activity index, porosity, rainwater collection index and lightning rate have little influence; the amount of fertilizer, temperature, rainfall, humidity, mechanical composition, soil C content, pH, field moisture, and topsoil density have the most influence. Research and select trial sites at Maize Research Institute, Dan Phuong, Hanoi, maize variety LVN17 to be planted in winter, on alluvial soil of the Red River. From the research results, the manager may propose measures to reduce N_2O gas from the corn - growing process.

Keywords: N_2O; DNDC; Model sensitivity; Model calibration; Greenhouse gas.

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1. Introduction

DNDC model is a biogeochemical model describing soil chemical processes under the conditions of changing biological and natural environmental factors (temperature, precipitation...) that affect the formation processes and release GHGs from the soil into the atmosphere. The model is built with a detailed structure, with high temporal resolution.

The DNDC model was first used by Li, et al., [1 - 3] to simulate greenhouse gas emissions from rice farming. Later, Pathak et al., [4], Babu et al., [5] continue to refine to calculate CO_2, CH_4, and N_2O emissions and emission reduction potential under different rice cultivation conditions in India. Next, Zhang et al., [6] applied DNDC to the emission reduction potential through studies on improved farming practices.

Salas [7] has launched the idea of building the proposed monitoring system of greenhouse gas emissions from rice cultivation areas of Vietnam using the model DNDC. Luc Thi Thanh and Mai Van Trinh [8] were used to calculating the DNDC model and forecast greenhouse gas emissions in rice cultivation on alluvial soils, and saline soils in Nam Dinh. The results show that using biochar in different fertilizer formulations can reduce from 3 - 9 tons of carbon dioxide equivalent emissions per crop (CO_2eq/ha/crop). Ngo Duc Minh [9] used the DNDC model to simulate greenhouse gas (CH_4, N_2O) emissions in the rice land environment of Vu Gia - Thu Bon river basin, Quang Nam province. Bui Thi Thu Trang [10] evaluate the sensitivity of the parameters and calibrate the DNDC model for the calculation of greenhouse gas emissions from wet rice farming.

Modeling method is one of the effective methods in quantitative research in particular and scientific research in general. However, in order for the research results to show high accuracy and reliability, all models need to perform an important step before being put into use, which is to evaluate the sensitivity of the parameters. Currently, studies using the DNDC model have not provided a set of standard parameters for the model. Therefore, the purpose of this study is to evaluate the sensitivity of the parameters for correction and to build standard parameters in the DNDC model to calculate N_2O GHG emissions from maize cultivation.

2. Methodology

2.1. Data collection method

Meteorological data: For the model to have accurate results, meteorological data must be representative of the study area. The collected information includes the coordinates of the research station, the highest air temperature of the day (Tmax), the lowest air temperature of the day (Tmin), the average air temperature of the day (Ttb), and the total number of sunshine hours. day, wind direction and speed, and daily precipitation (collected from the General Department of Hydrometeorology).

Soil data: Soil type, soil thickness, mechanical composition, physical and chemical properties of the soil (from Ngo Research Institute, Dan Phuong district, Hanoi).

Crop data: Maize varieties; physiological and biochemical characteristics of maize varieties; seasonal calendar; farming techniques (tipping, watering, fertilizing, weeding, spraying pesticides, etc.); types of fertilizers and their characteristics (collecting documents, books and scientific articles, information on varieties and results of seed trials from the Maize Research Institute, Dan Phuong district, Hanoi).

2.2. Using the DNDC model method

This method evaluates the sensitivity of the parameters in the model: Model sensitivity is performed by changing a single parameter of the model/input parameter within an observable range while keeping all other input parameters in the initial parameters (baseline). The input data for sensitivity assessment include climate (temperature, precipitation), soil properties (SOC, clay ratio, pH and density) or farming practices (use rate), chemical fertilizers, and organic fertilizers). These are the required elements of the DNDC model. The basis for choosing the change value is that the variation range is large enough that the estimated results in the actual scenario make a comparable difference. Sensitivity analysis results provide orientation for selecting important parameters for model calibration and model accuracy assessment in all different scenarios.

Scenarios for assessing the impact of factors on N_2O emissions from corn farming:

The analysis of the impact of inputs on the outputs of the model was carried out to determine which inputs have the greatest influence on the emissions calculation and whether this model determines significant differences in emissions under different farming practices. Scenarios for assessing the influence of inputs on outputs when applying the DNDC model to estimate N_2O emissions in the research area are described in Table 1.

In this research, scenarios for analyzing the impact of inputs were established based on meteorological conditions, land and practical farming methods in the farming system on alluvial soil of the Red River in Hanoi. Analysis of the impact of input factors is carried out by changing a single input parameter within an observed range; climate factors (temperature, precipitations, wind speed, humidity, amount of radiation), soil properties (OC content in the soil, clay fraction, soil pH,...) or farming management practices (nitrogen fertilizer, manure) within the research area, while retaining the values of other inputs at the initial value (precipitations and a practical day temperature of 2018, the average value of the properties of the research area, common farming methods are being used).

Table 1. Scenarios for researching the impact of inputs of the model to emissions N_2O

I	Meteorological data								
	Input data	**Unit**	**Year**	**Scenarios (Increase and Decrease from the initial value)**					
1	Maximum high temperature	ºC	2018	- 75 %	- 50 %	- 25 %	+ 25 %	+ 50 %	+ 75 %
2	Minimum low temperature	ºC	2018	- 75 %	- 50 %	- 25 %	+ 25 %	+ 50 %	+ 75 %
3	Total average precipitation	mm	2018	- 75 %	- 50 %	- 25 %	+ 25 %	+ 50 %	+ 75 %
4	Wind speed		2018	- 75 %	- 50 %	- 25 %	+ 25 %	+ 50 %	+ 75 %
5	Radiation		2018	- 75 %	- 50 %	- 25 %	+ 25 %	+ 50 %	+ 75 %
6	Humidity	%	2018	- 75 %	- 50 %	- 25 %	+ 25 %	+ 50 %	+ 75 %
II	**Soil data (kg/ha)**								
1	Soil properties - Texture		Silt Loam	Clay loam	Silty clay loam	Sandy clay loam	Loam	Sandy loam	Loamy sand
			1.28	3.22	8.74	16.58	18.20	12.66	8.96
	Input data	Unit	Initial value	Scenarios (Increase and Decrease from the initial value (%))					
				Decrease 75 %	Decrease 50 %	Decrease 25 %	Increase25 %	Increase50 %	Increase 75 %

2	Bulk density	g/cm^3	1.108	0.3	0.6	0.8	1.4	1.7	1.9
3	Soil pH		5.4	1.4	2.7	4.1	6.8	8.1	9.5
4	SOC at surface soil	kg C/ kg soil	0.05	0.01	0.03	0.04	0.06	0.08	0.09
5	Drainage efficiency (0-1)		0.5	0.1	0.3	0.4	0.6	0.8	0.9
6	Depth of water retention layer	m	9.99	2.50	4.95	7.43	12.49	14.94	17.33
7	Field capacity	wfps	0.4	0.1	0.2	0.3	0.5	0.6	0.7
8	Wilting point	wfps	0.2	0.05	0.1	0.15	0.25	0.3	0.35
9	Clay fraction (0-1)		0.014	0.00	0.01	0.01	0.02	0.02	0.02
10	Porosity (0-1)		0.485	0.121	0.243	0.364	0.606	0.728	0.849
11	Microbial activity index (0-1)		1	0.25	0.5	0.75	1.25	1.5	1.75
12	Soil salinity index (0-100)		0	10	20	30	40	50	60
13	Rainwater collection index		1	0.25	0.5	0.75	1.25	1.5	1.75
14	Initial Nitrate Concentration at surface soil	mg N/ kg	0.5	0.1	0.3	0.4	0.6	0.8	0.9
15	Initial Ammonium Concentration at surface soil	mg N/ kg	0.05	0.0125	0.025	0.0375	0.0625	0.075	0.0875
III	**Farming management practices**								
	Urea	kg/ha/ crop	40	30	60	90	150	180	210

2.3. Data processing methods

Using excel software to synthesize, process and calculate data according to the necessary criteria and criteria to serve the research process, and build tables and charts to represent the data.

Statistical according to each type of appropriate criteria, then use algorithms and functions in Excel to process and calculate data from the collected results, aggregate data with criteria necessary for the research process and calculation the results.

3. Research results

3.1. Impact of meteorological factors on N_2O emissions from maize cultivation

Assessment of the sensitivity of DNDC model parameters for N_2O emissions, the results of the sensitivity analysis show that the meteorological factor has a direct effect on the emission of N_2O emissions from maize cultivation, each factor has a different impact according to the increase or decrease of the content of each factor but mainly when increasing or decreasing the factors, the N_2O emissions are higher than the initial value.

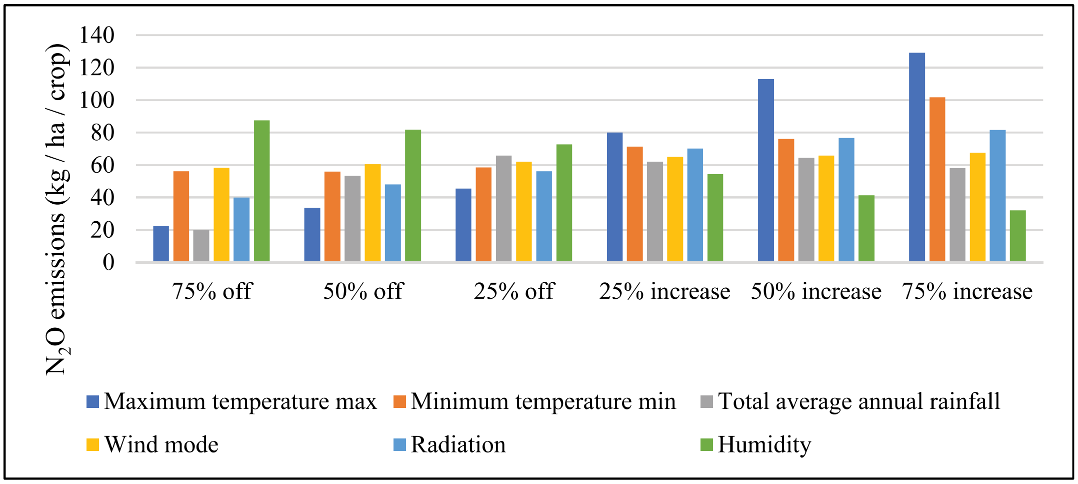

Figure 1: The impact of meteorological factors on N_2O emissions from maize cultivation

The most influential factor is temperature: When temperatures rise or fall by 25 %, 50 % and 75 % of the initial value (in 2018) N_2O emissions increase or decrease sharply, ranging from 22 - 155 %. This is consistent with Li's research, et al., [1], which is caused by the activity of microorganisms involved in N_2O production that increase significantly (density and intensity) as temperatures rise and decrease as temperatures decrease.

The meteorological factor that strongly affects the emission of N_2O ranked second is humidity, the lower the humidity, the higher the emissions, when the humidity is reduced to 75 %, the emissions increase by 87.5 %. This is the only meteorological factor that tends to decrease, the more emissions increase.

Precipitations are assumed to increase and decrease by 25 %, 50 % and 75 % of the initial value (2018), the simulation results show that the change in precipitation does not affect N_2O emissions much. This finding is consistent with published research by Yagi et al., (1996) [11], Adhya et al., (1994) [12], Lu et al., (2000) [13], Sapkota et al., (2011) [14].

Wind mode factors, temperature, and radiation levels are factors that tend to increase N_2O emissions as we increase the content of each factor.

3.2. Impact of soil factors on N_2O emissions from maize cultivation

3.2.1. Soil properties - texture affects N_2O emissions from maize cultivation

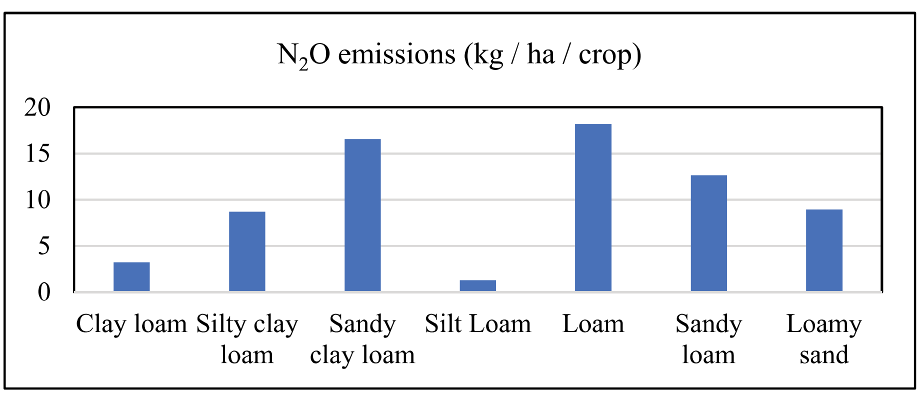

Figure 2: Impacts of soil properties - texture on N_2O emissions from maize cultivation

For the soil properties group, results from soil properties - texture tests showed that mechanical composition had a relatively large impact on N_2O emissions. N_2O emission levels in relation to mechanical composition have been calculated by using the DNDC model in other soils.

According to Figure 2, the type of arable land that most affects N_2O emissions is Loam (emissions 18.190705); Then, in turn, Sand Clay Loam, Sandy Loam, Loamy Sand, Silty Clay Loam, Clay Loam; the lowest is light mud/meat (Silt Loam) (emissions 1.276978). Thus, the selection of arable land directly affects the emission of N_2O gas in corn cultivation.

3.2.2. Impacts of chemical composition in soil on N_2O emissions from maize cultivation

N_2O emissions in relation to the chemical composition in the soil were calculated using the DNDC model in different scenarios: assuming an increase and decrease of 25 %, 50 % and 75 % over the initial value (2018).

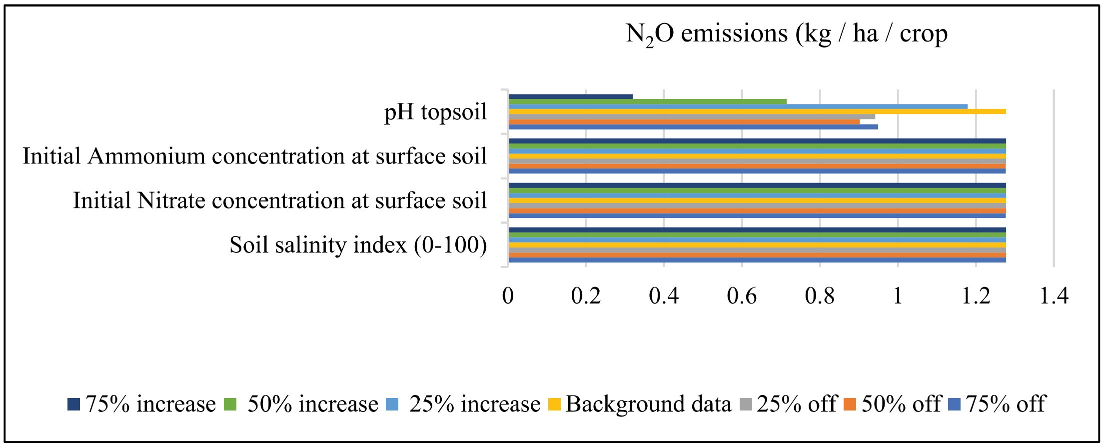

Figure 3: Impacts of chemical compositions in soil on N_2O emissions from maize cultivation

According to the results of the effect of chemical composition parameters in the soil on N_2O emissions: The ground floor pH changed, when increasing the pH in the initial soil by 5.4 to 9.5, the emissions of N_2O decreased by 7.66 %, 44.06 % and 74.92 % respectively. In contrast, when the initial pH (5.4) was reduced to 1.4, N_2O emissions decreased by 27 %, 30 % and -74 %, respectively.

The chemical parameters in the soil are ammonium concentration, the initial nitrate concentration at the surface, the salinity index of the soil does not change the emission of N_2O gases.

3.2.3. Impacts of C content in soil and microbial activity on N_2O emissions from maize cultivation

N_2O emission levels in relation to C content in soil and microbial activity were calculated by using the DNDC model in different scenarios: Assuming an increase and decrease of 25 %, 50 % and 75 % over the initial value (2018).

The results of the impact calculations showed that the C content in the soil (OC) had the strongest impact on N_2O emissions. When increasing the C content in the initial soil (0.05) to 0.06, 0.08, 0.09, the level of N_2O emissions increased by 120 % and 160 % and

180 %, respectively. In contrast, when decreasing the C content in the initial soil (0.05) to 0.04, 0.03, 0.01, the N_2O emissions decreased by -80 %, -60 % and -20 % respectively. Researches indicate that the higher the amount of OC, the more inorganic DOC and N (ammonium and nitrogen rate) are produced through decomposition, promoting the activity of nitrate and anti - nitrification processes.

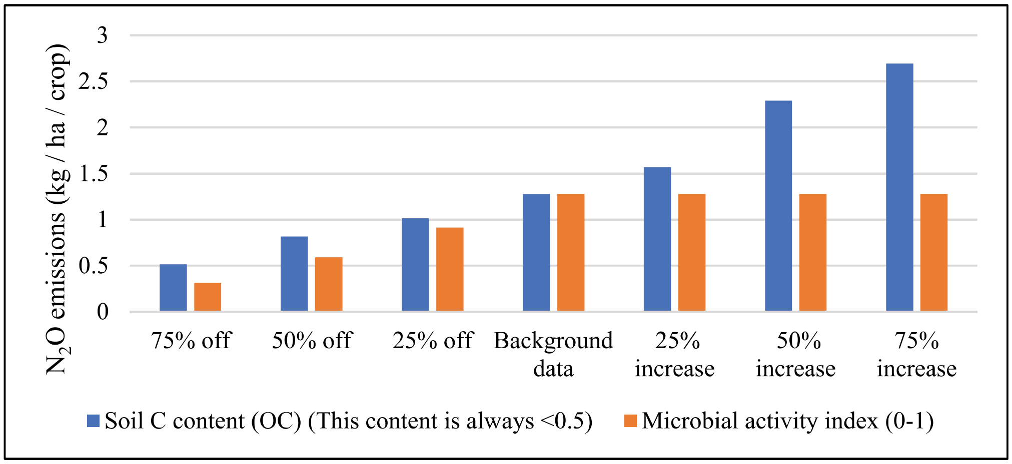

Figure 4: Impacts of C content in soil and microbial activity on N_2O emissions from maize cultivation

Microbial activity affects the emission of N_2O gases. Specifically, when reducing activity from 1 (initial data) to 0.75, 0.5, 0.25 emissions decreased by 25 %, 50 % and 75 % respectively. When organism activity increases, there is no change in N_2O emissions.

3.2.4. The impacts of physical composition in the soil on N_2O emissions from maize cultivation

N_2O emissions in relation to physical compositions in the soil were calculated by using the DNDC model in different scenarios: assuming an increase and decrease of 25 %, 50 % and 75 % over the initial value (2018).

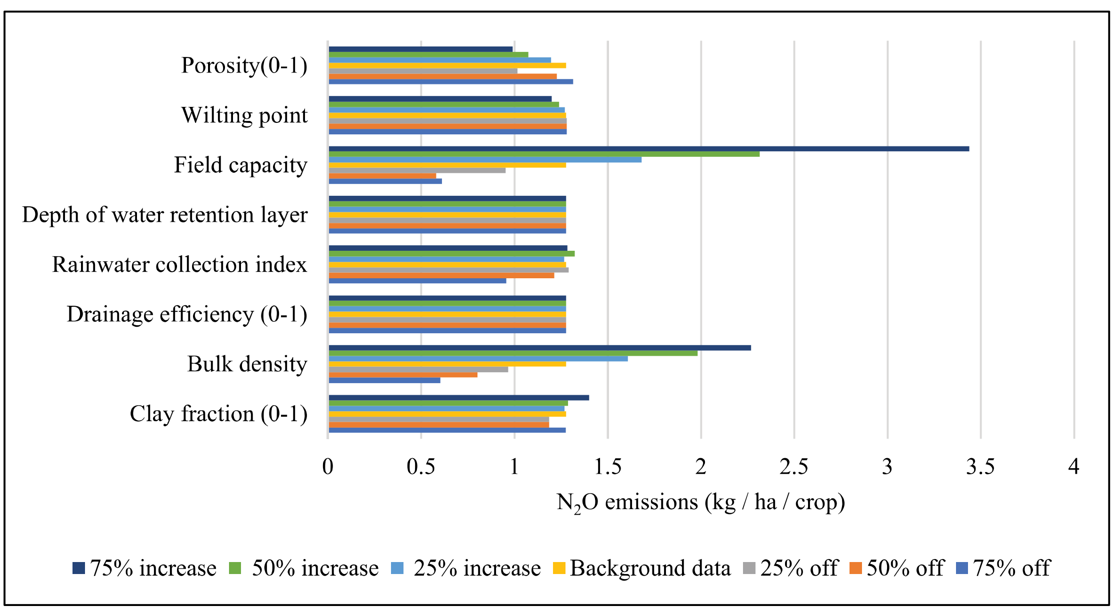

Figure 5: Impacts of physical compositions in the soil on N_2O emissions from maize cultivation

According to Figure 5, N_2O emissions change when changing the physical parameters in the soil:

The Field capacity has the strongest change. When increasing the humidity in the initial soil (0.4) to 0.5, 0.6, 0.7 makes N_2O emissions increase by 31 %, 82 % and 170 % respectively. In contrast, when the initial field humidity (0.4) was reduced to 0.3, 0.2, 0.1 that makes N_2O emissions decreased by 26 %, 55 % and 53 %, respectively.

The N_2O emissions of Bulk density have a marked and proportional change when increasing and decreasing the Bulk density index. Specifically, when increased from 0.3 (index decreased by 75 %) to 1.9 (index increased by 75 %), N_2O emissions increased from -53 % to 77.5 %.

The parameters of porosity, Wilting point, Clay fraction and Rainwater collection index have changed but are not pronounced. These results are similar to those reported in the research of Li (2000) [15], Wassman et al., (2000) [16].

The Drainage efficiency depth of the water retention layer index does not affect N_2O emissions when changing parameters. The trends in this research are similar to the research that has been reported in the research of Li et al., (1994, 1996) [2, 17] and Brouwman et al., (2002) [18].

3.3. Impact of fertilization regime on N_2O emissions from maize cultivation

The level of N_2O emissions in relation to the fertilization regime has been calculated by the DNDC model in different scenarios: assuming an increase in the amount of Urea fertilizer for corn from 40 kg/ha/crop to 60 kg/ha/crop, 90 kg/ha/crop, 120 kg/ha/crop, 180 kg/ha/crop, 210 kg/ha/crop.

Comparing N_2O emissions results according to fertilizer levels shows: At all points, the intensity of N_2O emissions is quite volatile at different times, in the recommended fertilizer formulas (the amount of nitrogen fertilizer is lower than the farmer's fertilization level of 40 kg/ha) the intensity of N_2O emissions is 1.276978. In the fertilizer formulas when increasing the amount of fertilizer to 75 %, the intensity of N_2O emissions is 2.99860, the emission of N_2O increased by 1.721625, corresponding to 135 %. In the same irrigation regime, the higher the average value of the N_2O emission intensity in the fertilizer formula, which tends to be higher than the fertilizer formula according to the farmer's fertilization level (the original value).

Erickson et al., (2001) have shown that nitrogen is an important factor in crop growth and N_2O emissions. High levels of ammonium (NH_{4+}) and Nitrate (NO_{3-}) will provide the substrate for the microorganisms that make N_2O in the soil. The process of de-nitrogenization usually occurs in environments with low oxygen concentrations. Nguyen Duc Thanh's research (2017) on the effect of protein dosage on the intensity of N_2O emissions on rice land in Thua Thien Hue showed that increasing nitrogen fertilization levels will increase N_2O emission levels: the intensity of N_2O emissions in 120 kg N/ha fertilizer formulations is highest compared to 80 kg N/ha and 100 kg N/ha formulations. In this study, as we increased the amount of nitrogen fertilizer, the higher the level of N_2O greenhouse gas emissions in corn production. The trends in this research are similar to other research that has been reported in the studies of Li et al., [2, 21] and Bouwman et al., [22].

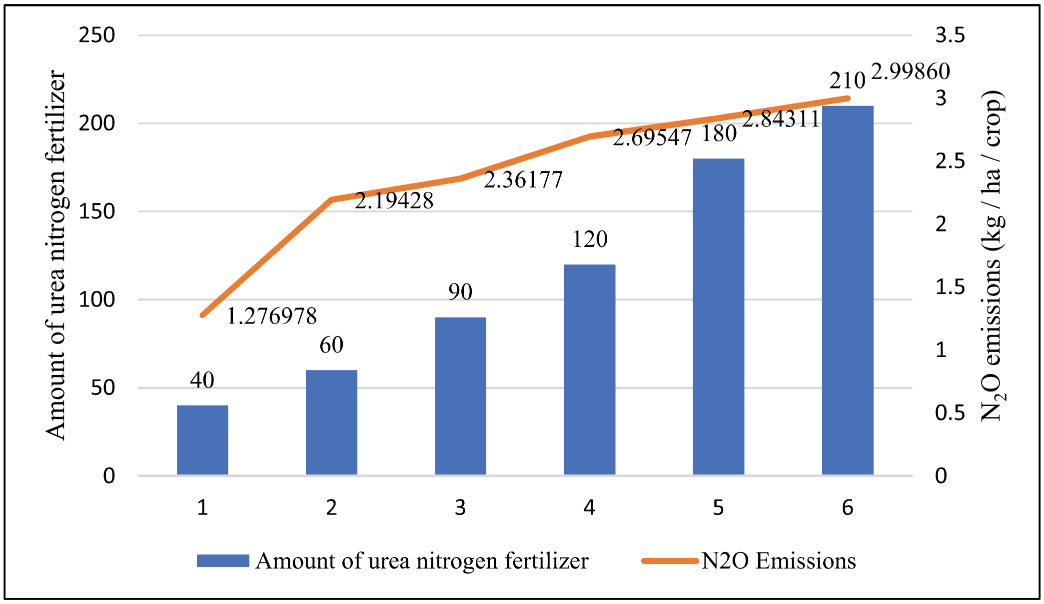

Figure 6: Impacts of farming methods - Urea nitrogen fertilizer on N_2O emissions from maize cultivation

4. Conclusion

From the results of the research, conclusions are given as follows:

- The emission of N_2O from maize cultivation has changed with the value of meteorological factors, soil and fertilizer application.

- Meteorological factors have a direct effect on the emissions of N_2O emissions from maize cultivation, each factor has a different impact according to the increase or decrease in the content of each factor but mainly when increasing or decreasing the factors, the emissions of N_2O are higher than the initial value.

- Soil factors: The mechanical composition mostly affects N_2O emissions, so it is necessary to consider the preferred choice of cultivation on Silt Loam soils. The chemical composition is only a pH factor that affects N_2O emissions. The C content in the soil is proportional to the emission of N_2O. The increased microbial activity index does not change the N_2O emissions compared to the initial value. The physical composition only has the field humidity factor and the surface density that clearly affects N_2O emissions.

- The fertilization regime has the most direct and strong impact on the emission of N_2O greenhouse gases. Because N_2O emissions mainly depend on the N content in the soil. Therefore, the more fertilizer is applied, the higher the emissions.

- The DNDC model is suitable for calculating N_2O greenhouse gas emissions in maize farming in agriculture.

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