

Response of Atmospheric Nitrogen Deposition to Different Ecosystems

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Abstract. Atmospheric nitrogen deposition is one of the most important elements in nitrogen biogeochemical cycles. It is not only one of the major processes for removing nitrogenous pollutants in the air, but also an important way for the ecosystem to obtain nitrogen from the atmosphere. In recent years, due to the combustion of minerals, the use of chemical fertilizers and the rapid development of livestock husbandry, human activities have led to the continuous increase of atmospheric active nitrogen concentration, which has aroused widespread concern of all parties. This paper introduces the types and sources of atmospheric nitrogen deposition and focuses on the response of atmospheric nitrogen deposition to different ecosystems.

1. Introduction

Sedimentation plays an important role in the exchange of matter between the atmosphere and different underlying surfaces. Nitrogen deposition in the atmosphere is one of the most important steps in the biogeochemical cycle of nitrogen. It is not only one of the major processes for removing nitrogenous pollutants in the air, but also an important way for the ecosystem to obtain nitrogen from the atmosphere. In recent years, due to the burning of minerals, the use of chemical fertilizers and the rapid development of animal husbandry, human activities have led to the continuous increase of atmospheric active nitrogen concentration [1-3], which has caused the atmospheric nitrogen deposition from developed areas expand rapidly to the global level.

2. Atmospheric nitrogen deposition types and sources

Atmospheric nitrogen deposition includes both dry deposition and wet deposition. Nitrogen deposition mainly consists of gaseous N_2O , NO , NH_3 , NH_4NO_3 and $(NH_4)_2SO_4$, as well as nitrogen adsorbed on other particles. Wet deposition mainly consists of NO_3^- and NH_4^+ , But also a small amount of soluble organic nitrogen [4]. Atmospheric deposition of nitrogen sources are many, in addition to lightning and other natural means, the atmospheric nitrogen compounds mainly from the industry (NO_x), fossil fuel combustion (NO_x), intensive livestock husbandry and farmland fertilization (NH_x) [5].

Whether wet deposition of atmospheric nitrogen or dry deposition of atmospheric nitrogen is a very complicated physical process. Nitrogen gas deposition and aerosol sedimentation by a variety of factors. Cloud removal, cloud removal and vegetation capture of cloud droplets are three forms of wet



deposition of nitrogen. The dry deposition of nitrogen refers to the process of nitrogen deposition directly to a specific surface (soil surface, water surface, vegetation) and exchange in the absence of wet deposition. Dry subsidence can be described in terms of resistance patterns due to the ability of these surfaces to absorb specific substances. In conclusion, the dry deposition of atmospheric nitrogen is controlled by physicochemical properties of nitrogen-containing compounds, atmospheric turbulence, the chemical potential gradient between the atmosphere and the receiving site, and the plant surface properties and activity [6].

3. Response of atmospheric nitrogen deposition to different ecosystems

Atmospheric nitrogen deposition largely interferes with carbon accumulation and carbon cycling in ecosystems through indirect or direct effects on carbon fixation, distribution of photosynthetic products, and plant growth. Human activities such as expansion of agricultural land, deforestation, dry matter combustion, industrial development and fertilizer application change the rate of nitrogen deposition by affecting the nitrogen cycle [7]. Obviously, the increasing amount of atmospheric nitrogen deposition has had or will have a profound impact on terrestrial and aquatic ecosystems.

3.1. The Impact of Atmospheric Nitrogen Deposition on Forest Ecosystems

Nitrogen is one of the three major nutrients in terrestrial ecosystems and is considered as a major limiting growth factor in forest ecosystems. It is believed that the current fertilization effect of atmospheric nitrogen deposition is a very important reason that forests in Europe and North America grow faster than in the early 20th century [8, 9]. In recent years, the situation has changed dramatically. The degree of atmospheric pollution caused by nitrogenous compounds emitted from industrial and agricultural production and energy use has led to the exceeding of the demand of many forest ecosystems for nitrogen deposition [10]. Studies have shown that if the nitrogen input has reached saturation even exceed the critical load that the ecosystem can bear, it will have a negative effect. Nitrogen saturation occurs when both input (mineralization and immobilization) and exogenous (eg, atmospheric deposition and fertilization) inputs of inorganic nitrogen exceed the absorption capacity of plant and soil organic matter [11].

Numerous studies have shown that the response of forest ecosystems to nitrogen deposition is such a process that initial nitrogen deposition can stimulate plant growth to a certain extent but plant growth is no longer accelerated when nitrogen accumulation reaches a certain level and nitrogen saturation is observed, even lower [12, 13]. Most of the northern coniferous and temperate forests are nitrogen-constrained ecosystems that significantly increase vegetation productivity in the early stages of increased nitrogen deposition rates [14]. Most of the nitrogen input to the atmosphere is trapped inside the system and can cause an increase in carbon accumulation for the first time [15]. However, the response of ecosystems to nitrogen deposition is only short-term.

Although the short-term effects of nitrogen deposition on plant growth can increase tree production to a certain extent and slow the atmospheric CO₂ concentration increase, when the nitrogen input into forest ecosystems exceeds the nutrient requirements of plants and microorganisms will change the genetic composition of plants and microorganisms and ecosystem nutrient cycle, the entire system is very unfavorable [16]. Fertilizing experimental studies have shown that long-term continuous input can significantly reduce Net Primary Productivity (NPP), even at low rates of nitrogen input [17, 18]. For example, in the experiment of Harvard Forest, biomass of pine forest decreased with the increase of nitrogen input after 9 years of treatment with nitrogen, and biomass of high-nitrogen treated quadrats significantly decreased compared with control. Some studies even show that lower nitrogen inputs can also lead to a decline in tree productivity [19]. In the NITREX study in Europe, the NPP increased by 50% after denitrification of forests with high nitrogen sinks [20], which on the other hand shows that excessive nitrogen has an inhibitory effect on plant growth. Studies have shown that in the simulation experiments of nitrogen deposition in the southern subtropical forests, medium nitrogen treatment can greatly promote the growth of tree seedlings, high nitrogen treatment gradually inhibited the growth of tree seedlings, with the increase of nitrogen input, Net photosynthetic rate first increased

and then decreased [21]. In high nitrogen depositional ecosystems, nitrogen inputs exceeding the biological requirements of nitrogen cause soil acidification due to nitrogen enrichment, lack of trace elements, increased activity of NO_3^- in the soil and accelerated movement of ecosystem nitrogen. As the ecosystem enters a "nitrogen-saturated" state, the continued increase in nitrogen input reduces the nitrogen holding capacity of the entire ecosystem and the loss of nitrogen is therefore likely to exceed the input [22, 23]. In tropical savannas and tropical forest ecosystems that develop on highly weathered soils, the supply of nitrogen is often excessive because they are mostly nitrogen-saturated ecosystems where the physiological and ecological processes of nitrogen are often restricted by Ca, P and other nutritional elements. N deposition in the rainforest ecosystem, mostly in the form of NO_3^- , further reduces the carbon storage capacity of ecosystems because NO_3^- will eventually be lost from topsoil by leaching, and the nitrification process and the acceleration of nitrogen loss will lead to salt-based ions out of the soil pH value decreased [24].

Most model studies suggest that more than 60% of atmospheric nitrogen deposition is fixed in the forest. In recent years, ^{15}N isotope labeling experiments in North America and Europe have shown that most of the atmospheric nitrogen deposition is fixed in the soil, while only about 3% is fixed in the wood [25]. Atmospheric nitrogen can be absorbed by some canopies into the forest ecosystem during the growing season, but its absorption has certain limits. The remaining nitrogen can cause soil acidification. Boxman [20] research shows that soil acidification caused by increased nitrogen deposition is most important in acidic coniferous and broad-leaved forests. In forest soils with sufficient nitrogen supply, a large amount of NH_4^+ can supply nitrification. The mobility of NO_3^- makes NO_3^- leach out of the soil profile [4]. The leaching of NO_3^- has a strong acidification effect, and the leaching of NO_3^- into groundwater causes other cations (such as Ca^{2+} and Mg^{2+}) loss, on the contrary can enhance soil acidification [26, 27]. Some experiments simulating nitrogen deposition show that the leaching of NO_3^- in soil increases with the increase of nitrogen deposition. The leaching of NO_3^- , whether caused by the addition of NO_3^- or nitrification, is intense acidification [28]. The higher nitrogen deposition not only leads to a large amount of NO_3^- but also causes salt-based cations to be leached with NO_3^- by the equivalent amount [29], which in turn causes some nutrients to decline in soil base saturation lack of. The effects of nitrogen deposition on forest ecosystems are manifold. In addition to the above, excess nitrogen deposition can also lead to imbalance of tree nutrients, affecting tree growth, leading to changes in species diversity and increasing the sensitivity of forests to stress factors [27].

3.2. *Effect of Atmospheric Nitrogen Deposition on Grassland Ecosystem*

China's current grassland area is $4.0 \times 10^6 \text{ km}^2$, accounting for about 41% of the total land area [30-31], accounting for about 8% of the total area of the world's grassland [32]. At present, the researches on atmospheric nitrogen deposition are mostly concentrated in forest ecosystems and their impact on grassland ecosystems is rarely reported. In forest ecosystems, due to the blockage of tall trees, the distribution of nitrogen deposition is very uneven. Areas near the edge of woodland tend to receive more settlements, and there are fewer near the interior [33]. Because of the absence of tall trees in the grasslands, the distribution of atmospheric nitrogen deposition may differ from the woodlands. Studies have shown that the amount of atmospheric nitrogen deposition input into the soil is significantly lower than that of non-forage grasslands on Canadian forage grasslands [34], probably due to nitrogen deposition fluxes and nitrogen cycling being affected by livestock activity and vegetation impact. The interaction of water and nutrients, especially nitrogen, in grassland ecosystems controls grassland productivity. In many types of grassland, especially in the northern grassland, the carrying capacity is generally high with less precipitation and grassland degradation. Some ammonium, nitrate and organic nitrogen are input into the grassland ecosystem through rainfall, snowfall and dry deposition. Grassland ecosystems in all aspects have a significant impact.

Atmospheric nitrogen deposition will have a certain impact on grassland plants. Zhang et al. [35] concluded that atmospheric nitrogen deposition may have different effects on different plant species, further affecting the composition and quantity of plant communities. Because Reich et al. [36] have

shown that atmospheric deposition is the major nitrogen source for small tropical parasitic plants, and the proportion of atmospheric sedimentation in the large nitrogen source of parasitic plants is significantly reduced. Some studies in Europe and the United States show that atmospheric nitrogen deposition has a significant impact on grassland vegetation composition. Gotelli and Ellison studies have shown [37] that long-term increasing nitrogen deposition increases the risk of periwinkle destruction. There are also studies showing that in the 1990s, acidification of prairie soil caused by increasing atmospheric nitrogen and sulfur deposition resulted in a sharp decrease of two typical plant arnica and meadow thistle on the Dutch steppe an important reason for this is that more than 100 μ mol of NH_4^+ can cause serious damage to both plants [38]. Yoshida et al. [39] have shown that in Europe, due to the enhanced competitiveness of some herbaceous plants (such as pinnate) under NH_4^+ precipitation, some of the heliophilic woodlands have gradually become grasslands. In recent years, due to the continuous improvement of observational instruments and research methods, more and more researches show that it may be due to the effect of atmospheric nitrogen deposition that during the past several decades, the seashore sage shrub vegetation in southern California has been gradually Replaced by Mediterranean annual grassy plants rather than what most people thought of as grazing and burning before. As atmospheric N depositions continue to increase, hi-nitrogen grassland plants are more competitive with soil resources than shrubs (adapted to low-nutrient shrubs) [40]. Atmospheric nitrogen deposition will not only change the total amount of nitrogen in the ecosystem, but also change the form of nitrogen in the soil. For example, plants that are favored by nitrifying plants are at a disadvantage, while hiaminium plants are in a favorable position due to the long-term increase in atmospheric nitrogen deposition that may shift the predominantly NO_3^- based soil to NH_4^+ . Some studies show that in Western Europe, due to the increasing atmospheric nitrogen deposition, the form of soil nitrogen gradually shifts from mainly NO_3^- to NH_4^+ , resulting in the danger of extinction of some dominant species such as mountain Jinti, *Gentiana pneumonanthe*, *Narthecium ossifragum*, *Dactylorhiza maculata*, *Pedicularis sylvatica*, etc. [38]. Vegetation in the Jasper Ridge Biological Preserve, a California steppe, dominated by rapidly growing annual and biennial herbs, where the Zavaleta team conducted a three-year mock trial that showed that 3 Years later, the plant species in the experimental area was reduced by 5% due to atmospheric nitrogen deposition [41].

Atmospheric nitrogen deposition will also have some impact on grassland soil microbes and soil animals. Mycorrhizal fungi are common microorganisms in the rhizosphere of grassland plants and play an important role in plants absorbing the nutrients in the soil. Because of the large variability of the main components of atmospheric nitrogen deposition, and the fact that most arbuscular mycorrhizae can make good use of ammonium nitrogen, it is difficult to utilize nitrate nitrogen. Therefore, atmospheric nitrogen deposition will inevitably produce grass soil mycorrhizal bacteria Different effects. Studies have shown that atmospheric nitrogen deposition on southern California shrub grasslands is not conducive to the growth of arbuscular mycorrhizae, as the local atmospheric nitrogen deposition mainly NO_3^- based [39], while in the Dutch shrub steppe, as the atmospheric nitrogen deposition to NH_4^+ as the main component, which is beneficial to the growth of mycorrhizal bacteria [38].

In addition, atmospheric nitrogen deposition reduces soil C/N, and a decrease in soil C/N value further affects soil microbial activity, which is called an indirect effect. Pang Xin and other studies have shown that due to different levels of soil nitrogen will lead to different microbial activity. Soil microbial activity was also higher in soils with high N supplies when organic carbon sources were abundant, but when the supply of carbon sources was insufficient, soil microbial activities were reduced in soils with high N supplies [42].

Because most soil animals are small in size and poor in activity, most of the nitrogen sediments will eventually enter the soil, which will inevitably have a great impact on the species, population, community composition, diversity and ecological functions of soil animals [43, 44]. At present, there is no specific global change experiment in the experimental study to evaluate the effect of nitrogen deposition on soil animals. However, some small-scale researches abroad on the impact of nitrogen change on soil animals can make us initially understand nitrogen deposition effects on animals. In

general, the effects of additional nitrogen in soils on soil animal communities are negative [45]. In terrestrial ecosystems, microbes and soil animals form a relative dynamic balance that is influenced by changing environmental factors and causes systemic changes. The direct impact of nitrogen deposition on soil animals is very complex and is influenced by a combination of factors such as the composition and concentration of nitrogen deposition, vegetation, soil conditions, and geographical conditions. At present, most researches on the impact of atmospheric nitrogen deposition on soil fauna still remain only in some speculation and simulation experiments. There is still a lack of direct observation and research on the response of atmospheric nitrogen deposition to soil fauna [35].

3.3. Impacts of atmospheric nitrogen deposition on marine ecosystems

At present, with the rapid development of industry and agriculture, more and more atmospheric pollutants directly settle into the sea through dry deposition and wet deposition, or indirectly enter the sea by means of infiltration, surface runoff and floods. Atmospheric deposition has become one of the major sources of pollutants in coastal marine environments [46]. Through atmospheric transformation and atmospheric circulation, 60% to 80% of the nitrogen that anthropogenic nitrogen generated from anthropogenic activities has re-settled into the vast land and marine ecosystems after it enters the atmosphere [47].

As an important source of nutrients for coastal marine ecosystems, dramatic changes in atmospheric nitrogen deposition will seriously affect ecosystem stability and productivity [48]. The impact of atmospheric nitrogen deposition on marine ecosystems has become a topic of widespread concern to scientists and the public in many countries because a large amount of precipitation input is likely to lead to the outbreak of red tides and consequently the hypoxia and eutrophication of the coastal ecosystem, Habitat decline and biodiversity loss. Scholars from Europe and North America have done a lot in the research on marine ecosystem due to wetting and wetting, and have achieved a lot of valuable results. They have studied in more detail and thoroughness the impact of nutrients on marine ecosystems [49]. J.D. Willey et al. [50] pointed out that NO_3^- in rainwater can increase the production of chlorophyll a, but PO_4^{3-} cannot. Rendell et al. [51] pointed out by R. Chester et al. [52] that the contribution of dry and wet atmospheric deposition to nitrogen input in the northern part of the North China Sea is roughly equivalent to that of dry nitrogen deposition of $102 \times 10^3 \text{ t} \cdot \text{a}^{-1}$. The amount is $126 \times 10^3 \text{ t} \cdot \text{a}^{-1}$. When primary productivity in the North Sea is often limited by nutrients, the atmosphere may be the most important source of nitrogen in offshore stratification areas, especially as NH_3 and NO_x releases to the atmosphere in Europe. Studies have shown that the dry and wet deposition of the atmosphere is the main source of nitrogen for 12 North Florida waters. In river water, the total dissolved nitrogen flux is similar to the sinking fluxes of ammonium and nitrate in the atmosphere [53].

3.4. Atmospheric nitrogen deposition on farmland ecosystem impact

Plant demand for nitrogen is generally very large, nitrogen is one of the essential nutrients for plant growth. For crops, the main ways to obtain nitrogen are: fertilizer, irrigation water, biological nitrogen fixation, atmospheric deposition [54]. At present, there are relatively few studies on the law of nitrogen deposition (especially dry deposition) and its agronomic effects in farmland ecosystems. However, the study of atmospheric nitrogen deposition mainly focuses on the study of natural ecosystems that are relatively sensitive to nitrogen, especially on the forest ecosystem. The traditional view is that the farmland ecosystem is greatly affected by human activities, especially nitrogenous fertilizer application, and it is relatively insensitive to atmospheric nitrogen deposition. However, recent studies show that the amount of nitrogen and the role of atmospheric input in farmland ecosystem may be greatly undervalued. Studies have shown that when nitrogen is the limiting factor for nutrient uptake by crops, 40% to 50% of the plots are in a nitrogen deficient state under environmental protection [55]. In our country, there is more surplus of farmland nitrogen budget in some areas, but the nitrogen deficiency of farmland in many areas is also very common [56-57], so the

atmospheric nitrogen deposition becomes the ecosystem (terrestrial ecosystem and aquatic ecosystem) an important complement to getting nitrogen.

At present, one of the key measures to ensure China's sustained high-yield agriculture and environment-friendly is to reduce the unreasonable investment of nitrogen fertilizer through the comprehensive management of nutrient resources and making rational use of all useful nitrogen resources [58]. However, in recent years, the annual application of fertilizer nitrogen in our country has been maintained at more than 24 million tons, because in actual production in recent years, people tend to overemphasize the input of nitrogen fertilizers, resulting in a large amount of surplus and loss of nitrogen in agro-ecosystems. In contrast, atmospheric nitrogen deposition, which is an important source of nutrients in agroecosystems, has not received sufficient attention. Therefore, it is not only able to provide the relevant parameters of soil N transformation/circulation model but also the reasonable application of N fertilizer in agricultural production, revealing the amount of dry and wet sedimentation, the spatial and temporal distribution of nitrogen and the plant availability of farmland ecosystem, provide an important basis .

4. Conclusion

The increasing concentration of active nitrogen compounds in the atmosphere has led to an increasing number of atmospheric nitrogen depositions to terrestrial ecosystems and aquatic ecosystems, which are causing irreversible changes in human habitats, such as the death of forests, the degradation of grasslands, water eutrophication and soil acidification and nitrate leaching and other environmental issues. The emergence of these problems makes it very important to further strengthen the study of atmospheric nitrogen deposition and has a profound impact on understanding the global nitrogen cycle and its ecological and environmental effects [6]. In recent 30 years, the study of nitrogen deposition and its ecological effect as an important component of atmospheric deposition has drawn the attention of scientists in the fields of atmosphere, environment, agronomy, ecology and oceans, and its research methods and technologies The improvement has laid a solid foundation for us to study the quantity and law of wetting and wetting and the effect of ecological environment.

References

- [1] E. Holland, F Dentener, B Braswell, et al. Contemporary and pre-industrial global reactive nitrogen budgets. *Biogeochemistry*, 1999, 46(1):7-43.
- [2] J.Galloway, F.Dentener, D.Capone, et al. Nitrogen cycles: past, present, and future. *Biogeochemistry*, 2004, 70(2):153-226.
- [3] P. Crutzen, M. Andreae. Biomass burning in the tropics: Impact on atmospheric chemistry and biogeochemical cycles. *Science*, 1990, 250(4988):1669.
- [4] H. L. Xiao. Effects of Atmospheric Nitrogen Deposition on Forest Soil Acidification. *Scientia Silvae Sinicae*, 2001, 37(4):111-116.
- [5] H. Paerl, Coastal eutrophication in relation to atmospheric nitrogen deposition: current perspectives. *Ophelia*, 1995, 41: 237-259.
- [6] X. J. Liu, X. T. Ju, F. S. Zhang, et al. Atmospheric Nitrogen Deposition and Its Impact on Ecosystems. Seventh "Soil and Environment" Symposium Abstract. 2001.
- [7] W. Currie, K. Nadelhoffer. Original Articles: Dynamic Redistribution of Isotopically Labeled Cohorts of Nitrogen Inputs in Two Temperate Forests. *Ecosystems*, 1999, 2(1):4-18.
- [8] R. Skeffington, Accelerated nitrogen inputs-A new problem or a new perspective? *Plant and Soil*, 1990, 128(1):1-11.
- [9] N.Van Breemen, H. Van Dijk. Ecosystem effects of atmospheric deposition of nitrogen in the Netherlands. *Environmental pollution*, 1988, 54(3-4): 249-274.
- [10] H. L. Xiao. Atmospheric Nitrogen Deposition and Nitrogen Dynamics in Forest Ecosystems. *Acta Ecologica Sinica*, 1996, 16(1):90-99.
- [11] B. Emmett, B. Cosby, R. Ferrier, et al. Modelling the ecosystem effects of nitrogen deposition: Simulation of nitrogen saturation in a Sitka spruce forest, Aber, Wales, UK.

- Biogeochemistry, 1997, 38(2):129-148.
- [12] J. Aber, K. Nadelhoffer, P. Steudler, et al. Nitrogen saturation in northern forest ecosystems. *BioScience*, 1989, 39(6):378-386.
- [13] J. Aber, A. Magill, S. McNulty, et al. Forest biogeochemistry and primary production altered by nitrogen saturation. *Water, Air, & Soil Pollution*, 1995, 85(3):1665-1670.
- [14] P. Matson, K. Lohse, S. Hall. The globalization of nitrogen deposition: consequences for terrestrial ecosystems. *AMBIO: A Journal of the Human Environment*, 2002, 31(2):113-119.
- [15] C. Q. Lv, H. Q. Tian, Y. Huang. Ecological effects of increased nitrogen deposition in terrestrial ecosystems. *Journal of Plant Ecology*, 2007, 31(2):205-218.
- [16] H. Spiecker, K. Meilikainen, M. Kohl, et al. *Growth trends in European forests [M]: Springer*, 1996.
- [17] A. Magill, J. Aber, G. Berntson, et al. Long-term nitrogen additions and nitrogen saturation in two temperate forests. *Ecosystems*, 2000, 3(3):238-253.
- [18] B. Emmett, D. Boxman, M. Bredemeier, et al. Predicting the effects of atmospheric nitrogen deposition in conifer stands: evidence from the NITREX ecosystem-scale experiments. *Ecosystems*, 1998, 1(4):352-360.
- [19] D. J. Li, J. M. Mo, Y. T. Fang, et al.. Impact of nitrogen deposition on forest plants. *Acta Ecologica Sinica*, 2003, 23(9):1891-1900.
- [20] A. Boxman, K. Blanck, T. Brandrud, et al. Vegetation and soil biota response to experimentally-changed nitrogen inputs in coniferous forest ecosystems of the NITREX project. *Forest Ecology and Management*, 1998, 101(1-3):65-79.
- [21] D. J. Li, J. M. Mo, Y. T. Fang, et al. Effects of simulated nitrogen deposition on the growth and photosynthesis of three south subtropical tree species. *Acta Ecologica Sinica*, 2004, 24 (5), 876-882
- [22] A. Townsend, B. Braswell, E. Holland, et al. Spatial and temporal patterns in terrestrial carbon storage due to deposition of fossil fuel nitrogen. *Ecological Applications*, 1996, 6(3):806-814.
- [23] J. Aber, W. McDowell, K. Nadelhoffer, et al. Nitrogen saturation in temperate forest ecosystems. *BioScience*, 1998, 48(11):921-934.
- [24] P. Vitousek, J. Aber, R. Howarth, et al. Human alteration of the global nitrogen cycle: sources and consequences. *Ecological Applications*, 1997, 7(3):737-750.
- [25] X. K. Wang, Y. Y. Bai. Missing sink in global carbon cycle and its causes. *Acta Ecologica Sinica*, 2002, 22(1):94-103.
- [26] Corbin, J., P. Avis, R. Wilbur. The role of phosphorus availability in the response of soil nitrogen cycling, understory vegetation and arbuscular mycorrhizal inoculum potential to elevated nitrogen inputs. *Water, Air, & Soil Pollution*, 2003, 147(1):141-162.
- [27] Q. H. Wang, Y. B. Gong, J. Zhang. Impact of Forest Ecosystems on Atmospheric Nitrogen Deposition. *Journal of Sichuan Forestry Science and Technology*, 2006, 27(1):19-24.
- [28] B. Bergkvist, L. Folkeson. Soil acidification and element fluxes of a *Fagus sylvatica* forest as influenced by simulated nitrogen deposition. *Water, Air, & Soil Pollution*, 1992, 65(1):111-133.
- [29] I. Fernandez, L. Rustad. Soil response to S and N treatments in a northern New England low elevation coniferous forest [J]. *Water, Air, & Soil Pollution*, 1990, 52(1):23-39.
- [30] X. Q. Guan, J. C. Yu. Grassland bio-nitrogen fixation and intensive grassland animal husbandry. *Grassland Science*, 1997, 14(3):12-16.
- [31] L. Z. Wang. Modern science and technology and grass industry modernization. *Grassland Science*, 1996, 13(1):61-66.
- [32] B. Li. Current Situation and Management Countermeasures of Grassland Resources in China. *Exploration of Nature*, 1997, 16(1):12-14.
- [33] A. Spangenberg, C. Killing. Nitrogen deposition and nitrate leaching at forest edges exposed to high ammonia emissions in southern Bavaria. *Water, Air, & Soil Pollution*, 2004, 152(1):233-255.

- [34] M. Kchy, S. Wilson. Variation in nitrogen deposition and available soil nitrogen in a forest? Grassland ecotone in Canada. *Landscape Ecology*, 2005, 20(2):191-202.
- [35] Y. Zhang, X. M. Cui. M. S. Fan. Atmospheric N deposition and its influences on the grassland biodiversity. *Pratacultural Science*, 2007, 24(007):12-17.
- [36] A. Reich, nJ. Ewel, N. Nadkarni, et al. Nitrogen isotope ratios shift with plant size in tropical bromeliads. *Oecologia*, 2003, 137(4): 587-590.
- [37] N. Gotelli, A. Ellison. Nitrogen deposition and extinction risk in the northern pitcher plant, *Sarracenia purpurea*. *Ecology*, 2002, 83(10):2758-2765.
- [38] G. Heil, M. Werger, W. De Mol, et al. Capture of atmospheric ammonium by grassland canopies. *Science*, 1988, 239(4841):764.
- [39] L. Yoshida, E. Allen. Response to ammonium and nitrate by a mycorrhizal annual invasive grass and native shrub in southern California. *American Journal of Botany*, 2001, 88(8): 1430.
- [40] Bobbink, R., M. Hornung, J. Roelofs. The effects of air-borne nitrogen pollutants on species diversity in natural and semi-natural European vegetation. *Journal of Ecology*, 1998, 86(5): 717-738.
- [41] E. Zavaleta, M. Shaw, N. Chiariello, et al. Additive effects of simulated climate changes, elevated CO₂, and nitrogen deposition on grassland diversity. *Proceedings of the National Academy of Sciences of the United States of America*, 2003, 100(13):7650.
- [42] X. Pang, F. S. Zhang. Effect of different nitrogen levels on SMB-N and microbial activity. *Plant Nutrition and Fertilizer Science*, 2000, 6(4):476-480.
- [43] J. Lawton, D. Bignell, G. Bloemers, et al. Carbon flux and diversity of nematodes and termites in Cameroon forest soils. *Biodiversity and Conservation*, 1996, 5(2):261-273.
- [44] D. Wall, J. Moore. Interactions underground: soil biodiversity, mutualism, and ecosystem processes. *BioScience*, 1999, 49(2):109-117.
- [45] G. L. Xu, J. M. Mo, G. Y. Zhou, et al. Relationship of Soil fauna and N cycling and its response to N deposition. *Acta Ecologica Sinica*, 2003, 23(11):2453-2463.
- [46] Z. X. Yang. Research progress of n atmospheric subsidence fluxes. *Marine Environmental Science*, 2008, 27(A02):160-164.
- [47] A. Moffat. ECOLOGY: Global Nitrogen Overload Problem Grows Critical. *Science*, 1998, 279(5353):988.
- [48] Van Breemen, N. Nitrogen cycle: Natural organic tendency. *Nature*, 2002, 415(6870):381-382.
- [49] J. L. Zhang and Z. G. Yu. Wet and dry deposition and its influences on marine ecosystem. *Marine Environmental Science*, 1999, 18(1):70-76.
- [50] J. Willey, L. Cahoon. Enhancement of chlorophyll a production in Gulf Stream surface seawater by rainwater nitrate. *Marine Chemistry MRCHBD*, 1991.34(1/2).
- [51] A. Rendell, C. Ottley, T. Jickells, et al. The atmospheric input of nitrogen species to the North Sea. *Tellus B*, 1993, 45(1):53-63.
- [52] R. Chester, G. Bradshaw, C. Ottley, et al. The Atmospheric Distributions of Trace Metals, Trace Organics and Nitrogen Species over the North Sea [and Discussion]. *Philosophical Transactions: Physical Sciences and Engineering*, 1993, 343(1669):543-556.
- [53] J. Winchester, L. Escalona, J. Fu, et al. Atmospheric deposition and hydrogeologic flow of nitrogen in northern Florida watersheds. *Geochimica et Cosmochimica Acta*, 1995, 59(11): 2215-2222.
- [54] T. J. Wang, Q. Liu, H. Zhao, et al. Atmospheric nitrogen deposition in agroecosystem in red soil region of Jiangxi province. *Acta Pedologica Sinica*, 2008, 45(2):280-287.
- [55] H. Kloen, P. Vereijken. Testing and improving ecological nutrient management with pilot farmers. *Process Reports of Research Network on Integrated and Ecological Arable Farming System for EU and Associated Countries, Concerted Action AIR3-CT920755, Progress Report*, 4:70-84.
- [56] C. Gao, T. L. Zhang. Nitrogen management in Chinese agriculture since early 1980s: status and

- problems. *Journal of Nanjing University (Natural Science)*, 2002, 38(5):716-721.
- [57] Z. F. Li. Nitrogen Loss in soil of Organic Agriculture and its control procedure. *Agro-environmental Protection*, 2002, 21(1):90-92.
- [58] F. S. Zhang, W. Q. Ma. Relationship between fertilizer input level and nutrient use efficiency. *Soil and Environmental Sciences*, 2000, 9(2):154-157.