Science of the Total Environment 563–564 (2016) 10–18

Contents lists available at ScienceDirect

Science of the Total Environment

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

Spatial variability of soil nitrogen in a hilly valley: Multiscale patterns and affecting factors

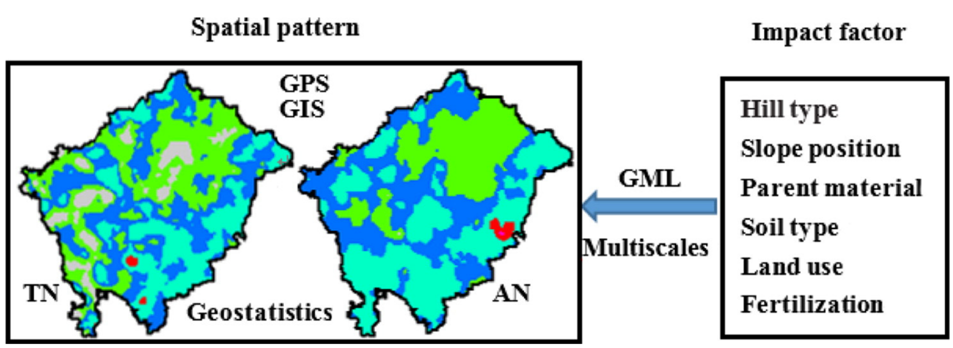
Shirong Zhang [a,*], Chunlan Xia [a], Ting Li [b], Chungui Wu [c], Ouping Deng [b], Qinmei Zhong [a], Xiaoxun Xu [a], Yun Li [b], Yongxia Jia [b]

[a] College of Environmental Science, Sichuan Agricultural University, Wenjiang 611130, PR China
[b] College of Resources, Sichuan Agricultural University, Wenjiang 611130, PR China
[c] Agricultural Bureau in Shehong, Shehong 629200, PR China

HIGHLIGHTS

- Spatial patterns of soil TN and AN among three hill types showed obvious difference.
- Hill type with different heights was a key factor for spatial variabilities.
- Effects of slope position, parent material, land use, etc. increase with upscaling.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 February 2016
Received in revised form 15 April 2016
Accepted 16 April 2016
Available online xxxx

Editor: Jay Gan

Keywords:
Total nitrogen
Available nitrogen
Hilly region
Multiscale
General linear model
Affecting factor

ABSTRACT

Estimating the spatial distribution of soil nitrogen at different scales is crucial for improving soil nitrogen use efficiency and controlling nitrogen pollution. We evaluated the spatial variability of soil total nitrogen (TN) and available nitrogen (AN) in the Fujiang River Valley, a typical hilly region composed of low, medium and high hills in the central Sichuan Basin, China. We considered the two N forms at single hill, landscape and valley scales using a combined method of classical statistics, geostatistics and a geographic information system. The spatial patterns and grading areas of soil TN and AN were different among hill types and different scales. The percentages of higher grades of the two nitrogen forms decreased from low, medium to high hills. Hill type was a major factor determining the spatial variability of the two nitrogen forms across multiple scales in the valley. The main effects of general linear models indicated that the key affecting factors of soil TN and AN were hill type and fertilization at the single hill scale, hill type and soil type at the landscape scale, and hill type, slope position, parent material, soil type, land use and fertilization at the valley scale. Thus, the effects of these key factors on the two soil nitrogen forms became more significant with upscaling.

1. Introduction

Soil total nitrogen (TN) plays a key role in building soil fertility and enhancing soil productivity (Franzluebbers and Stuedemann, 2009). As an important part of soil TN, available nitrogen (AN) supplies plant

* Corresponding author.
E-mail address: srzhang01@aliyun.com (S. Zhang).

http://dx.doi.org/10.1016/j.scitotenv.2016.04.111

nutrients during the growth period (Mengel et al., 2006). Nitrogen deficiency in soils impedes plant growth and leaf photosynthesis (Boussadia et al., 2010). However, excess nitrogen in soil is the largest contributor of non-point-source pollution (Basso et al., 2016) and may result in severe environmental issues, such as eutrophication, soil acidification and gaseous emissions (Oorts et al., 2007; Rode et al., 2009; Velthof et al., 2014).

Soil nitrogen heterogeneity is caused by widely varying soil-forming factors including climate, topography, parent material, land use and human activity (Aubert et al., 2005; Basso et al., 2016). Therefore, knowledge of the spatial variability of soil nitrogen is indispensable in environmental monitoring and management (Foster et al., 2005; Córdova et al., 2012). In recent years, studies of the variation of soil nitrogen have benefited from the combination of geostatistics with global positioning system (GPS) and geographic information system (GIS) (Raines, 2002; Lamsal et al., 2006; Yamashita et al., 2010). Recent many studies have focused on the spatial variability inherent in soil nitrogen at a single scale (Dharmakeerthi et al., 2005; Momtaz et al., 2009; Jackson-Blake et al., 2012). Nevertheless, relatively little attention has been devoted to studying their spatial patterns in the same region at multiple scales (Yemefack et al., 2005; Oenema et al., 2010) although the various environmental conditions, land use and management may lead to highly diverse distribution patterns in different regions or at multiple spatial scales (Rode et al., 2009).

The spatial patterns of soil nitrogen are the cumulative result of all acting soil-forming factors (Zeleke and Si, 2006). Among all factors affecting soil nitrogen heterogeneity, only a few are usually studied at one time in most literature. For example, Rodríguez et al. (2011) reported the effect of plant species on the spatial variability of the labile organic nitrogen and inorganic nitrogen in a forest soil with single-factor analysis of variance (ANOVA). Wang et al. (2009) suggested that land use and topography were the dominant factors affecting TN by single-factor ANOVA and correlation analysis and Tremblay et al. (2011) evaluated the effect of nitrogen fertilizer rates on soil nitrate-N using ANOVA. However, it remains unclear how the dominant factors together influence the variability of soil nitrogen (Aubert et al., 2005; Wang et al., 2009; Oenema et al., 2010). Consequently, it is essential to improve our understanding of the main effects of the multiple factors affecting the variability of soil TN and AN, especially by applying the univariate general linear model (GLM) across different spatial scales (Huang et al., 2007; Mairura et al., 2007; Cobo et al., 2010).

Hills are one of the most extensive landforms in East Asia including south China (Wang et al., 2009), Vietnam (Schmitter et al., 2010) and Thailand, and cover up to 180 million ha (Aumtong et al., 2009). Despite the large areas of hill soils, only a limited number of researchers have examined the spatial variability of soil TN and AN in these regions (Yemefack et al., 2005; Oenema et al., 2010; Li et al., 2016). Therefore, it is essential to develop systematic studies into understanding the spatial patterns and crucial affecting factors in hilly regions at multiple scales (Zhang et al., 2007; Li et al., 2016).

The Fujiang River Valley, as a typical hilly region of the central Sichuan Basin (Fig. 1), is one of the most vulnerable ecological regions in the upper Yangtze River Valley. This is mainly because of the high population density, erosion-prone soil, high cropping intensity and traditional management (He et al., 2007; Wang et al., 2009). In the valley, three hill topographies (low hill, medium hill and high hill) are present, and their geographical landscapes vary according to the assemblages of landforms, parent material, soil type, land use and management. However, the spatial patterns and dominant factors affecting soil N are unclear. Hence, we hypothesized that soil TN and AN show different spatial patterns and dominant affecting factors within a single valley at multiple scales.

The objectives of this study were to: (1) characterize the spatial patterns of soil TN and AN using a combination of classical statistics, geostatistics, GPS and GIS at the single hill, landscape and valley scales; and (2) evaluate the main effects of the dominant affecting factors on soil TN and AN across multiple scales using univariate GLM.

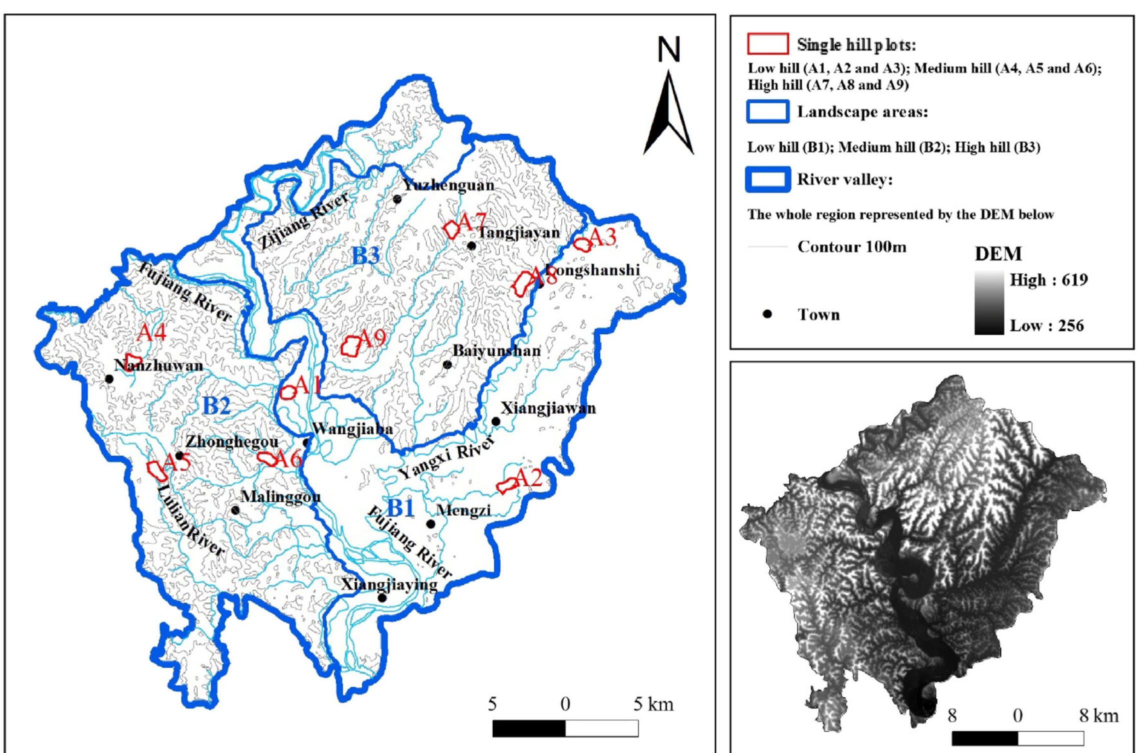


Fig. 1. Sampling sites for the single hill, landscape and valley scales in the study area. Nine plots (A1–A9) were selected for single hill scale. Three areas (B1–B3) were selected for the landscape scale. Region C was the whole river valley.