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Atmospheric wet deposition of nitrogen and sulfur in the agroecosystem in developing and developed areas of Southeastern China

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HIGHLIGHTS

- DON is an important contributor in the wet deposition in the agroecosystem.
- Similar total N and S deposition fluxes were observed in the two sites.
- Annual N and S wet deposition reached 33.9 kg ha^{-1} N and 57.5 kg ha^{-1} S, respectively.
- Such high N and S deposition would deteriorate agroecosystems in Southeastern China.

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ABSTRACT

Atmospheric nitrogen (N) and sulfur (S) deposition is a significant and growing issue for ecological environment in many parts of the world such as China. However, the study on atmospheric deposition, especially N deposition, is still at the initial stage and usually neglected in agro-ecosystems. To assess the characteristics of N and S wet deposition in agro-ecosystems, we selected Yingtan Station (YTS) located in the developing area and Changshu Station (CSS) in the developed area as typical, agricultural study sites in Southeastern China during 2010–2011. In the two areas, the total N and S wet deposition were in ranges of 30.49–37.37 kg ha^{-1} year^{-1} N and 56.02–59.06 kg ha^{-1} year^{-1} S, respectively, surpassing their corresponding critical loads in China. The annual means of NH_4^+–N, NO_3^-–N and dissolved organic N (DON) deposition contributed 49.6%, 26.4% and 24.0% of the total deposition, respectively. Similar total N and S deposition data were observed in the two sites, but their N species, especially DON, were different due to different numbers of slaughter pigs and types of N fertilizers applied. In conclusion, DON was identified as an important contributor to the total N deposition and should also be monitored in the future. Such high N and S deposition would deteriorate agroecosystems in Southeastern China. Related political measures on livestock industries, managements of motor vehicles and technologies of coal and oil combustion should be improved timely and implemented effectively for reducing the regional N emission and deposition in the future.

1. Introduction

Atmospheric nitrogen (N) and sulfur (S) deposition is a topical environmental issue which leads either to benefits (fertilization) or drawbacks (acidification, accumulation of excess nutrients and reduction in biodiversity) and further captures the attention of policy makers in the world (Kim et al., 2009; Cornell, 2011; Hu et al., 2013).

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N and S deposition has leveled off or stabilized in the developed countries such as US and Europe since late 1980s or early 1990s due to different types of protocols on reducing N and S in air (Phoenix et al., 2006; Fowler et al., 2007; Liu et al., 2011). Under the pressure from various environmental groups, the Chinese government has implemented some control programs including the adjustment of energy structure since 2006. Consequently, SO_2 emissions in China have leveled off (Lu et al., 2010). However, N and S deposition is still increasing, especially in Southeast China due to the growing agricultural and industrial activities (Larssen et al., 2006; Liu et al., 2013; Song et al., 2013). Recent modeling studies have suggested that China is now a hotspot for N deposition (Galloway et al., 2008). In fact, the study on N deposition in China is still at the initial stage, and the reports of the dissolved organic N (DON) deposition especially in agro-ecosystems are even fewer (Cape et al., 2001; Neff et al., 2002; Cornell, 2011; Zhang et al., 2012). This represents a big gap in the knowledge of the magnitude and spatiotemporal variability of N deposition. Therefore, further studies on N and S deposition should be conducted in China.

China is a large agricultural country with a huge population and a long history of agricultural activity. Usually, N and S deposition is neglected in the agro-ecosystems because fertilizers including N and S fertilizer are applied on farmlands to increase yields to meet the demand of growing population (Pryor et al., 2001; Cui et al., 2010). Also, the data on N and S deposition are currently not available in China for its complex anthropogenic and natural environments. Recently, some studies showed that wet deposition of only dissolved inorganic N (DIN, the sum of NH_4^+–N and NO_3^-–N) peaked at 38.5 kg ha^{-1} $year^{-1}$ N and S deposition peaked at 20.3 kg ha^{-1} $year^{-1}$ S in Northern China (Liu et al., 2006; Pan et al., 2013). Most studies have suggested that the impacts of short-term or moderate N and S deposition increased plant growth, whereas long-term or excessive N and S deposition would lead to a reduction through acidification and nutrient imbalances (Bleeker et al., 2011; Liu et al., 2013). Actually, few studies have been conducted on the total dissolved N (TDN, the sum of DIN and DON) and S deposition in agro-ecosystems of regions with different development levels. Recently, Tian et al. (2011) found that DIN wet deposition only in wheat seasons was up to 15 kg ha^{-1} N in a developed area. Our group found that TDN wet deposition only during the monsoon season (April–June) peaked at 65.2 kg ha^{-1} N in a developing area (Cui et al., 2014), noticeably greater than the global average of 3.5 kg ha^{-1} $year^{-1}$ N (Phoenix et al., 2006) and even exceeding the critical loads of N deposition (25 kg ha^{-1} N; Kim et al., 2009). At the same time, S wet deposition peaked at 23.4 kg ha^{-1} S during the monsoon season (Cui et al., 2014), which approached the critical loads of S deposition (32 kg ha^{-1} S; Kim et al., 2009). The excess N and S deposition in agricultural ecosystems may have a wide range of effect. Hence, it is urgent to identify the deposition magnitudes of N including DON and S for its ecological effect in agro-ecosystems of Southeastern China.

This work is aimed: 1) to estimate N and S wet deposition fluxes and 2) to discuss the component of N wet deposition in two typical agricultural sites of southeast China during 2011–2012. The results will help us better understand N and S deposition and its cycle in agro-ecosystems. In addition, this study will provide valuable data for assessing the effect of N and S deposition on agro-ecosystems and help the creation of an effective policy to reduce N and S deposition.

2. Data and methods

2.1. Site description

The study was conducted between January 2011 and December 2012 in the two monitoring stations, Red Soil Ecological Experiment Station (116°55′ E, 28°12′ N) and Changshu Agroecological Experimental Station (120°38′ E, 31°33′ N), Chinese Academy of Sciences (CAS). Two stations both have been selected as the long-term agro-ecosystem monitoring sites by the CAS, and the former is the typical hilly region in the developing area and the latter is the typical plain region in the developed area of Southeast China (Fig. 1). Red Soil Ecological Experiment Station and Changshu Agroecological Experimental Station are located in Yingtan city of Jiangxi province and Changshu city of Jiangsu province, usually known as Yingtan Station (YTS) and Changshu Station (CSS), respectively. YTS covers a total area of 120 ha, and lies in 10 km northeast of Yingtan urban region. Surrounding YTS, there are three pig farms within 50 km^2. One pig farm is in the direction of North-Northwest to North and the other two are in the East-Southeast to East of the sample site. More than 480 kg ha^{-1} $year^{-1}$ N fertilizers are applied mainly in March or April, June and July when peanut and rice are planted. Usually, pig manure is transported during the three months (November–January) and applied in March or April. The CSS covers a total of 3 ha, and is located 10 km northeast of Changshu urban region. Surrounding CCS, there are no pig farms but some plants such as garment factories. On the farmlands, more than 600 kg ha^{-1} $year^{-1}$ N fertilizers are applied mainly in March, June, August and November when winter wheat and rice are planted. Remarkably, additional pig manures were applied in YTS in January 2012 and in CCS in May 2011. The mainly meteorological parameters of the two sites were listed in detail in Table 1.

2.2. Deposition sampling and analysis

An ASP-2 automatic sampler (Wuhan-Tianhong Inc., China) was equipped to collect deposition samples. During a rain event, a wetness detector was triggered to open the lid of the wet deposition bucket. Once the rain stopped, the lid was closed and sealed the bucket to prevent evaporation and contamination of the sample. Wet deposition samples were collected immediately after each rain event in YTS while sampled at a 4-week interval in CSS during 2011–2012. To eliminate the effects of microbial activities on rainwater chemical compositions in CCS, some doses of methyl propylphenol were added to rainwater samples at the base of the rainfall after every event (ratio of methyl proyl phenol to rainwater sample = 450 mg to 1 L) (Cape et al., 2001; HJ/T165-2004).

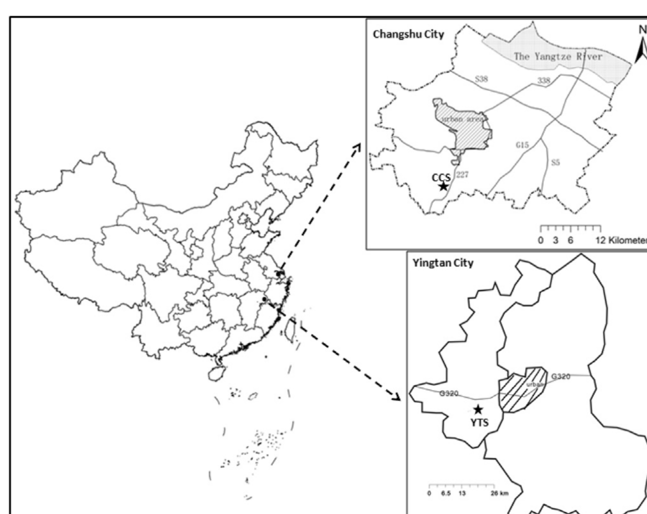

Fig. 1. The study sites in Yingtan City and Changshu City, China.