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Evaluation of the mixing of sands into soils on nitrification potential from different land-use systems

Jing Wang [a], Jinbo Zhang [a, b, c, d, *], Christoph Müller [e, f], Zucong Cai [a, b, c, d]

[a] School of Geography Sciences, Nanjing Normal University, Nanjing 210023, China
[b] Jiangsu Provincial Key Laboratory of Materials Cycling and Pollution Control 210023, China
[c] Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application 210023, China
[d] Key Laboratory of Virtual Geographical Environment (VGE), Ministry of Education, Nanjing Normal University 210023, China
[e] Department of Plant Ecology, Justus-Liebig University Giessen, Heinrich-Buff-Ring 26, 35392 Giessen, Germany
[f] School of Biology and Environmental Science, University College Dublin, Ireland

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A B S T R A C T

Quartz sand is often mixed with soil to enable leaching in studies where nitrate leaching is simulated. However, the addition of sand may also have an effect on the N transformations dynamics but this aspect has never been studied so far. A ^{15}N tracer experiment was conducted to investigate this effect on coniferous forest soil (CF), rice-rice rotation soil (RR), rice-wheat rotation soil (RW) and maize-wheat rotation soil (MW). Results showed that the addition of quartz sand into the three agricultural soils (RR, RW and MW) reduced the net production of NO_3^--N, but the mechanisms involved in the reduction among the three soils were different. In the RR soil, the addition of quartz sand had no effect on gross NO_3^--N production (autotrophic nitrification + heterotrophic nitrification), but enhanced gross NO_3^--N consumption (NO_3^--N immobilization + dissimilatory NO_3^- reduction to NH_4^+), resulting in reduced NO_3^--N built-up. In the RW soil, the addition of quartz sand significantly inhibited gross autotrophic nitrification rates and stimulated gross NO_3^--N immobilization rate. In the MW soil, only dissimilatory NO_3^- reduction to NH_4^+ (DNRA) rate was stimulated by the addition of quartz sand. In contrast, in the CF soil sand addition did not have an effect on the gross N transformation rates. Our results show that sand additions will alter N transformations dynamics in an unforeseeable manner and should be considered with the utmost caution.

1. Introduction

Simulated nitrate (NO_3^-) leaching in soil experiments has been widely employed to study the characteristics and controlling factor of NO_3^- leaching in relationship to soil heterogeneity, climatic conditions, plant uptake and other factors [1–5]. Commonly, quartz sand is homogeneously mixed with the soil to promote leaching [6–11]. However, it is largely unknown whether the mixing of quartz sand into soil would also influence soil N transformation processes and thus alter nitrate leaching characteristics.

For instance, the addition of quartz sand alters the soil texture by increasing the sand content, which in turn influences soil structure [12], pore size distribution, the water holding capacity, water permeability and cation exchange capacity [13–15]. Furthermore, the addition of sand alleviates soil compaction especially in heavy clay soils [16]. It was found that N mineralization rates in sieved soils were twice as high as in undisturbed soil [17], and sieving caused a temporary increase in the mineralization of C and N due to an altered soil texture [18]. Results from a long-term laboratory incubation experiment showed that highest N mineralization rates in fine-textured, N-rich soils, but the proportions of soil N mineralized were inversely related to fine particle concentrations [19]. Moreover, nitrification rates were negatively correlated with the clay content, while the amounts of N retained in the microbial biomass in un-amended soils increased with clay content [20]. Therefore, we hypothesized that the addition of quartz sand into soil would not only influence the leaching

* Corresponding author. School of Geography Sciences, Nanjing Normal University, Nanjing 210023, China.
E-mail address: zhangjinbo@njnu.edu.cn (J. Zhang).

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characteristics but also the some of the gross nitrogen transformation processes. A-^{15}N tracer laboratory experiment was performed to clarify the effect of quartz sand application on soil N transformations under different land-use systems. Although our incubation studies do not necessarily reflect simulated soil column experiments due to the differences in incubation period and the proportion of sand mixed into soil [6–11], our laboratory study aimed to provide a deep understanding of soil N dynamics in response to the addition of quartz sand into soil.

2. Materials and methods

2.1. Soil samples

Soils were collected from four diverse land-use systems: coniferous forest (CF), rice-rice rotation (RR), rice-wheat rotation (RW) and maize-wheat rotation (MW). The rice-rice rotation site was located in Yingtan National Agroecosystem Field Experiment Station, Chinese Academy of Sciences, in Jiangxi Province in southern China (28°15′ N, 116°55′ E). Yingtan is a typical subtropical humid monsoon climate region. The mean annual precipitation and temperature was approximately 1788 mm (30-year average) and 17.6 °C, respectively. The soil in this region is characterized by acid soil reaction, and is strongly oxidized, and classified as Orthic Acrisol in FAO soil classification. The coniferous forest site was located in the Wanmulin Nature Reserve in Fujian Province in eastern China (27°0.3′N, 118°0.9′E). This region is a middle subtropical monsoon climate, which has a mean annual precipitation of 1731 mm, most of which falls between March and August, and a mean annual air temperature of 19.4 °C. The mean annual evapotranspiration is 1466 mm in this region. The parent material of the soil is granite and soils are classified as red soils (humic Planosols in the FAO system). The rice-wheat rotation and maize-wheat rotation system sites were located in Yanting Agro-Ecological Station of Purple Soil, a member station of the Chinese Ecosystem Research Network (CERN), Chinese Academy of Sciences, in the center of Sichuan Province in southwestern China (31°16′N, 105°28′E). This region is located in a moderate subtropical humid monsoon climate, with annual precipitation of 907 mm and mean annual temperature of 16.7 °C. The soils is alkaline, and classified as Eutric Regosols in FAO soil classification. Three composite soil samples (0–20 cm) were collected from each site. After sampling, the soils were immediately sieved (<2 mm), kept moist and stored at 4 °C in sealed plastic bags prior to analysis.

2.2. Preparation of quartz sand

Quartz sand was sieved (<2 mm), and soaked in the water until the water became clear to dislodge clay and organic matter from quartz sand. Then 3% HCl solution was added to the above treated quartz sand samples for 1 week to remove $CaCO_3$. Finally, quartz sand samples were washed with deionized water, oven-dried at 80 °C to a constant weight, and stored in sealed plastic bags before the onset of the incubation experiment.

2.3. ^{15}N label experiment

For each soil, a series of 250-ml Erlenmeyer flasks were prepared which contained the homogeneous mixture of 20 g fresh soil (oven-dry basis) and 10 g quartz sand (<2 mm). There were two ^{15}N label treatments in this study (each in triplicate): an ammonium label ($^{15}NH_4NO_3$) and a nitrate label ($NH_4^{15}NO_3$), both at 10 atom% ^{15}N excess at N application rates of 20 mg NH_4^+-N kg^{-1} soil and 20 mg NO_3^--N kg^{-1} soil. The soils were incubated at 25 °C and 60% maximum water-holding capacity for 3 (RW and MW) or 6 (RR and CF) days under dark conditions. The soils were extracted at 0.5, 24, 48 and 72 h for RW and MW, 0.5, 48, 96 and 144 h for RR and CF after ^{15}N addition with 100 ml 2 M KCl solution to determine the concentrations and ^{15}N enrichment for the NH_4^+ and NO_3^-. The different incubation periods were due to the availability of NH_4^+ in

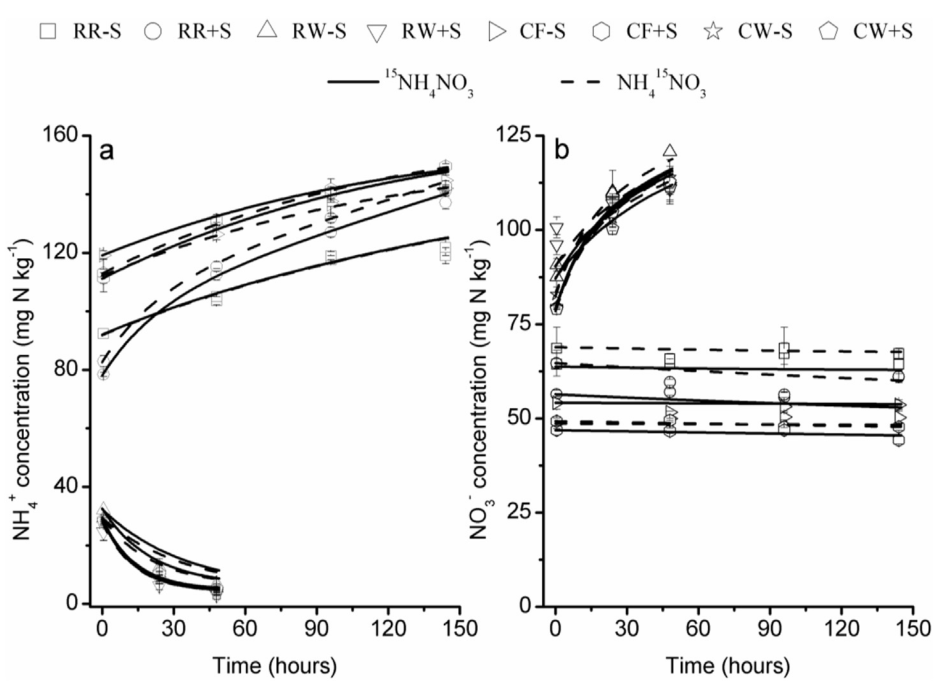

Fig. 1. Measured (*point*) and modeled (*line*) concentrations of the NH_4^+ pools (**a**) and NO_3^- pools (**b**) in different land-use systems. "RR+S, RW+S, CF+S, MW+S", treatment with quartz sand in different land use soils; "RR-S, RW-S, CF-S, MW-S", treatment without quartz sand in different land use soils. *Error bars* SD.