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WHY DO WE NEED TO WORRY ABOUT NITROUS OXIDE EMISSIONS IN A CLIMATE-CHANGING WORLD?

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Why do we need to worry about nitrous oxide emissions in a climate-changing world?

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In dedication to World Environment Day 2026, raising awareness about nitrous oxide and its impact on climate and environmental sustainability.

Abstract

The theme for World Environment Day 2026, "Inspired by nature, for climate, for our future", places special focus on the call for climate action that is sustainable and provides a goal for the world to unite in the fight against climate change. It is true that all efforts to curb climate change begin with CO2; however, there is another colourless and odourless greenhouse gas that has long been ignored, and that is nitrous oxide (N2O). It is the gas that is known to be the most dangerous and is worsening climate change at an alarming rate (Tian et al., 2020). The world is trying to solve the problem of world hunger by relying on an economically driven agricultural practice that provides incentives to treat land with an abundant supply of nitrogen to produce more crops. Once the soil has an abundant supply of Nitrogen, it undergoes a series of microbial transformations, including nitrification and denitrification, that result in copious amounts of N2O released into the environment (Butterbach-Bahl et al., 2013). From a scientific perspective, N2O has a Global Warming Potential that is 273 times that of CO2. It also has a long residence time, being able to survive in the atmosphere for over a century. The other atmospheric concern is the depletion of the Ozone Layer (Ravishankara et al., 2009). There is an alarming environmental paradox that is related to food security, whereby the agricultural practices that have been developed to bring food security are simultaneously threatening ecological security and environmental sustainability. The increase in N2O emissions is now associated with the degradation of soil, the imbalance of the atmosphere, the loss of biodiversity and climate instability. Looking at the "Inspired by nature. For climate. For our future" theme, it has become critical to reduce Nitrous Oxide emissions to achieve the goal of sustainable Nitrogen management, sustainable agriculture and nature-based climate solutions. The core focus addresses the vital needs to ensure the environment and safety for the future of humanity.

The Science and History of the "Silent Threat": From Medical Miracle to Climate Crisis

The N2O history began in 1772 with the discovery of the molecule by the English chemist Joseph Priestley. Then, its mild anaesthetic properties were further studied by Humphry Davy. Davy called the gas 'laughing gas'. For a long time, N2O was considered a medical miracle. In the early 20th century, the invention of the Haber-Bosch process allowed the production of synthetic nitrogen fertilisers (Erisman et al., 2008). This industrial process further disrupted the already existing imbalance of the nitrogen cycle. In the 20th century, agriculture was further advanced by an even larger production of crops. The negative consequences of this large-scale agricultural process were first studied by the scientist and Nobel Prize winner Paul Crutzen in the 1970s. He showed that excess nitrogen in soil was being converted to N2O, which was then emitted to the atmosphere (Crutzen, 1970). N2O is a silent threat to the environment as it is invisible to the human eye. In addition, it is a completely colourless and odourless gas. N2O is also extremely stable as a molecule. The gas is made up of two nitrogen atoms and a single oxygen atom (N-N-O). This stability, in addition to its asymmetrical structure, allows for excellent absorption of infrared radiation, which ultimately contributes to the greenhouse gas effect. In addressing the management of N2O, researchers categorise its sources into two distinct groups (Tian et al., 2020). Enlist the two groups. Natural sources contribute to a portion of global emissions, predominantly emitted by microorganisms in tropical forests, natural soils, and oceans as part of the Earth's intrinsic nitrogen cycle. Conversely, anthropogenic sources have significantly exacerbated the situation. The vast majority of human-induced N2O emissions originate from agricultural activities, particularly the extensive use of synthetic fertilisers and animal manure (Syakila & Kroeze, 2011). Additionally, some smaller, anthropogenic sources include industrial chemical production, wastewater treatment, and the combustion of fossil fuels and biomass. The release of N2O from agricultural soils presents significant atmospheric concerns. This molecule exhibits an exceptionally prolonged atmospheric lifespan, persisting for approximately 114 years prior to decomposition. Due to its extended duration and heat-absorbing chemical properties, N2O possesses a Global Warming Potential (GWP) that is 273 times greater than that of carbon dioxide CO2 over a century. Additionally, N2O exhibits unique behaviour as it ascends into the atmosphere. It gradually migrates into the stratosphere, where it undergoes a reaction with ultraviolet sunlight to form nitric oxide NO. This secondary chemical reaction actively depletes the Earth's protective ozone layer. Currently, N2O is identified as the predominant ozone-depleting substance emitted by anthropogenic activities (Ravishankara et al., 2009). N2O is increasingly recognised by scientists as a significant concern for the future, as it lies at the intersection of climate change and global food security. With the global population nearing eight billion, the demand for food and, consequently, the fertilisers required for its production is expected to escalate. Without an urgent transformation in agricultural practices to mitigate these emissions, the rising levels of N2O pose a threat to negate the climate progress achieved through the reduction of CO2 and fossil fuel usage. Addressing this silent threat is essential for achieving the climate action objectives set for World Environment Day 2026.

Impact of Nitrous Oxide on Agriculture and Environmental Sustainability

Modern agriculture faces a critical environmental challenge: while nitrogen fertilisers are vital for boosting food production, they also contribute to climate change through N2O emissions. As farmers strive to meet the demands of a growing global population, they increasingly depend on synthetic nitrogen. However, a large portion of this nitrogen is not utilised by crops, leading to microbial processes like nitrification and denitrification that release N2O, a potent greenhouse gas (Butterbach-Bahl et al., 2013). These dynamic turns fertile soils into significant greenhouse gas sources, compounding the effects of climate change. The repercussions go beyond atmospheric warming; they pose severe risks to global food security. As temperatures rise and weather patterns become erratic, resulting in prolonged droughts, floods, and heatwaves, agricultural productivity takes a hit, especially in regions already vulnerable to food shortages (Lobell et al., 2011). Staple crops such as wheat, rice, and maize are particularly susceptible to these climatic stresses, leading to reduced yields and lower nutritional quality. This interplay between agricultural practices and climate change highlights the urgent need for sustainable farming strategies that minimise nitrogen loss while maintaining food security in a rapidly changing world. Excessive nitrogen application not only boosts short-term crop output but also gradually deteriorates soil health. It increases soil acidity, depletes organic matter, and disrupts the diversity of beneficial microorganisms, which are essential for maintaining soil fertility and nutrient cycling (Guo et al., 2010). Over time, this degradation undermines the soil's ability to retain water and nutrients, leading to greater reliance on chemical inputs for agricultural productivity. Moreover, nitrogen runoff from these fields contaminates rivers, groundwater, and wetlands, resulting in eutrophication and algal blooms, which threaten aquatic biodiversity (Smith et al., 1999). This degradation creates a vicious cycle: declining soil fertility compels farmers to apply even greater volumes of fertilisers, exacerbating environmental harm, economic burdens, and greenhouse gas emissions. N2O thus emerges not only as a potent greenhouse gas but also as a key indicator of the imbalance between food production, soil health, and climate stability. To tackle these challenges effectively, adopting approaches like precision farming, sustainable nitrogen management, regenerative agriculture, and nature-based solutions is crucial. These practices aim to protect soil health, ensure long-term food security, and meet global climate goals, safeguarding the future of humanity and the environment.

Mitigation Measures: Toward Sustainable Nitrogen Management

Emission of N_2O has become an imperative issue that needs to be dealt with for making agriculture climate resilient and sustainable. Considering that agriculture is the main source of N_2O emissions, sustainable nitrogen management becomes a key approach for mitigating N_2O emissions. The excessive use of nitrogen fertilisers needs to be replaced with precision-based use of fertilisers according to soil type and crop requirements. Organic farming, crop rotation, conservation agriculture, and

biofertilizer use will improve the soil conditions without increasing the level of greenhouse gas emissions (Kanter et al., 2020). Scientific experts are also encouraging the use of nitrification inhibitors and controlled-release fertilisers for reducing the loss of nitrogen and limiting N_2O emissions (Akiyama et al., 2010). In addition, efficient irrigation system management and proper manure management also play a significant role in reducing emissions. Moreover, activities like afforestation and agroforestry also assist in maintaining ecological balance and enhancing carbon sequestration. It also requires a robust policy approach, scientific advancement, and education for farmers to make farming practices more climate-smart (Fig. 1). Keeping in view the objectives of World Environment Day 2026, sustainable and nature-based solutions are needed to reduce Nitrous Oxide emissions.

Fig.1: Strategies for mitigating N2O Emissions Toward Climate-Resilient and sustainable agriculture

Conclusion

N_2O deserves consideration for its unparalleled potential to accelerate global climate change and environmental disruption. N_2O has emerged as the most significant greenhouse gas linked to the global agricultural sector. The excessive use of nitrogen fertilisers and unsustainable practices of land management have been the main culprits. Although fertilisers containing nitrogen have been pivotal in increasing the production of food globally, their excessive and inefficient use has caused disruption to the natural nitrogen cycle and caused farming systems to become ongoing sources of atmospheric pollution. This represents an extraordinary paradox that agriculture is both a major contributor and one of the main victims of the current climate crisis. Increasing temperatures and recurrent droughts and floods, combined with soil degradation and loss of biodiversity, are leading to a loss of resilience in crops and threaten the production of food globally as well as the sustainability of agriculture in the long term. Furthermore, the climate change-induced reductions in food availability are likely to increase inflation and economic instability, and lead to migration and increased geopolitical tensions and conflicts for resources. This will have impacts on the foundations of human and societal wellbeing. N_2O deserves the status of the most critical consideration for its atmospheric persistence, potential to drive global warming, and the unique and critical depletive effect on ozone in the upper atmosphere. The use of sustainable practices of nitrogen management combined with regenerative agriculture, precision farming, and climate-related practices, integration of these practices, and mitigation of emissions from soil is the ethical and scientific imperative to enable the retention of the soil's nitrogen and enhance food security. This "silent threat" should be the primary consideration for protecting the well-being of humanity and the planet.

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