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Effects of Atmospheric Nitrogen Deposition on Nitrous Oxide Emission from Mountainous Forest Soils in Southwest Karst Region

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Abstract: Forests are the most important component of terrestrial ecosystems, and they are also direct bearers of large areas of nitrogen deposition. Atmospheric nitrogen deposition has many hazards to forest ecosystems, and the emission of soil nitrous oxide is an important reference indicator. However, current research on atmospheric nitrogen deposition has focused on carbon emissions. The purpose of this article is to study the effect of atmospheric nitrogen deposition on the emission of nitrous oxide from soils of mountain forests in the karst areas of Southwest China. To this end, this paper studied the vegetation types and soil types of mountain forests in the karst areas of Southwest China and the production of nitrous oxide by means of literature research and experimental methods. Mechanism. The main mechanisms of nitrous oxide production are: nitrification, denitrification, nitrifying bacteria denitrification, fungal denitrification, and abiotic processes. The factors affecting soil nitrous oxide emissions were studied. The urea was used to simulate atmospheric nitrogen deposition. The soil nitrous oxide flux was measured through experiments. The nitrogen dioxide emissions in various areas before and after simulated nitrogen deposition were compared. The research results show that the growth rate of nitrous oxide emission is highest in the areas where the Pinus massoniana forest is planted, reaching 36.8% in yellow soil and 25.1% in lime soil. The growth rate of nitrous oxide emission of yellow soil in karst area after atmospheric nitrogen deposition is significantly higher than that of lime soil. It may be because alkaline urea is more easily absorbed in acidic yellow soil, but more difficult to absorb in the same alkaline lime soil. In addition, there may be effects of moisture and microorganisms.

1. Introduction

The increase of atmospheric nitrogen deposition is one of the most important characteristics of

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global change and also an important indicator reflecting the change of atmospheric environmental quality. It has an important impact on global grain production, carbon and nitrogen cycle and environmental quality [1]. As the largest developing country in the world, China has also been recognized as one of the regions with the most serious nitrogen deposition in the world. People predict that nitrogen deposition in China may continue to grow rapidly in a long period of time, and people also carry out experimental research on ecological environmental effects of nitrogen deposition, environmental quality status assessment and environmental governance policy research based on this prediction [2]. For a long time, more researches have been carried out on the dynamic changes and spatial patterns of nitrogen deposition in China. However, due to the lack of long-term series of scientific data covering the whole country, it has been difficult to give the overall scientific knowledge of the temporal and spatial patterns of the total amount of atmospheric nitrogen deposition in China and the relative contributions of each component, which limits people's understanding of the influencing factors and driving mechanisms of the temporal and spatial variations of nitrogen deposition [3]. Nitrogen deposition will increase the probability of plants suffering from cold and freeze injury [4]. Nitrogen deposition will cause the reduction of root-shoot ratio, the growth of fine roots and the reduction of mycorrhizal colonization, thus causing the reduction of the ability of plants to obtain water, thus increasing the sensitivity to early [5]. Nitrogen is an important determinant of the palatability of plant tissues. The increase in nitrogen content increases the palatability of leaves or buds, resulting in an increase in insect eating [6]. The transformation of atmospheric nitrogen deposition in China over the past 35 years is the result of the combined effect of economic restructuring and a variety of environmental control measures. To a certain extent, it has been proved that a series of environmental control measures in China over the past 10 years have achieved results in atmospheric environmental control. This not only provides an important scientific basis for China's environmental control, but also provides a decision-making reference for ecological environmental protection in other developing countries [7].

Although nitrous oxide is produced through denitrification, nitrification, denitrification by nitrifying bacteria and nitrification-denitrification coupling, fungal denitrification, chemical denitrification, and dissimilation and reduction of nitric acid to ammonium, biological denitrification may still be the main pathway for nitrous oxide production in general farmland soil [8]. At present, people still face many challenges in understanding the production and consumption of nitrous oxide in farmland soil. The main manifestations are as follows: First, nitrous oxide emission from farmland soil mainly comes from emission peaks generated by irrigation immediately after natural precipitation, especially after fertilization [9]. The in-depth study on the production and consumption of nitrous oxide at this stage is of great significance for proposing measures to reduce nitrous oxide emission from farmland soil [10]. Secondly, reducing the N2O/N2 product ratio during soil denitrification is one of the effective measures to reduce N2O emission. Therefore, it is necessary to deeply understand the influence of environmental factors and control measures on the denitrification product ratio and its mechanism, so as to provide the basis for realizing nitrous oxide emission reduction by reducing the product ratio [11]. Furthermore, it is also of great significance to strengthen the understanding of nitrous oxide reduction process and its influencing factors [12]. Finally, people encountered great challenges in finding key microorganisms related to nitrous oxide emissions [13]. This is closely related to the broad spectrum of functional groups of denitrifying microorganisms and the diversity of physiological types. It is believed that this problem can be gradually solved with the development of molecular biology and gene chip technology. [14] At the same time, comprehensive utilization of new technologies and methods to further explore the effects of soil physical, chemical and biological factors on nitrogen transformation process, nitrous oxide key site emissions and associated microbial diversity, and to construct nitrogen balance and related nitrous oxide emission models can further provide theoretical basis for nitrous oxide emission mechanism and related influencing factors [15].

Feng studied the effects of slope and soil layer on soil microbial biomass and abundance, and found that soil organic carbon, available nitrogen and phosphorus are the key factors of SMBC and SMBN variation, respectively, while available nitrogen and available phosphorus are the important factors that affect bacterial abundance change, and the main factor of fungal abundance change is available potassium [16]. Wang studied the influence of karst rocky desertification on the soil fungal community in southwest China, and the research showed that KRD had significant influence on the soil fungal community [17]. Zhi studied the effect of forest structure on the natural regeneration of male wood population in southwest Guangxi. The study found that seedling diameter was mainly affected by adult density, and seedling height was mainly affected by the combination of adult density and area [18]. HOU reviewed the research on ecological vulnerability in southwest karst region based on the framework of structure-function-habitat. It is necessary to strengthen the research on ecological vulnerability in different succession stages of karst rocky desertification in order to promote rocky desertification prevention and ecological restoration and reconstruction [19]. Li found that among the soil properties, soil moisture, silt content and total nitrogen content are the most important variables that affect EEA variation. Meanwhile, soil properties in karst areas can well explain the variation of regional EEA [20]. Fang studied the characteristics of plant communities in karst areas of southwest China and their relationship with soil properties [21]. DUAN studied the spatial pattern of cultivated land quality in Guangxi based on landscape index and Gini coefficient. The study found that the concentration of different cultivated land use levels in the central karst plain area was relatively high. The combination of cultivated land quality grades in northeast Guangxi is rounder than that in southeast Guangxi. Therefore, the combination of land use grades shows the opposite rule [22]. Žebre studied Mesozoic limestone and dolomite. The lithology of karst carbonate rocks is almost completely free of surface runoff, and the typical karst morphology dominates. A wide range of karst areas are affected by Quaternary glaciers, so the modern landscape has the characteristics of glacier landform. The focus of this map is to provide basis for further study of Quaternary glaciers in SNE, Nik and GorskiKotar regions. At the same time of studying the map, a legend of glacier landscape mapping was also put forward [23]. Luo studied the dynamics and man-made effects of various karst flow systems in the mountainous areas of South China [24]. Sartégou studied the quantification of incision rates since the early Miocene: novelty, potential and limitations [25].

The main research content of this article is roughly divided into five parts. The first part is the introduction of the study, the purpose and significance of the study and the current situation of the study, a brief introduction of atmospheric nitrogen deposition and nitrous oxide emissions from soil[26-27]. The second part is the theory and method, explaining the principle of nitrous oxide production and the basic characteristics of atmospheric nitrogen deposition. The mechanism of nitrous oxide production mainly includes nitrification, denitrification, denitrification by nitrifying bacteria, denitrification by fungi, dissimilatory reduction of nitric acid to ammonium and non-biological processes. The third part introduces the specific research steps of this paper. Firstly, this paper refers to the literature and makes a simple investigation and explanation on the variables that need to be controlled in the experiment. Then the selected areas were divided, urea was used to simulate atmospheric nitrogen deposition, and nitrous oxide flux in each area was recorded. The fourth part is the analysis of data, analyzing the impact of atmospheric nitrogen deposition on nitrous oxide emissions from mountain forest soil in southwest karst region. The fifth part is the conclusion, which briefly summarizes and combs the contents of this article, and finally discusses and explains the analysis results. The results showed that the nitrous oxide emission growth rate was the highest in the area planted with Pinus massoniana forest, reaching 36.8% in yellow soil and 25.1% in calcareous soil. The growth rate of nitrous oxide emission from yellow soil in karst area is significantly higher than that of calcareous soil after atmospheric nitrogen deposition. It may be that alkaline urea is easier to be absorbed in acidic yellow soil, while it is harder to be absorbed in calcareous soil which is also alkaline. In addition, there may be water, microorganisms and other effects.

2. Proposed Method

2.1. Principle of Nitrous Oxide Production

(1) Nitrification

Nitrification usually has two processes: ammonia oxidation and nitrite oxidation. The ammonia oxidation process is that autotrophic ammonia oxidizing bacteria or archaea catalytically oxidize ammonia into hydroxylamine under the catalysis of ammonia monooxygenase, and further generate nitrite ions under the catalysis of hydroxylamine oxidoreductase. Nitrite oxidation refers to the process in which nitrite ions are oxidized to nitrate ions under the action of nitrite oxidizing bacteria. Recent studies have found the existence of complete ammonia oxidizing bacteria, which can directly oxidize ammonium nitrogen to nitrate nitrogen, called complete nitrification process. This discovery overturns the classical cognition that nitrification process must go through a two-step reaction process. In addition to autotrophic nitrification, heterotrophic nitrification refers to the process in which heterotrophic microorganisms oxidize organic nitrogen to nitrite nitrogen or nitrate nitrogen, among which bacteria and fungi are involved in this activity. Nitrous oxide is not an intermediate product of nitration process, and its production is closely related to intermediate products hydroxylamine and nitrite ions. Nitrification has a lower direct contribution to nitrous oxide emissions.

(2) Denitrification

Denitrification usually refers to biological denitrification, that is, the process in which denitrifying microorganisms gradually reduce nitrate ions or nitrite ions to NO, nitrous oxide and N2 under anaerobic conditions. Enzymes required for this process include dissimilated nitrate reductase, dissimilated nitrite reductase, nitric oxide reductase, and nitrous oxide reductase[28]. Denitrification is usually the main source of nitrous oxide in soil. Some studies show that the contribution of denitrification to nitrous oxide emission is 54.5%, 72.8% and 77.1% respectively in farmland, tea garden and bamboo garden soil. At the same time, low soil pH or high nitrate ion content will inhibit the formation of nitrous oxide reductase. In addition, under the condition of low soil carbon availability, nitrous oxide reductase has a weaker ability to compete for electrons compared with other dissimilatory reductases, thus also causing an increase in nitrous oxide emissions.

(3) Denitrification by nitrobacteria

Denitrification of nitrifying bacteria is a process in which ammonia oxidizing microorganisms directly use nitrite produced during ammonia oxidation as electron acceptor to carry out denitrification. It usually occurs under aerobic or hypoxic conditions. The microorganism carrying out this reaction is usually ammonia oxidizing bacteria (AOB). No archaea ammonia oxidizing bacteria (AOA) has been found to have this reduction capability. In addition, because AOB lacks nitrous oxide R coding gene, its final product is mostly nitrous oxide, not N2. Denitrification by nitrifying bacteria may account for a relatively high proportion of nitrous oxide emissions from soil. Under the condition of low oxygen concentration, nitrobacteria denitrification is the main source of nitrous oxide emission from soil after ammonium nitrogen fertilizer is applied. Many heterotrophic denitrifying bacteria can also directly dissimilate and reduce nitrite ions, thus overestimating the contribution of denitrifying bacteria to nitrous oxide emissions.

(4) Nitrification-denitrification coupling

It is generally believed that nitrification and denitrification occur under aerobic and anaerobic conditions respectively, i.e. the two processes are carried out in different niches. The essence of nitrification-denitrification coupling is the coupling of nitrification and denitrification processes simultaneously existing in two adjacent micro-domain spaces. Nitrite or nitrate, which occurs in aerobic space and is produced by nitrification process, is directly utilized by denitrifying microorganisms existing in anaerobic or hypoxic space as substrate, thus leading to nitrous oxide emission at aerobic-anaerobic interface. Nitrification-denitrification coupling plays an important role in nitrogen removal in sewage and nitrogen transformation in sediment and farmland soil. Denitrification under aerobic conditions and convective transport of pore water in sediments can make the two processes more closely coupled in space and time.

(5) Fungal denitrification

Denitrification of fungi is mainly a process in which nitrite is taken as a substrate and is reduced to nitrous oxide with the participation of various enzymes. Some fungi can also reduce nitrate to nitrous oxide. Different from bacterial denitrification process, nitrous oxide cannot be further reduced to N2 because fungi lack nitrous oxide R on mitochondrial membrane. It is generally believed that nitrous oxide production in soil is dominated by bacteria-dominated denitrification process. In recent years, more and more evidences show that fungi contribute to nitrous oxide emission from soil in different ecosystems, especially under acidic soil conditions. For example, fungal denitrification contributes as much as 70% to nitrous oxide emission from low pH tea garden soil. This is mainly related to the fact that fungal communities dominate under low pH conditions while bacteria are more sensitive to acidic soil environmental conditions.

(6) Non-biological processes

In addition to biological processes, the contribution of non-biological processes to nitrous oxide emissions has received renewed attention in recent years. The non-biological process of producing nitrous oxide is also called chemical denitrification, which includes the decomposition of nitrite ion, electron transfer process caused by the interaction of nitrite ion and NH2OH with metal ion, and photochemical reaction. The occurrence of non-biological processes is mainly related to unstable intermediates NH2OH and nitrite ions released during nitrification and denitrification. The application of ammonium nitrogen fertilizer at high soil pH will easily lead to the accumulation of nitrite ions, which can react with Fe2+ to generate NO and nitrous oxide. In addition, nitrous acid ions in soil can also be nitrosylated with SOM, and nitrous oxide production is positively correlated with SOM content.

2.2. Basic Characteristics of Atmospheric Nitrogen Deposition

(1) Settlement pattern

Nitrogen forms in atmospheric nitrogen deposition are divided into inorganic and organic forms. Inorganic nitrogen mainly includes water soluble ions such as ammonium ion, nitrate ion, nitrite ion, gaseous NO2, N2O, NH3 and HNO3, etc. Among them, nitrate nitrogen and ammonia nitrogen are the main components: the former mainly comes from the combustion and lightning strike process of petroleum and organisms, and the migration distance can reach more than a few Qian Qian meters. The latter mainly comes from volatilization of NH3 in soil, fertilizer and livestock manure and combustion of biomass and fossil fuel, with the migration distance generally within 100km. The composition of organic nitrogen deposition is relatively complex, which is generally divided into three categories: organic nitrate (oxidized organic nitrogen), reduced organic nitrogen and biological organic nitrogen. The current research mainly focuses on wet deposition. The water-soluble organic nitrogen (DON) in rainfall accounts for about 30% of the total water-soluble nitrogen. Since the previous studies only considered inorganic nitrogen deposition.

(2) Settlement process

The main processes of atmospheric nitrogen deposition include wet deposition, dry deposition and invisible precipitation. Wet deposition includes two stages: rain removal and scouring: the former adsorbs surrounding substances during the formation of raindrops and ice crystals in the cloud. Invisible precipitation refers to the process in which smaller droplets are intercepted by branches and leaves and gradually merge into larger droplets when the fog mass contacts the surface of the plant body, and fall to the ground when the water storage capacity of the vegetation canopy is exceeded. The main manifestation of wet deposition in forest ecosystem is through rain, that is, wet deposition that falls to the ground through gaps between canopies or contact with canopies. Precipitation quantity decreases after interception and evaporation by canopy. However, due to ion exchange and other effects when precipitation washes the leaves and branches of the canopy, the chemical composition in wet deposition will change, and the types and proportions of nitrogen captured and absorbed by different canopies are quite different. Nitrogen content in penetrating rain is also higher in areas with higher nitrogen deposition, while the canopy in areas with lower nitrogen deposition is more inclined to retain nitrogen.

(3) Time variation

Nitrogen deposition flux varies greatly in different regions, and also has different changing trends in different time scales. Its main influencing factors include emission source intensity, meteorological conditions, external interference, etc. In cities, motor vehicle exhaust emissions are mainly concentrated in the commuting time of the day, and NO and nitrate emissions increase correspondingly, resulting in an increase in their deposition flux, which is proportional to the light intensity. Farming operations and coal-fired heating activities are also important causes of seasonal changes. The volatilization intensity of NH3 will increase with the application of fertilizer, which will lead to an increase in its sedimentation.

3. Experiments

3.1. Experimental Control Variable

Atmospheric nitrogen deposition itself is a complicated process. The types, concentrations and proportions of nitrogen-containing chemicals are changing all the time, and nitrogen deposition varies greatly with different regions. For nitrous oxide emissions, there are a lot of influencing factors, whether it is time, temperature, airflow, precipitation, or differences in the soil itself will have a great impact. Even if there are two adjacent lands, the types and quantities of microorganisms in them are different, and the thickness of soil layer is also different. Therefore, controlling variables is the focus and difficulty of this experiment.

(1) Temperature

Under the background of global warming, the influence of temperature on nitrous oxide emission is very important. In high latitudes, soil temperature is the main factor affecting nitrous oxide emissions. For example, soil temperature can explain 16%~33% variation of nitrous oxide emissions under different nitrogen application conditions in Sanjiang Plain of China. Temperature can directly and indirectly affect nitrous oxide emission from soil. Direct regulation is mainly manifested in its effect on soil microbial growth and enzyme activity. For example, lowering soil temperature can inhibit soil biological activity and further reduce nitrous oxide production. Its indirect regulation mainly changes the content of soil oxygen and available carbon through microbial activities. In addition, the dissolution and release of oxygen in soil solution are also indirectly affected by temperature. Temperature affects the reactivity of soil microorganisms, which in turn affects nitrous oxide emissions. Increasing soil temperature can reduce the contribution of nitrification to nitrous oxide and increase the amount of nitrous oxide produced during denitrification. With the increase of soil temperature, nitrous oxide emission from denitrification increases.

(2) Moisture

Soil moisture is one of the most important factors in environmental driving force. Water affects the metabolic activity of soil microbial cells and the transportation of nutrients, and has a decisive influence on nitrification and denitrification processes. Under the condition of soil water saturation or flooding, high soil water content hinders the diffusion of gas, which causes the soil to form an air-repellent environment and increases the potential and rate of soil denitrification. At the same time, under this condition, nitrification proceeded slowly, and the nitrifying microorganisms participating in the reaction had higher activity in the oxidation area around the plant root system. In the unsaturated zone of soil moisture, nitrification is easy to proceed. Denitrification mainly occurs in soil aggregates and soil environment under this moisture condition. Water content affects the activity of nitrification and denitrification microorganisms in soil. Within a few hours after soil flooding, denitrifying genes increased significantly and reached a peak in the soil. That is to say, when soil oxygen concentration changed due to water content, denitrifying bacteria would react quickly to adapt to the new environmental conditions, indicating that the occurrence of N2O emission peak after rainfall or irrigation was related to denitrifying process.

(3) Soil pH

Soil pH can directly regulate nitrous oxide emissions by affecting biological and non-biological processes. PH can also change the effectiveness of soil substrate. Large sample analysis confirmed that lowering soil pH will increase nitrous oxide emissions. In China's farmland soil, due to excessive application of nitrogen fertilizer, soil pH will drop significantly or nitrous oxide emissions will increase significantly. Research shows that pH is positively correlated with nitrous oxide produced by denitrifying bacteria, but negatively correlated with nitrous oxide produced by denitrifying bacteria. Under aerobic conditions, denitrification dominates nitrous oxide production when the soil pH is below 4.4. Lowering the soil pH can significantly increase the contribution of denitrification to nitrous oxide, which may be related to fungal denitrification. Increasing soil pH will increase soil denitrification rate and promote nitrous oxide reduction, resulting in less nitrous oxide production. The main reason is that low pH will interfere with the assembly of nitrous oxide reductase during denitrification and reduce the activity of the enzyme, resulting in an increase in nitrous oxide emissions during denitrification. In addition, soil pH will also significantly affect the contribution of non-biological processes to nitrous oxide.

(4) Oxygen

Soil oxygen content is one of the key factors driving biogeochemical cycle, and is also one of the decisive factors affecting the relative contribution of nitrification and denitrification to nitrous oxide emissions. In the natural ecosystem, air convection and gas diffusion affect the oxygen content in soil. At the same time, the occurrence of heterotrophic microorganism respiration, microorganism oxygen consumption decomposition and nitrification will also reduce the soil oxygen concentration. The increase of water content and the application of organic fertilizer increased the enrichment of available carbon and nitrogen in soil, thus affecting the distribution of oxygen concentration in soil. In a soil environment with limited oxygen and abundant available carbon, nitrous oxide emission is dominated by denitrification. The heterogeneous distribution of oxygen concentration in soil is also an important reason for the difference in nitrous oxide production or emission.

(5) Soil microorganism

Nitrous oxide production in farmland soil is closely related to the microbial transformation process of nitrogen. Nitrous oxide is produced in both biological nitrification and denitrification processes. Nitrous oxide in nitrification process is mainly produced by reduction of ammonia oxidizing bacteria with nitrite ion as electron acceptor. The biological denitrification process is the respiration process of denitrifying bacteria, which is considered as the main process of nitrous oxide production in soil. Denitrifying bacteria are widely distributed in various genera of bacteria and have specific distribution in different soils. Denitrifying bacteria have complex enzyme systems, which will inevitably lead to differences in nitrous oxide emissions. Although some bacteria are not nitrifying microorganisms or denitrifying microorganisms, they can still participate in the process of releasing nitrous oxide. They produce and release nitrous oxide through non-respiratory (heterotrophic) nitric acid reduction process, and some can also carry out heterotrophic nitrification process at the same time.

(6) Nitrogen source

Nitrous oxide emission increases exponentially and nonlinearly with the increase of nitrogen application rate. Recent studies have found that nitrous oxide emissions can be significantly reduced by deep application of urea nitrogen in the soil of film-covered rice and conventional flooded rice planting systems. This may be due to the fact that urea nitrogen after deep application is mostly stored in the form of ammonium nitrogen under the environment of soil reduction and is not easy to move, thus reducing the substrate required for nitrification and denitrification reactions. Compared with different fertilizer types, the large sample analysis and model of field test show that the nitrous oxide emission from urea application is higher than that from ammonium sulfate, which also leads to similar conclusion in indoor culture test. At the same time, applying high-efficiency nitrogen fertilizer such as coated nitrogen fertilizer can significantly reduce nitrous oxide emission from soil.

3.2. Experimental Step

The variables in this experiment are difficult to control completely. First, we need to know the main vegetation types of mountain forests in southwest karst region. There are mainly shrubs, Pinus massoniana forests, broad-leaved forests, abandoned farmland, ferns, etc. Karst landform is the result of the erosion of carbonate rock by groundwater. Its soil is less, the soil layer is thin, and it is mostly transported by flowing water, thus the soil formation is slow. However, as most karst landforms are mainly distributed in areas with good vegetation and high-water content, the soil is mostly calcareous soil, yellow soil, red soil, and rarely black soil. Because of the variety, we need to choose the main types to carry out the experiment. The grouping of experimental areas is shown in Table 1.

Table 1. Experimental area grouping

Area Number	Agrotype	Vegetation Form
1	Limestone Soil	Bushwood
2	Limestone Soil	Bushwood
3	Limestone Soil	Pinusmassoniana
4	Limestone Soil	Pinusmassoniana
5	Yellow Soil	Bushwood
6	Yellow Soil	Bushwood
7	Yellow Soil	Pinusmassoniana
8	Yellow Soil	Pinusmassoniana

Each area is 4 square meters in size and square in shape. First, nitrous oxide flux is measured in each area for 4 hours from 11 o'clock to 15 o'clock, and the average value is taken. Then urea with a concentration of 0.3% is sprayed on each area as fertilizer to simulate atmospheric nitrogen deposition, and nitrous oxide flux is measured from 11: 00 to 15: 00 two days later. Measurement dates vary from region to region, but sunny days are selected. During the experiment, the daily weather temperature in the same area remained basically the same. The measurement data are shown in Table 2.

Table 2. Flux of nitrous oxide

Area Number	Pre-spray Flux(μg N m^{-2} h^{-1})	Post-spray Flux(μg N m^{-2} h^{-1})
1	23.6	27.6
2	18.7	23.4
3	27.4	30.9
4	48.2	52.5
5	16.7	21.0
6	13.6	18.6
7	24.3	29.4
8	32.9	37.8

The data in the experiment are average values. Karst landform is relatively complex, and various factors are difficult to control. It is difficult to obtain data from all regions. Therefore, the experiment has certain contingency. However, it does not prevent the study of the impact of atmospheric nitrogen deposition on nitrous oxide emissions.

4. Discussion

4.1. Nitrous Oxide Emission Flux

In most parts of the earth, especially in temperate and northern mountain ecosystems, the growth of land plants is mainly restricted by nitrogen content. As indicated by a large number of fertilization experiments, the increase of nitrogen can promote the increase of net primary productivity (NPP) before other nutrients become limiting factors. However, a large number of research results by many scholars at home and abroad show that with the increasing nitrogen deposition, atmospheric nitrogen deposition exceeds the demand of the system, and nitrogen deposition poses a serious threat to the earth and fragile ecosystems. According to experimental data, nitrous oxide flux before nitrogen deposition is plotted as a column chart, as shown in Figure 1.

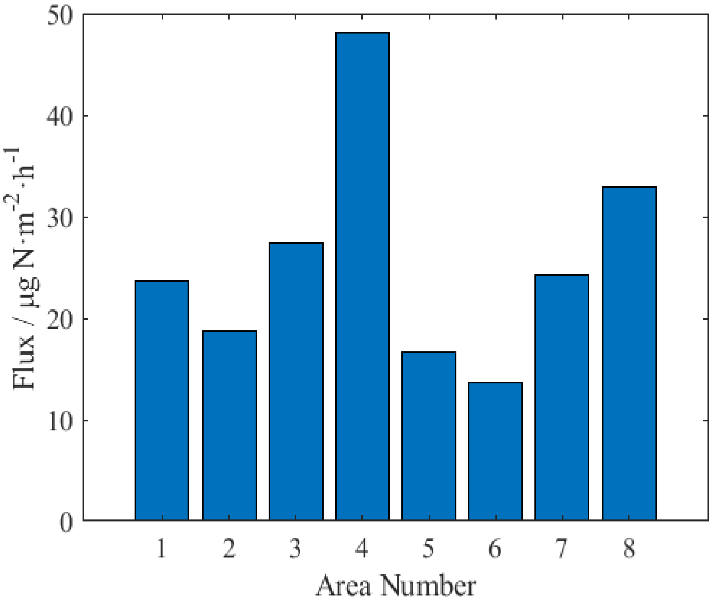

Figure 1. Nitrous oxide flux before nitrogen deposition

From the above figure, it can be seen intuitively that the nitrous oxide emission in Area 4 is extremely high, followed by Area 8. Both areas are wasteland after returning farmland. The possible reason is that fertilizer has been used before returning farmland to wasteland, resulting in high soil nitrogen content. In order to compare whether nitrous oxide increases or decreases before and after nitrogen deposition, the nitrous oxide flux before and after nitrogen deposition is plotted as a line chart, as shown in Figure 2.

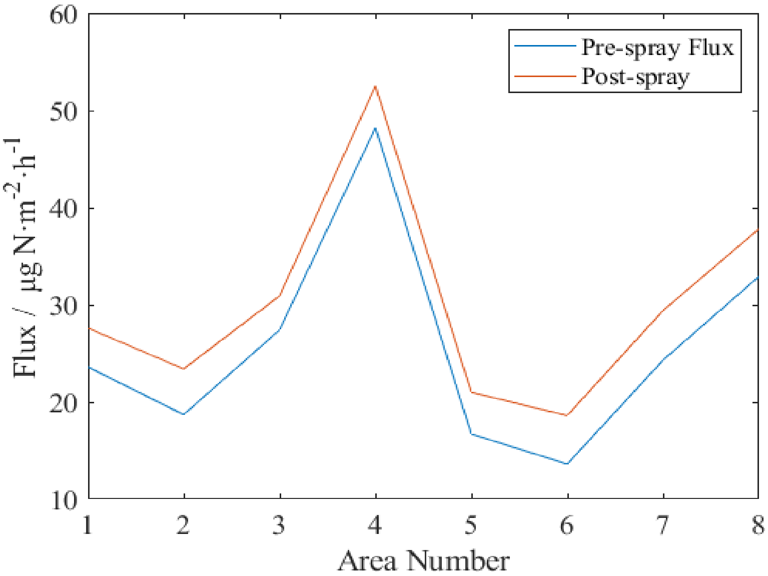

Figure 2. Nitrous oxide flux comparison

From the above figure, it can be seen that nitrogen deposition has a promoting effect on nitrous oxide emission, but the promoting effect for each group is not the same, and even there are great differences. The nitrous oxide emission of calcareous soil is higher than that of yellow soil, but the growth rate is not necessarily.

4.2. Nitrous Oxide Emission Growth Rate

In order to compare the more specific impact of nitrogen deposition on nitrous oxide emissions, we calculated the nitrous oxide flux growth after nitrogen deposition, and the calculation results are shown in Table 3.

Table 3. Nitrous oxide emission growth rate

Area Number	Rate of Growth (%)	Area Number	Rate of Growth (%)
1	16.9	5	25.7
2	25.1	6	36.8
3	12.8	7	20.9
4	8.9	8	14.9

In order to intuitively compare the growth rates, we plot the nitrous oxide emission growth rate caused by nitrogen deposition into a column chart, as shown in Figure 3.

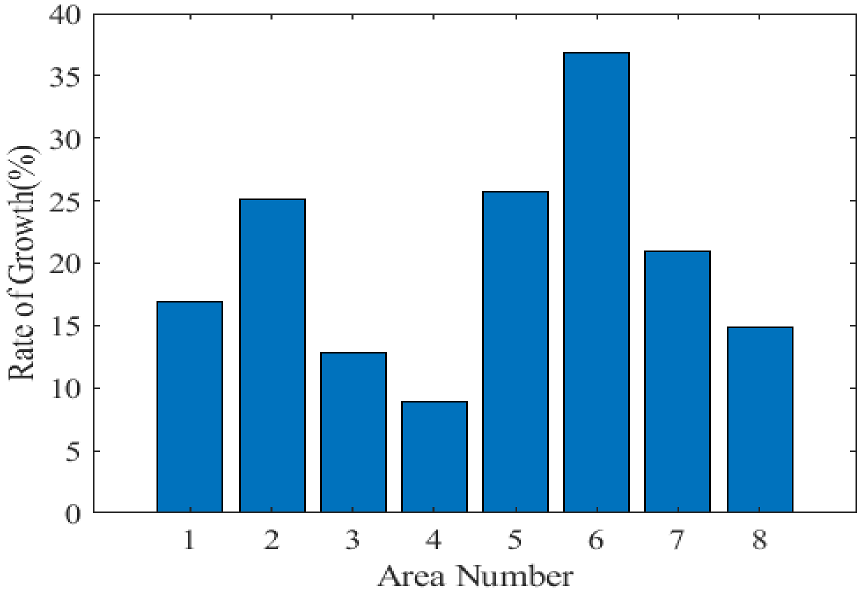

Figure 3. Nitrous oxide emission growth rate

From the bar chart, it can be seen that the 6th area is most affected by nitrogen deposition, up to 36.8%. This was followed by Region 5, with a growth rate of 25.7%. Region 4 has the lowest growth rate, only 8%. In addition, it can be seen from the figure that nitrogen deposition has different effects on nitrous oxide emission from different soils and different vegetation types. For visual comparison, nitrous oxide emission growth rate is plotted as a line chart according to soil and vegetation types, as shown in Figure 4.

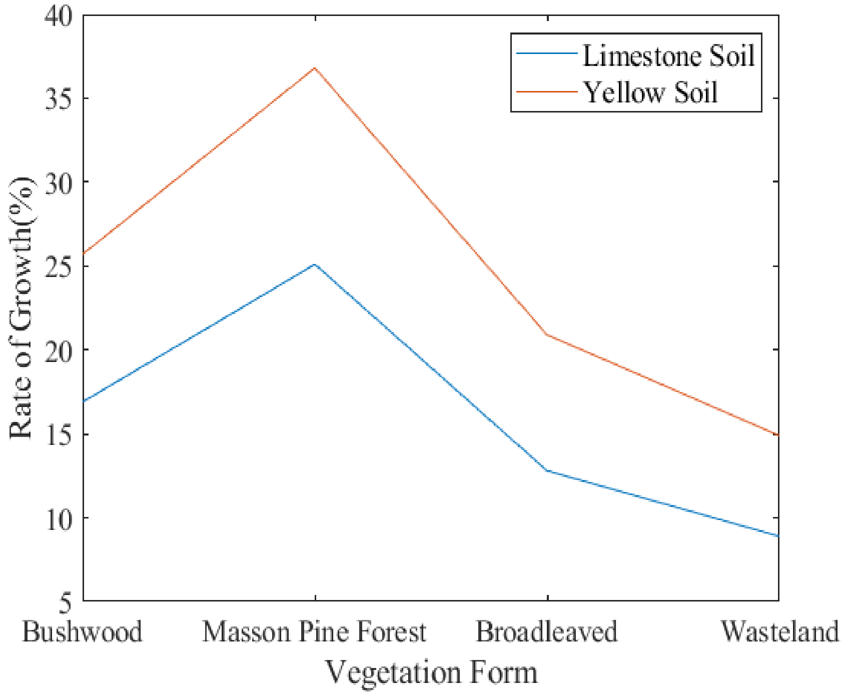

Figure 4. Growth rate of different soil vegetation types

From the line chart, it can be clearly seen that the growth rate of nitrous oxide emission in yellow soil after being settled by atmospheric nitrogen is significantly higher than that in calcareous soil. Analysis of the possible reasons may be that urea is alkaline, yellow soil is acidic and lime soil is alkaline. Alkaline urea is easier to be absorbed in acidic yellow soil, while it is harder to be absorbed in calcareous soil which is also alkaline. In addition, there may be water, microorganisms and other effects.

According to the vegetation type, the nitrous oxide emission growth rate is the highest in the area planted with Pinus massoniana forest, reaching 36.8% in yellow soil and 25.1% in calcareous soil. The second is the area planted with irrigation forest, reaching 25.7% in yellow soil and 16.9% in calcareous soil. The reason may be that different vegetation types have different nitrogen absorption capacity and different water conservation capacity, resulting in different microbial, water and oxygen contents in the soil, and pH value is often affected. The leaching of nitrate ions in soil increases with the increase of nitrogen deposition. Nitrate ion leaching, whether caused by nitrification or nitrogen oxide input, has a strong acidification effect. In an ecosystem saturated with nitrogen, an appropriate increase in nitrogen deposition will lead to an increase in nitrate leaching and an increase in soil acidity. Higher nitrogen deposition can also cause leaching of basic cations with nitrate ions in an equivalent amount. This will in turn lead to a decline in soil base saturation and a lack of some nutrients. There is already evidence that the leaching of basic cations increases due to the production of excess nitrate ions in the soil. Soil acidification will in turn dramatically increase the flux of cations in the soil. Among them, the increase of aluminum level can cause forest phosphorus deficiency, and also harm plant roots and mycorrhizae. Soil acidification caused by atmospheric helium deposition not only affects the chemical properties of soil, but also may affect the physical properties of soil. Some studies have pointed out that soil acidification can promote the decomposition of soil humus, is not conducive to the formation of soil aggregates, and may cause deterioration of soil physical properties.

5. Conclusion

(1) The mechanism of nitrous oxide production mainly includes nitrification, denitrification, denitrification by nitrifying bacteria, denitrification by fungi, dissimilatory reduction of nitric acid to ammonium and non-biological processes.

(2) Nitrous oxide emissions are affected by many factors, including time, temperature, airflow, precipitation, microorganisms, pH, etc.

(3) The nitrous oxide emission growth rate of yellow soil in karst area is significantly higher than that of calcareous soil after atmospheric nitrogen deposition. It may be that alkaline urea is easier to be absorbed in acidic yellow soil, while it is harder to be absorbed in calcareous soil which is also alkaline. In addition, there may be water, microorganisms and other effects.

(4) The growth rate of nitrous oxide emission is the highest in areas planted with Pinus massoniana forests, reaching 36.8% in yellow soil and 25.1% in calcareous soil.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] SartÉGou A, Braucher R, Blard P H, et al. Quantifying Incision Rates Since the Early Miocene: Novelties, Potentialities and Limitations. Journal of Biogeography, 2018, 12(5):122-128. https://doi.org/10.1016/j.quageo.2017.09.005

[2] Yang M, Su G. Study of Rock Desertification Processes and Driving Force in Southern Part of Yunnan, China, between 1994 and 2014 - A Case Study on Thirty Counties Based on Remote Sensing. Journal of Hydrology, 2017, 33(4):38-45. https://doi.org/10.1109/ICISCE.2017.361

[3] ZhiEng Zhang, Lei Cai. Substrate and Spatial Variables Are Major Determinants of Fungal Community in Karst Caves in Southwest China. Journal of Biogeography, 2019, 88(6):66-72. https://doi.org/10.1111/jbi.13594

[4] LIAO Hong-Kai, LONG Jian, LI Juan, et al. Effects of Chinese Prickly Ash Plantation on Soil Water-Stable Aggregate Distribution and Organic Carbon Turnover in Karst Mountain Area. Chinese Journal of Ecology, 2015, 34(1):106-113.

[5] Zhenwei Li, Xianli Xu, Chaohao Xu, et al. Dam Construction Impacts on Multiscale Characterization of Sediment Discharge in Two Typical Karst Watersheds of Southwest China. Journal of Hydrology, 2018, 558(7):144-149. https://doi.org/10.1016/j.jhydrol.2018.01.034

[6] Nong Y, Li-Hua L U, Jia H Y, et al. Community Biomass and Understory Plant Diversity under Different Vegetation Restoration Models of Karst Region in Southwest Guangxi. Chinese Journal of Ecology, 2017, 30(2):200-205.

[7] Yan Deng, Zhongcheng Jiang, Yi-Ming Kuo, et al. Effects of Canopy Interception on Epikarst Water Chemistry and Its Response to Precipitation in Southwest China. Hydrogeology Journal, 2017, 34(1):1-10. https://doi.org/10.1007/s13146-017-0379-9
[8] Jiale Wang, Menggui Jin, Guoping Lu, et al. Investigation of Discharge-Area Groundwaters for Recharge Source Characterization on Different Scales: The Case of Jinan In Northern China. Chinese Journal of Ecology, 2018, 88(3):234-239.
[9] Shi-Liang Liu, Nan-Nan An, Jue-Jie Yang, et al. Effects of Different Land-Use Types on Soil Organic Carbon and Its Prediction in The Mountainous Areas in The Middle Reaches of Lancang River. The Journal of Applied Ecology, 2015, 26(4):981-988.
[10] Er-Fu Dai, Xiao-Li Wang, Jian-Jia Zhu, et al. Quantifying Ecosystem Service Trade-Offs for Plantation Forest Management to Benefit Provisioning and Regulating Services. Hydrogeology Journal, 2017, 7(2):7807-7821. https://doi.org/10.1002/ece3.3286
[11] WANG Kun, ZHOU Zhong Fa, LIAO Juan, et al. Model for Estimating Tobacco Leaf Area Index in Guizhou Karst Mountainous Areas Based on SAR Data. Chinese Journal of Ecology, 2015, 21(6):34-39.
[12] Ya Xiang Liu, Yang Bing Li, Xing Song Yi, et al. Spatial Evolution of Land Use Intensity and Landscape Pattern Response of The Typical Basins in Guizhou Province, China. Chinese Journal of Ecology, 2017, 28(11):3691-3702.
[13] Vilenica, Marina; Ivković, Marija; Sartori, et al. Mayfly Emergence Along An Oligotrophic Dinaric Karst Hydrosystem : Spatial and Temporal Patterns, and Species–Environment Relationship. Journal of Soil & Water Conservation, 2017, 77(5):444-449. https://doi.org/10.1007/s10452-017-9626-3
[14] Xiao Rong Huang, Shi Long Pang, Wen Hui Shen, et al. Herb Diversity and Its Affecting Factors of Community Invaded by Praxelis Clematidea in Karst Mountainous Area of Guangxi Province, China. The Journal of Applied Ecology, 2016, 27(3):815-821.
[15] Liu C, Tong L, Qi S. Susceptibility of Rocky Desertification Based on Analytical Hierarchy Process and Certainty Factor (AHP-CF) Method: A Case from Changshun County, Guizhou Province, SW of China. Journal of Soil & Water Conservation, 2015, 557(8):543-549. https://doi.org/10.1007/978-3-319-09054-2_104
[16] Feng S Z, Su Y R, Zhang W, et al. Effects of Slope Position and Soil Horizon on Soil Microbial Biomass and Abundance in Karst Primary Forest of Southwest China. Journal of Landscape Research, 2015, 36(10):3832-3838.
[17] P.C. Wang, B.T. Mo, Y. Chen, et al. Effect of Karst Rocky Desertification on Soil Fungal Communities in Southwest China. Journal of Landscape Research, 2016, 15(3):233-239. https://doi.org/10.4238/gmr.15038460
[18] Zhi Yang Ou, Shi Long Pang, Zhang Qiang Tan, et al. Effects of Forest Structure on Natural Regeneration of Excentrodendron Hsienmu Population in Southwest Guangxi, China. The Journal of Applied Ecology, 2017, 28(10):3181-3188.
[19] HOU Wenjuan, GAO Jiangbo, PENG Tao, et al. Review of Ecosystem Vulnerability Studies in The Karst Region of Southwest China Based on A Structure-Function-Habitat Framework. Journal of Forestry Research, 2016, 35(3):654-659.
[20] Dejun Li. Determinants of Soil Extracellular Enzyme Activity in A Karst Region, Southwest China. European Journal of Soil Biology, 2017, 80(4):69-76. https://doi.org/10.1016/j.ejsobi.2017.05.001
[21] Fang Hu, Hu Du, Fuping Zeng, et al. Plant Community Characteristics and Their Relationships with Soil Properties in A Karst Region of Southwest China . Journal of Forestry

Research, 2017, 10(6):707-716. https://doi.org/10.1134/S1995425517060051

[22] DUAN Zheng-Song, LUO Chong-Lian, ZUO Xu-Yang, et al. Spatial Pattern of Cultivated Land Quality in Guangxi Based on Landscape Index and Gini Coefficient. Journal of Southern Agriculture, 2015, 38(4):667-669.

[23] Žebre Manja, Uroš S. Glaciokarst Geomorphology of the Northern Dinaric Alps. Journal of Maps, 2015, 12(5):873-881. https://doi.org/10.1080/17445647.2015.1095133

[24] Mingming Luo, Zhihua Chen, Robert E. Criss, et al. Dynamics and Anthropogenic Impacts of Multiple Karst Flow Systems in A Mountainous Area of South China. Hydrogeology Journal, 2016, 24(8):1-10. https://doi.org/10.1007/s10040-016-1462-3

[25] SartÉGou A, Braucher R, Blard P H, et al. Quantifying Incision Rates Since the Early Miocene: Novelties, Potentialities and Limitations. Hydrogeology Journal, 2018, 34(6):334-339.

[26] Shan, P., & Lai, X. (2019) "Influence of CT Scanning Parameters on Rock and Soil Images", Journal of Visual Communication and Image Representation, 58(1), pp. 642-650. https://doi.org/10.1016/j.jvcir.2018.12.014

[27] Zhao, J. , Huang, J. , Wang, R. , Peng, H. R. , & Ji, S. . (2020). Investigation of the optimal parameters for the surface finish of k9 optical glass using a soft abrasive rotary flow polishing process. Journal of Manufacturing Processes, 49, 26-34. https://doi.org/10.1016/j.jmapro.2019.11.011

[28] Zhang, Y., Li, Y., & Bai, C. (2017) "Microstructure and Oxidation Behavior of Si–Mosi2 Functionally Graded Coating on Mo Substrate", Ceramics International, 43(8), pp. 6250-6256. https://doi.org/10.1016/j.ceramint.2017.02.024