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An Integrated Quantitative Method to Simultaneously Monitor Soil Erosion and Non-Point Source Pollution in an Intensive Agricultural Area*1

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ABSTRACT

In China, some areas with intensive agricultural use are facing serious environmental problems caused by non-point source pollution (NPSP) as a consequence of soil erosion (SE). Until now, simultaneous monitoring of NPSP and SE is difficult due to the intertwined effects of crop type, topography and management in these areas. In this study, we developed a new integrated method to simultaneously monitor SE and NPSP in an intensive agricultural area (about 6 000 km^2) of Nanjing in eastern China, based on meteorological data, a geographic information system database and soil and water samples, and identified the main factors contributing to NPSP and SE by calculating the NPSP and SE loads in different sub-areas. The levels of soil total nitrogen (TN), total phosphorus (TP), available nitrogen (AN) and available phosphorus (AP) could be used to assess and predict the extent of NPSP and SE status in the study area. The most SE and NPSP loads occurred between April to August. The most seriously affected area in terms of SE and NPSP was the Jiangning District, implying that the effective management of SE and NPSP in this area should be considered as a priority. The sub-regions with higher vegetation coverage contributed to less SE and NPSP, confirming the conclusions of previous studies, namely that vegetation is an effective factor controlling SE and NPSP. Our quantitative method has both high precision and reliability for the simultaneous monitoring of SE and NPSP occurring in intensive agricultural areas.

Key Words: nutrient load, soil particles, spatial variation, vegetation coverage, water runoff

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INTRODUCTION

Soil erosion (SE), nitrogen (N) and phosphorus (P) losses occur simultaneously in a continuous, dynamic process and are the main contributors to non-point source pollution (NPSP) (Huang *et al*., 2001; Wu *et al*., 2008; Shen *et al*., 2012). When N and P in soil particles move into downstream waters, some will be dissolved and become soluble N and P (Leon *et al*., 2001; Braskerud, 2002; Wu *et al*., 2010a, b). In recent years, the NPSP caused by SE in some intensive agricultural areas in China has become a serious environmental concern (Bu *et al*., 2005; Jiang *et al*., 2005; Wu *et al*., 2010a, b). Apart from the contributions of N and P carried by soil particles during SE, the N and P carried by water runoff is the other major contributor to NPSP (Yan and Tang, 2005; Wu *et al*., 2011).

To date, several quantitative methods have been applied to monitor SE and NPSP. For example, the universal soil loss equation (USLE) and soil and water assessment tool (SWAT) are the most widely used for monitoring SE (Wischmeier and Smith, 1978; Renard *et al*., 1997) and NPSP (Yong *et al*., 1989; Ouyang *et al*., 2010). The USLE is commonly used in China to monitor SE (Xia *et al*., 2007). However, there have been few studies focusing on the monitoring NPSP with the USLE or modified USLE in China. This is due to the differences in crop land type, topography and management practices between China and USA (Edwin *et al*., 2010; Ongley *et al*., 2010). Therefore, a

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goal of this study was to either develop a specific model or further modify the USLE such that it could be used to monitor NPSP, together with SE, in China.

During the course of our previous studies (Bu *et al.*, 1999; Xia *et al.*, 2007; Ma *et al.*, 2011), we developed an integrated method for quantitative monitoring of SE and NPSP based on the USLE. The modified method was applied to different areas in China (Shandong, Jiangsu, Yunnan, Fujian and Jiangxi provinces) with a total monitoring area of about 200 000 km^2. The results showed that the precision of soil loss monitoring using this method reaches 80% to 90% in nonintensive agricultural areas (Bu *et al.*, 2005; Jiang *et al.*, 2005). However, for the simultaneous monitoring of SE and NPSP in some intensive agricultural areas such as Nanjing area, this integrated method needs to be further developed.

Nanjing is an important economic, cultural and transportation center in eastern China. Areas with intensive agricultural use surround the city center. Rapid urbanization during recent years caused deforestation and increased reclamation of sloping land for agriculture, which resulted in increased soil erosion and water pollution (Lin *et al.*, 2008). Thus, the development of a quantitative monitoring and analysis system for SE and NPSP is required to provide a sound basis for a better management of city development and land use.

The objectives of this study were: 1) to map SE and NPSP in the Nanjing area using the integrated quantitative model to assess SE and NPSP simultaneously, based on the meteorological data, a geographic information system (GIS) database and chemical analysis of soil and water samples collected from 2001 to 2010 in the Nanjing area, and 2) to identify the main factors contributing to NPSP and SE by calculating the NPSP and SE loads in different sub-areas. The findings are expected to yield a rational basis for future land management policy with respect to SE and NPSP in similar intensive agricultural areas.

MATERIALS AND METHODS

Study area description

The Nanjing area (31°14′–32°36′ N, 118°32′–119° 14′ E) is located in the Yangtze River Delta, eastern China and covers about 6 590 km^2. The mountains and down lands, plains and basins, and surface waters are comprise approximately 58.4%, 41.6% and 10.2% of the total Nanjing area, respectively. The region belongs to the north subtropical monsoon climatic zone, with an annual average temperature of 17.8 °C. The sunshine duration is 1 687 h and the annual average rainfall is 1 034 mm. Four rivers of Yangtze River, Qinhuai River, Shuiyang River and Chuhe River traverse the region which also includes Gucheng Lake and Shijiu Lake, with the total water capacity of 428 million m^3 (Lin *et al.*, 2008) (Fig. 1a).

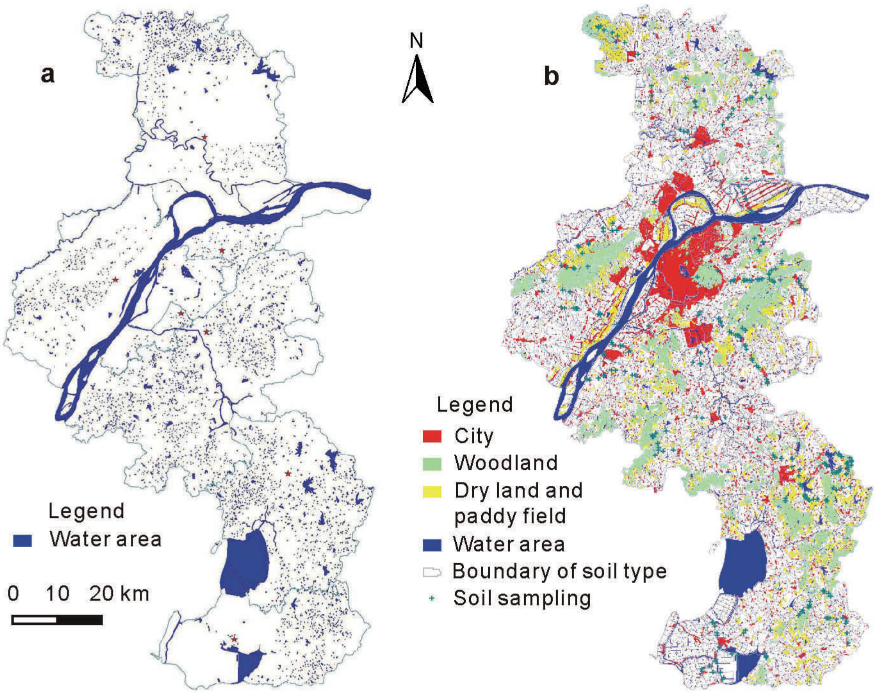

Fig. 1 Water system (a) and soil sampling points (b) in Nanjing area, eastern China.