Catena 147 (2016) 797–808

Contents lists available at ScienceDirect

Catena

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

# Nitrogen and phosphorus losses by runoff erosion: Field data monitored under natural rainfall in Three Gorges Reservoir Area, China

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ARTICLE INFO

*Article history:*
Received 22 January 2016
Received in revised form 10 August 2016
Accepted 5 September 2016
Available online 17 September 2016

*Keywords:*
Agricultural non-point source
Runoff
Natural rainfall
Three Gorges Reservoir Area
Nitrogen
Phosphorus

ABSTRACT

Nitrogen (N) and phosphorous (P) from agricultural non-point source (ANPS) pollution are the great threats to the regional water quality in the Three Gorges Reservoir Area (TGRA) of China. To explore the pollution of N and P loss from the sloping land in TGRA agricultural areas, field-scale plot experiment under natural rainfall was conducted from May 1 to October 31 in 2012. We monitored and analyzed rainfall, runoff volume, sediment yield, and nutrient concentration under different conditions (3 soil types, 3 surface slopes, and 5 cropping systems) in 30 experimental plots of 20 $m^2$ during the rainy season. The results indicated that average loss ratio of N was 1.90%, while that of P was 1.54%. N and P loss ratios from surface runoff in 15° plots of sloping farmland were the highest. Purple soil (PS) was the most severe soil and nutrient loss. Within all the 5 cropping systems, the loss ratios of N and P from intercropping of citrus and grass (C-G) were the lowest. The practice of C-G, which was the most beneficial cropping system, should be further encouraged especially in TGRA to cope with the serious issues of N and P losses. These findings provide useful and valuable information for decision makers and planners to take sustainable measures for the control of ANPS pollution in TGRA, and are beneficial for the agro-ecological environment management of the local agricultural watersheds.


## 1. Introduction

Eutrophication caused by uncontrolled discharges of nitrogen (N) and phosphorus (P) has become one of the most rapidly growing environmental issues (Xu et al., 2013; Ma et al., 2015). The situation is getting worse and worse in Three Gorges Reservoir Area (TGRA), People's Republic of China (Ma et al., 2011; Shen et al., 2013). Recently, the significant improvement in point source depuration technologies has highlighted problems regarding N and P pollution of surface and groundwater caused by agricultural non-point sources (ANPS) (De Wit and Giuseppe, 2001; Chen et al., 2009). In TGRA, the low quality of the available land and the shortage of easily cultivated land have driven cultivation to spill over into marginal lands, which results in conflict to the official policy of de-farming less productive lands (Jim and Yang, 2006). Moreover, 38.3% of the area is utilized for traditional agriculture, with a high cropping index (average times of crops grown in 1 year) and frequent tillage, which has led to serious soil erosion and ecological deterioration (Wei et al., 2008; Xia et al., 2014).

The widespread use of fertilizers, pesticides, composting is not the sole reason responsible for such pollution, but the same agricultural practices that favour the release of the above mentioned sub-products into the environment are an equal contributor (Kuhn et al., 2012; Recanatesi et al., 2013). Indeed nutrient carried by eroding sediments and water runoff may degrade surface water quality while those leached into soil and through the crop root zone by infiltration may eventually contaminate groundwater.

Extensive research efforts have identified and quantified factors contributing to N and P losses in runoff including the amount and type of fertilizer or manure applied (Kleinman and Sharpley, 2003; Brennan et al., 2012), timing of the rainfall event after application of fertilizer or manure (Smith et al., 2007; Allen and Mallarino, 2008), the volume of runoff generated, antecedent hydrologic conditions and field position, flow path length (McDowell and Sharpley, 2002), vegetative cover (Zhang et al., 2003a) and surface slope (Wang et al., 2013). The length of time that has elapsed since manure application was also found to affect runoff nutrient concentrations (Gilley and Eghball, 2002). For example, Randall and Mulla (2001) reported that the largest losses of N in an agricultural field occurred after frequent precipitation events with above normal precipitation and when crops were not actively growing. The heavy rainfall increased both surface runoff and loss of particulate N with the simultaneous erosion of topsoil (Kwong

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http://dx.doi.org/10.1016/j.catena.2016.09.004
0341-8162/

et al., 2002). Simultaneously, the highest soil P loss occurred in years with above normal precipitation and during fallow periods (Udawatta et al., 2004). Besides, Eghball and Gilley (1999) found that no-till application of manure resulted in greater dissolved P but less particulate P loss in runoff than when manure was incorporated by disking. Particulate P transport increases with increasing runoff and erosion, which is attributed to the stronger rainfall intensities (Quinton et al., 2001). Soil erosion can be reduced below the desirable threshold and soil properties greatly improved by selecting appropriate tillage methods and land cover patterns, among which mulching has been widely studied and proven to be effective (Abrisqueta et al., 2007; Liu et al., 2012). These research findings elaborate the mechanistic approach regarding the fate of N and P from soil to water bodies and help the development of management practices capable of minimizing the excessive nutrient problem.

Following construction of the Three Gorges Dam, many farmers resettled in surrounding mountain areas and cultivated marginal lands, which are mostly on steep slopes with soil of poor structure. In addition, the topography is largely rugged and steep which speeds up erosion in some small watersheds of TGRA, transport of eroded soil and runoff into rivers while giving less chance for deposition. Due to high operational costs and measurement difficulties, there are few in situ monitoring data suitable for calibrating an ANPS pollution loading model in TGRA. Hence, a field-scale plot study was conducted to investigate the characteristic of N and P losses from the sloping land in TGRA agricultural land, and to evaluate the impact of the contributing factors (soil type, surface slope, and cropping system) on runoff, sediment yield, and nutrient depletion.

## 2. Materials and methods

### 2.1. Study area

TGRA lies between 28°56′–31°44′N and 106°16′–111°28′E (Fig. 1), covers the lower section of the upper Changjiang River, including a low–mountain canyon in Hubei Province and a parallel valley of ridged and hilly areas in Chongqing Municipality. It consists of two cities (Chongqing Urban and Yichang Urban) and 19 counties or districts, with a total area of 58,000 km$^2$ (Fig. 1). In 2012, the rural population was 11.5 million, accounted about 68% of the total population in TGRA (MEPPRC, 2013). Geographically, the TGRA is bordered by the foothills of the Daba Mountains in the north and the margin of the Yunnan–Guizhou Plateau in the south. Due to the monsoon climate, there is obvious seasonality at the TGRA. The precipitation ranges from 1000 to 1400 mm, with 80% of the rainfall occurring between April to October. The temperature is approximately 10.8–18 °C.

After the water level of TGRA was raised, many slopes along the Changjiang River and its tributaries began to deform, and a number of mass movements were reactivated or newly produced (Ehret et al., 2010). At the beginning of the resettlement, some farmers need to cultivate the sloping land due to the lack of arable lands. TGRA has a complex and rugged topography, with 95.7% of the total area consisting of mountains and hills at elevations of 175 m to about 2000 m. The main soil types in this area are purple soil (PS, Regosols in FAO taxonomy, Entisol in USD A taxonomy), calcareous soil (CS, Cambisols in FAO taxonomy, Inceptisols in USD A taxonomy) and yellow soil (YS, Ferralosols in FAO taxonomy, Oxisols in USD A taxonomy), which accounting for 47.8%, 34.1% and 16.3%, respectively. Agriculture and crop farming is the principal economic activity in the region. Traditionally the TGRA is well-known for rice, wheat, peanut, corn, citrus, tea, and medicinal plant (Fig. 2). About 70% of farmland in TGRA is sloping land, and 17.60% is located on >25° slopes (Fig. 2), through field investigated by Hubei Province Agriculture Ecological Environmental Protection Station, P.R. China.

### 2.2. Experimental design and treatment

Based on agriculture land characteristics of TGRA, including cultivated slopes, soil types, and cropping systems, 30 field runoff plots were designed and constructed in 2004, 2005, and 2009, located in Xingshan (XS), Zigui (ZG), Badong (BD), Kaixian (KX), Wanzhou (WZ), and Shizhu (SZ), with 5 plots in each county of TGRA (Table 1). Data were

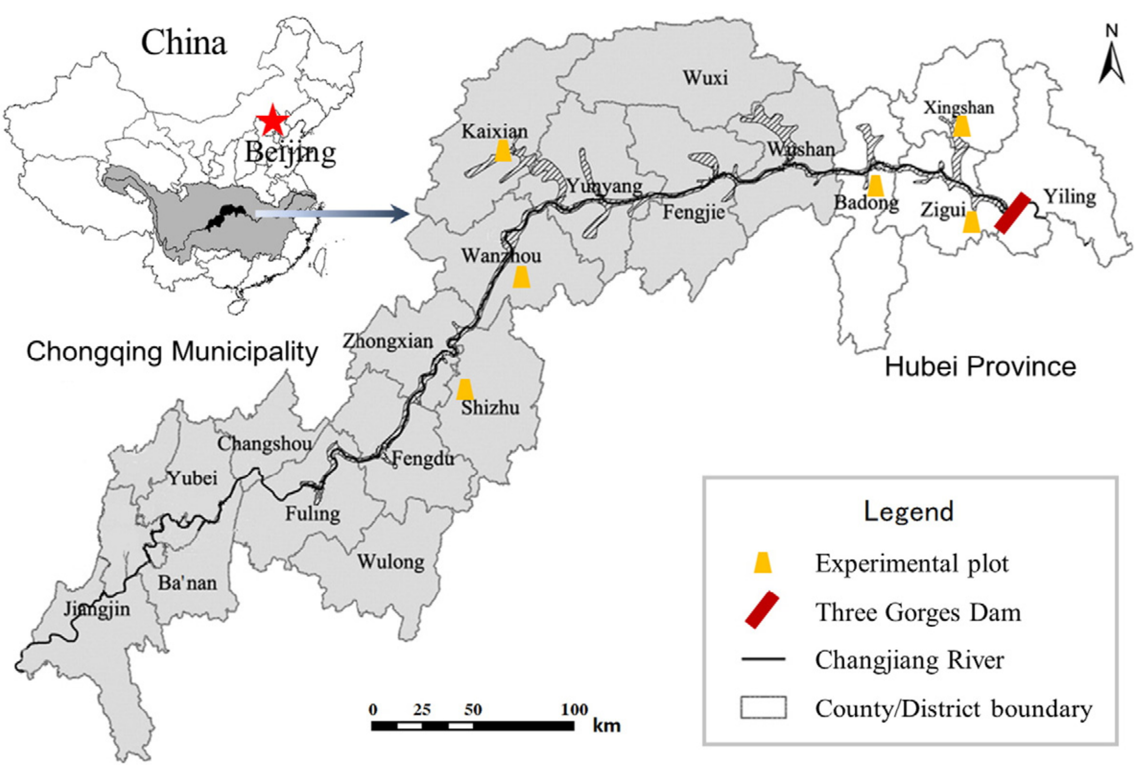


**Fig. 1.** Location of experimental plots in TGRA.