Atmospheric Environment 82 (2014) 121–129

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Atmospheric wet deposition of nitrogen and sulfur to a typical red soil agroecosystem in Southeast China during the ten-year monsoon seasons (2003–2012)

Jian Cui [a,b,*], Jing Zhou [a,b,c,*], Ying Peng [d], Yuanqiu He [a,b], Hao Yang [e], Jingdong Mao [f]

[a] Institute of Soil Science, Chinese Academy of Sciences, 71st East Beijing Road, Nanjing 210008, PR China
[b] Red Soil Ecological Experiment Station, Chinese Academy of Sciences, Liujiazhan Plantation, Yingtan 335211, PR China
[c] National Engineering and Technology Research Center for Red Soil Improvement, 602nd Nanlian Road, Nanchang 330200, PR China
[d] Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, 73rd East Beijing Road, Nanjing 210008, PR China
[e] College of Geography Science, Nanjing Normal University, 1st Wenyuan Road, Nanjing 210046, PR China
[f] Department of Chemistry and Biochemistry, Old Dominion University, Norfolk 23529, VA, United States

HIGHLIGHTS

- N and S wet deposition had an increased trend in the monsoon seasons.
- Total N wet deposition ranged from 3.34 to 65.17 kg ha^{-1} N in the monsoon seasons.
- S wet deposition was in the range of 7.17–23.44 kg ha^{-1} S in the monsoon seasons.
- NH_4^+–N and DON contributed 48.5% and 20.8% of the wet deposition of total N, respectively.
- The acid rain type was shifted from sulfur to a mixed one during the five-year monsoon seasons (2008–2012).

ARTICLE INFO

Article history:
Received 11 March 2013
Received in revised form
5 October 2013
Accepted 7 October 2013

Keywords:
N and S deposition
Wet deposition
Monsoon season
Red soil farmland
Southeast China

ABSTRACT

Biological processes in agroecosystems have been affected by atmospheric nitrogen (N) and sulfur (S) deposition, but there is uncertainty about their deposition characteristics in the monsoon season. We collected rain samples using an ASP-2 sampler, recorded rainfall and rain frequency by an auto-meteorological experiment sub-station, and determined total N, NO_3^- – N and NH_4^+ – N levels in precipitation with an AutoAnalyzer 3 and SO_4^{2-} – S with a chromatography, in order to characterize the wet deposition of N and S to a typical red soil agroecosystem by a ten-year monitoring experiment in Southeast China. The results indicated that N and S wet deposition had an increased trend with the flux of total N (3.34–65.17 kg ha^{-1} N) and total S (SO_4^{2-} – S) (7.17–23.44 kg ha^{-1} S) during the monsoon seasons. The additional applications of pig mature in 2006 and 2007 led to the peaks of DON (dissolved organic nitrogen) and total N wet deposition. On average, NH_4^+ – N was the major N form, accounting for 48.5% of total N wet deposition and DON was not a negligible N form, accounting for 20.8% during the ten-year monsoon seasons (except 2006 and 2007). Wet deposition of N and S has been intensively influenced by human activities in the monsoon season, and would increase the potential ecological risk in the red soil agricultural ecosystem.

1. Introduction

Atmospheric nitrogen (N) and sulfur (S) deposition is a very topical environmental issue, and captures the attention of policy makers in the world (Kim et al., 2010; Bobbink et al., 2010; Cornell, 2011). Although kinds of protocols on reducing N and S in air have been executed since 1980, the N and S deposition still causes a broad range of detrimental effects and perturbations to ecosystems (Wright et al., 2001; Phoenix et al., 2006; Tørseth et al., 2012; Payne et al., 2013). In China, N and S deposition is increasing although there has been a decline for total emission of N and S (Liu et al., 2013; Song et al., 2013). Prior studies on N and S deposition mostly focused on forest and aquatic ecosystems but neglected agroecosystems due to substantial use of N fertilizers on farmlands

* Corresponding authors. Institute of Soil Science, Chinese Academy of Sciences, 71 East Beijing Road, Nanjing 210008, PR China. Tel.: +86 25 8688 1219/1203; fax: +86 25 8688 1000.
E-mail addresses: jcui@issas.ac.cn (J. Cui), zhoujing@issas.ac.cn (J. Zhou).

1352-2310/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.atmosenv.2013.10.023

(Pryor et al., 2001; Cui et al., 2010). In fact, our group found N wet deposition ranged from 10 to 94 kg ha^{-1} yr^{-1} N (Cui et al., 2012), which was significantly greater than the global average of 3.5 kg ha^{-1} $year^{-1}$ N (Phoenix et al., 2006). Moreover, there have been only a few reports on dissolved organic N (DON) deposition for its different chemical families, low concentrations and instability after collection (Cape et al., 2001; Cornell, 2011; Zhang et al., 2012). In fact, DON is of similar bioavailability to inorganic N, plays an important role in N deposition and accounts for a significant fraction (33 ± 19%) of total N deposition (Neff et al., 2002; Zhang et al., 2012). Therefore, it is important to further discuss the characteristics of N and S deposition in agroecosystems for understanding N and S deposition and evaluating their ecological effects.

Red soils are the highly leached soils and usually designated under the orders of Oxisols, Ultisols, occasionally Alfisols, Mollisols and even Inceptisols (Baliger et al., 2004). It is widely distributed in (sub-) tropical regions and potentially constitutes one of the most important soil resources for food production in the world. In China, the red soil regions cover an area of 2.6 million km^2 and account for over 20% of the country's total land area. The red soils of China are highly weathered and inherently infertile, dominated by low mountains and hills, and are typical of similar red soils that occur throughout (sub-) tropical South America, Africa, South and East Asia and other regions.

Red soils are not able to preserve moisture for their poor water holding capacity and as the soils frequently occur in areas subject to droughts at certain times of the year (Baliger et al., 2004). Therefore, crops are cultivated mostly during the monsoon reason. In the red soil regions of China, drought has become more and more frequent and intensive in these regions (He et al., 2001). Hence, the monsoon season, especially rainfall, plays an important role in the regions (Wang, 2006). However, temporal characteristics of N and S deposition have most often been recorded in various regions of the world based on monthly, seasonal, and annual data (Pryor et al., 2001; Cui et al., 2010; Tørseth et al., 2012; Liu et al., 2013), but few studies estimated the N and S deposition in the monsoon season and evaluated its ecological effect on farmlands. In our previous study, we found that inorganic N wet deposition in the monsoon season ranged from 5.0 to 20.2 kg ha^{-1} N, accounting for 17.6–51.9% of annual inorganic N deposition on a farmland during 2005–2012 (Cui et al., 2012). On the same farmland, Yang et al. (2005) also found S wet deposition in the monsoon season contributed 29.7% to the annual S wet deposition. In addition, the monsoon season is very critical for peanut and early rice growth on the farmland. Moreover, red soils are generally acidic in nature and deficient in most essential nutrients (Baliger et al., 2004). Larger amounts of organic matter and nutrients are also lost from the cultivated land (He et al., 2001), making the agroecosystems fragile. Then the N and S deposition in the monsoon season might have a great ecological effect on, for example, the yields, the acidification and alteration of nutrient balances of the agricultural ecosystems. However, now it is still unclear regarding: 1) characteristics of N and S deposition; and 2) proportions of N forms, such as NH_4^+ – N, NO_3^- – N, and dissolved organic nitrogen (DON) in the long term.

In the present study, we focused on a typical agroecosystem in the red soil region, southeastern China to: 1) determine N and S wet deposition fluxes and trends, and 2) estimate the proportion of N forms in the monsoon season by a long-term observation (2003–2012). The results could not only supply a valuable parameter for assessing the effect of N and S deposition on agroecosystems and an effective policy to reduce N and S deposition, but also attribute to the understanding of N and S cyclings and their nutrient management of red-soil agroecosystems in China and also around the world.

2. Data and methods

2.1. Site description

Yingtan city lies in the northern part of Jiangxi Province, southeast China (116°35′–117°30′ E, 27°35′–28°41′ N), and covers a total area of 3556.7 km^2 (Fig. 1). The primary soil type is red soil. Geomorphologically, the city consists of hills, basins and high, steep, clustered mountains in its northern, central and southern parts. Its ground elevation varies from 16 to 1541 m above sea level. Subtropical humid monsoon climate prevails in the city, with an

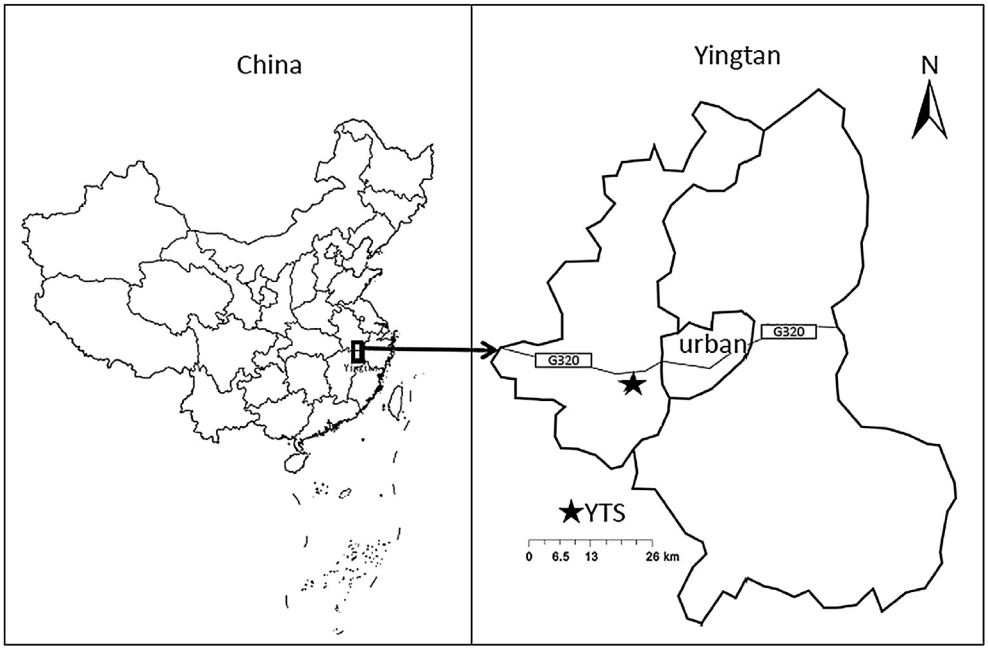

Fig. 1. The study site in Yingtan city, Jiangxi Province, China.