The Impact of Nitrous Oxide Produced by Agricultural Products on Global Warming

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Abstract. Nitrous oxide (N2O) stands as a potent greenhouse gas, often overlooked yet significantly influential in shaping the Earth's climate system. Understanding the multifaceted nature of N2O emissions and their complex interactions with environmental systems is essential for developing effective strategies to combat climate change and mitigate its adverse impacts. At a time of growing concerns about climate change, the study reveals multiple sources of N2O, ubiquitous concentrations, and far-reaching environmental impacts. By elucidating the pivotal role of human activities, particularly the widespread use of nitrogen fertilizers and manures, the study indicates potential drivers fueling the surge in atmospheric N2O levels. Moreover, it elucidates regional differences in N2O emissions, accentuating the disproportionate burden borne by developing economies from intensive agricultural practices. Through an exploration of existing mitigation measures such as nitrification inhibitors and enhanced nitrogen efficiency within the food chain, the study highlights the urgency of adopting sustainable interventions to curb N2O emissions effectively. The study's significance lies in its comprehensive examination of the interplay between human activities, N2O emissions, and the broader climate change pattern. It provides valuable insights into evidence-based policymaking, agricultural practices, and environmental management initiatives, thus pointing the way to a more sustainable future.

Keywords: Nitrous Oxide; Greenhouse Gas Emissions; Agricultural Impact; Global Warming Consequences.

1. Introduction

In recent years, global warming has become one of the more serious problems in environmental protection. In line with findings from the Fifth Assessment Report (AR5) carried out by the Intergovernmental Panel on Climate Change (IPCC), there has been a warming trend observed in the climate system. Precisely, the Earth's mean surface temperature has increased by roughly 0.65°C to 1.06°C from 1880 to 2012 [1]. Apart from carbon dioxide, the widely recognized greenhouse gas accountable for global warming, nitrogen monoxide is also a significant contributor. Nitrous oxide (N2O) is a noteworthy greenhouse gas produced by human activities, with agriculture being its main source. It lies at the core of discussions about the effectiveness of biofuels, the climate-altering effects of population growth, and how reducing emissions other than CO2 can aid in mitigating the negative impacts of climate change [2]. Although researchers have demonstrated the significant impact of N2O on global warming, specific aspects of this effect remain unresolved.

Human activities, particularly the application of nitrogen (N) fertilizers and organic matter like manures applied to farmland, are the primary contributors to the ongoing rise in atmospheric N2O concentrations observed over the past century [3]. The increasing levels of N2O can exacerbate environmental impacts, contributing to air pollution, ozone depletion, and climate change. The primary sources of global N2O emissions are predominantly from East Asia, South Asia, Africa, and South America. Synthetic fertilizer emissions are the primary concern in China, India, and the United States, whereas in Africa and South America, emissions from fertilizer use as livestock manure take precedence [4]. The largest rises in emissions are happening in developing economies, particularly in countries like Brazil, China, and India, as a result of increasing crop yields and livestock populations [4]. The escalating levels of N2O emissions, primarily driven by human activities such as agricultural practices, pose a significant threat to environmental stability. As global temperatures continue to rise, exacerbated by greenhouse gases like N2O, urgent action is needed to mitigate the environmental impacts and combat climate change.

This paper aims to look at the effect of N2O gas produced by crops on atmospheric levels of N2O, how human activities affect and contribute to the gas emissions, and current treatments to solve the serious problem.

2. Sources of Nitrous Oxide

N2O is a greenhouse gas, alongside carbon dioxide and methane, that significantly influences climate change. At present, the primary origins of N2O emissions include indirect sources from agriculture, industry, biomass burning, and atmospheric deposition [2]. Biomass combustion produces N2O during agricultural and industrial operations, while N2O in the soil is also released into the atmosphere during erosion runoff. This could seriously affect climate change. In agricultural livestock, the largest sources of N2O emissions are associated with animal production, mainly through the internal water cycle of livestock (urine) and direct emissions from manure, with a small portion from waste management and utilization [3].

Scientists and researchers used to have difficulty measuring or predicting the amount of anthropogenic N2O produced in the air. That is because N2O emissions from agricultural soils vary greatly at different scales in the spatial domain [5].

As researchers delve deeper into their investigations, they can quantify the levels of anthropogenic N2O in the atmosphere and their respective proportions. Approximately 70% of the N2O released into the atmosphere from natural sources originates from soil and crops [6]. The measurement method they used was provided by the OECD National N2O Inventory Project. Another study also showed that the major source of atmospheric N2O is soil, accounting for about 57% of total annual global emissions [7]. They determined the major sources of nitrogen and N2O by chemistry at soil pH (hydrogen potential) less than 5, based on a more reliable method that also measured fluxes of N2O and nitrogen in agricultural soils. Currently, the proportion of N2O directly emitted in inorganic nitrogen in agricultural soils is 1.25 (0.25 ± 2.25) % [8] and the results can be measured by top-down and bottom-up estimation methods.

3. Human Impact

Human activities play an important role in N2O emissions, especially after the industrial era. With the increasing population nowadays, the food problem has become more and more serious, reaching a situation where the supply exceeds the demand. As demand for food production increases, the area of soil used to grow rice and other crops, as well as N2O emissions, will continue to increase in the coming decades. As agricultural soils serve as the primary origin of N2O emissions, an expansion in agricultural lands will correspondingly result in a rise in N2O emissions [2]. A significant origin of atmospheric N2O is agricultural ecosystems, where soil-dwelling microorganisms engaged in nitrification and denitrification processes contribute to its production. People apply excessive nitrogen fertilizer to agricultural fields, which promotes microbial activity and converts nitrogen to N2O through nitrification and denitrification processes. The increasing global demand for food to sustain a growing population poses a significant challenge in a world striving to reduce greenhouse gas emissions and address global change concerns [3].

N2O, among other greenhouse gases such as carbon dioxide, contributes about eight percent of the global radiation forcing. Human activities play a significant role in this, with agriculture accounting for about fourteen percent of these emissions [5]. In addition to this, since fertilizers began to spread with human agricultural activities, soils, floods, and agricultural watering, water the loss of nitrogen to humans through runoff has been significant [9]. Moreover, soil aeration can result in significant atmospheric emissions of N2O through the heavy use of mineral nitrogen fertilizers by humans due to nitrification and denitrification reactions of active nitrifying and denitrifying populations, leading to an increase in the share of agriculture in global N2O emissions [8].

The levels of N2O emissions also vary greatly from country to country. In Australia, nearly 80% of its emissions come from agricultural land, including 32% nitrogen fertilizer, 38% soil, and 30% animal manure [10]. Within flooded rice fields in the Riverina Plain, Australia, the emissions of N2O varied between 0.02% and 1.4% of the total nitrogen from fertilizers. However, a significant nitrogen loss of 15.4% occurred during just four days of irrigated crops. In crop roots, N2O use reached 9.9%, and fertilized plantations emitted more N2O than other large livestock pastures [10]. In France, the Seine estuary plays a large role in French nitrogen emissions as a basin area with high population density and a combination of heavy industry and agriculture. Ammonium nitrogen is widely used in agriculture, but when it occurs in tidal freshwater estuaries nitrification can lead to strong summer oxygen deficits, and nitrogen concentrations are closely related to nitrification. The total emissions of N2O in the same sector were 40 kg N d-1 [11].

4. Influence on the Environment

N2O is a very important greenhouse gas that, although low in the atmosphere, should not be underestimated, possessing a global warming capacity 298 times stronger than that of carbon dioxide [3]. The damage caused by natural disasters mainly involves industries such as agriculture, forestry, fisheries, retail trade, animal feed, and fertilizers [12]. Not only is N2O powerfully destructive to the stratospheric ozone layer, but it also has irreversible negative effects on climate change, summer droughts, and temperate grasslands, and can even lead to an increase in another greenhouse gas, carbon dioxide [2]. The nitrogen cycle resulting from the use of excessive nitrogen fertilizers leads to increased N2O emissions in agricultural systems compared to the broader tropical environment [6]. Advancing the denitrification process is environmentally important because it eliminates soluble nitrogen without transferring pollution that may 1) impact public health by presenting elevated concentrations in drinking water and food, and 2) through high concentrations in surface waters promoting eutrophication [5]. In addition to this, many behaviors in nature can be caused by the increase in N2O, for example, in tropical versus temperate climates, over-stimulation of nitrogen mineralization in plants temporarily reduces nitrogen competition between plants and microorganisms, for example, and thus subconsciously increases N2O emissions [8].

Increased levels of N2O emissions from agricultural plants have an indelible negative impact on the environment and biosphere. Global warming has caused lake and river glaciers to melt earlier than before, with longer ice-free periods and warmer water temperatures [13]. Climate change will also change the migratory patterns of five species of birds, fish, and mammals. This alteration may impact animal transport patterns and the discharge of pollutants into the environment [14].

5. Current Treatments for N2O Emission

The government and the relevant economic authorities have mitigated the environmental impact of N2O produced by agriculture. For example, in Australia, the government considers it necessary to examine the emission factors of N2O emissions. One and a half percent of the nitrogen content of fertilizer or animal manure occurs as N2O [10]. To address this issue, on agricultural land, it was decided to match the use of mineral nitrogen with the needs of crops and pastures to reduce N2O emissions. Additionally, the availability of mineral nitrogen is regulated by using diluting materials, such as nitrification inhibitors. For manure management, the Australian government uses measures such as the immediate burial of manure in the soil to reduce direct emissions of N2O [10].

In the United States, agricultural management proposes that dietary choices and service waste will be addressed through more sophisticated systemic measures to achieve significant emission reduction goals [3]. However, some regions benefit from increased agricultural production due to climate change, while others suffer declines [15]. The environmental impact of nitrogen fertilizer can be reduced by improving the efficiency of crop and pasture use, for example, by managing the frequency, timing, and amount of irrigation, applying nitrogen fertilizer as needed by the crop, and not performing soil maintenance. The shift in human dietary preferences, favoring vegetables over meat, has the potential to significantly change nitrogen consumption patterns. This shift may lead to improvements in nitrogen efficiency within the food chain [16]. Also, the use of nitrification inhibitors to suppress N2O emissions is one of the main management solutions [6].

More and more economic sectors around the world are also involved in N2O limitation activities by using resources from the Global Positioning System (GPS) and tools from Geographic Information Systems (GIS) to improve the use of feed crude protein [16]. In addition, direct measurement techniques can be used to apply high enrichment (approximately 20% to 80%) fertilizers on defined lands. Nitrogen-labeled fertilizers with high enrichment (between twenty and eighty percent) can be applied on defined lands to detect post-denitrification nitrogen content and N2O gas production by quantifying the increase in atmospheric nitrogen content [17].

6. Conclusion

In conclusion, this study highlights the urgent need for comprehensive actions to address the rising levels of nitrous oxide (N2O) emissions and their significant contribution to global warming and environmental instability. With the Earth's climate system showing an alarming warming trend, exacerbated by greenhouse gases like N2O, urgent measures are imperative to mitigate these environmental impacts and combat climate change effectively. The study highlights the primary role of human activities, particularly in agriculture, as the main contributors to the rise in atmospheric N2O concentrations. These activities include the application of nitrogen fertilizers and manures, which promote microbial activity and N2O emissions through nitrification and denitrification processes. Moreover, the study identifies the disproportionate impact of N2O emissions across different regions, with developing economies experiencing the most significant increases due to rising crop yields and livestock populations.

The detrimental effects of N2O emissions on the environment are substantial, ranging from air pollution and ozone depletion to disruptions in climate patterns and ecosystems. As such, advancing denitrification processes and implementing sustainable agricultural practices are crucial for mitigating nitrogen pollution and its adverse consequences on public health and aquatic ecosystems. Furthermore, the study emphasizes the importance of regulatory measures and technological solutions, such as nitrification inhibitors and improved nitrogen efficiency within the food chain, in reducing N2O emissions.

The outlook of the study suggests the significance of continued studies to develop sustainable agricultural practices and mitigation strategies. This includes further exploration of dietary shifts, adoption of technologies like GPS and GIS, and the use of nitrification inhibitors to reduce N2O emissions. Overall, this study highlights the complex interplay between human activities, N2O emissions, and their environmental impacts. Addressing this issue requires a multifaceted approach that integrates scientific research, policy interventions, and technological innovations to achieve sustainable development goals and safeguard the planet for future generations.

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