

# Spatio-temporal variation of erosion-type non-point source pollution in a small watershed of hilly and gully region, Chinese Loess Plateau

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**Abstract** Loss of nitrogen and phosphorus in the hilly and gully region of Chinese Loess Plateau not only decreases the utilization rate of fertilizer but also is a potential threat to aquatic environments. In order to explore the process of erosion-type non-point source (NPS) pollution in Majiagou watershed of Loess Plateau, a distributed, dynamic, and integrated NPS pollution model was established to investigate impacts of returning farmland on erosion-type NPS pollution load from 1995 to 2012. Results indicate that (1) the integrated model proposed in this study was verified to be reasonable; the general methodology is universal and can be applicable to the hilly and gully region, Loess Plateau; (2) the erosion-type NPS total nitrogen (TN) and total phosphorus (TP) load showed an overall decreasing trend; the average nitrogen and phosphorus load modulus in the last four years (2009–2012) were 1.23 and 1.63 t/km<sup>2</sup> · a, respectively, which were both decreased by about 35.4 % compared with the initial treatment period (1995–1998); and (3) The spatial variations

of NPS pollution are closely related to spatial characteristics of rainfall, topography, and soil and land use types; the peak regions of TN and TP loss mainly occurred along the main river banks of the Yanhe River watershed from northeast to southeast, and gradually decreased with the increase of distance to the left and right river banks, respectively. Results may provide scientific basis for the watershed-scale NPS pollution control of the Loess Plateau.

**Keywords** Erosion-type nonpoint source pollution · Returning farmland · Dynamic model · Spatio-temporal variation · Chinese Loess Plateau

## Introduction

Nitrogen and phosphorus are important nutrient factors for crop growth (Giles 2005). In addition to parts of the plain areas, the nitrogen and phosphorus in most areas of the Chinese Loess Plateau are deficient (Jia et al. 1994); extensive use of fertilizers has become necessary means for increasing crop yields, but it also leads to serious water environment problems (Hart et al. 2004; Ongley et al. 2010; Sun et al. 2012). Chinese Loess Plateau is considered as one of the region with the largest soil loss in the world; its annual sediment output accounts for 90 % of the total sediment loads of the Yellow River, most of the Loess Plateau has a very typical characteristic of “soil and water flow together,” and water flow in this area performs with a high sand content (Jiao et al. 1999). Serious soil loss results in nitrogen and phosphorus loss of soil (Zhang et al. 2004). Special processes of water and soil in the Loess Plateau lead to the loss mechanisms of water, sediment, nitrogen, and phosphorus are greatly different from other areas of China (Austin et al. 2004; Wu et al. 2015). Majiagou is a first grade tributary of the Yanhe River;

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Majiagou watershed is the drinking water source protection area of Ansai County and one of the most typical soil erosion regions in the hilly and gully region of the Loess Plateau. The implementation of the returning farmland policy in 1997 is an important measure to improve ecological environments of the Loess Plateau (Xie et al. 2010; Teng et al. 2015). Therefore, studying impacts of returning farmland on NPS nitrogen and phosphorus load in the Majiagou watershed of the loess hilly and gully region is of great scientific significance for the protection of the ecological environment in Northern Shaanxi and the development of regional economies in the Loess Plateau.

Models are the necessary means for the extension research of NPS nitrogen and phosphorus pollution load from multipoint monitoring to the whole river basin (Zhang et al. 2007b; Yao et al. 2012). In the world, the simulation research has experienced statistical models, empirical models, mathematical models, quantitative models, physical models, management models, and integrated models coupling with information technology since the 1950s, and these models have been widely used in different regions of the world (Borah and Bera 2003). Modeling is also one of the main research methods of NPS pollution in China (Zhang et al. 2007c), but they are usually direct application or partial correction at present (Shen et al. 2012). The essence of the erosion-type NPS pollution is soil loss (Hu and Ma 2008; Mo et al. 2012); it can be interpreted as that soil loss carries a lot of sediments and nutrition substances into various water area and becomes a typical nonpoint pollution to water environment (Shi 1997). The universal soil loss equation (USLE) or its revised form (RUSLE) is extensively applied in modeling pollutants attached to the sediment due to well solving the problem of quantitative estimation of long-term average soil loss (Xia and Xue 2010; Yu et al. 2011). For example, according to the current situation of China's soil and water conservation, Liu et al. (2001) proposed simple Chinese soil loss equation (CSLE) based on USLE/RUSLE; it has been used in the quantitative study of soil erosion in many regions by Chinese scholars (Cheng et al. 2009); AnnAGNPS model was applied in a small watershed of Jiulong river basin in Fujian Province (Hong et al. 2005); RUSLE equation considering the sediment delivery ratio factor was used in the middle and lower reaches of Jialing river basin (Wu et al. 2012); and SWAT model was applied in the Heihe river basin (Huang and Zhang 2004; Qin et al. 2009) and Three Gorges Reservoir area (Chen et al. 2012).

Therefore, the objectives of this study are to (1) propose a distributed and dynamic erosion-type NPS pollution model suitable for the hilly and gully region of Loess Plateau, (2) estimate spatiotemporal distributions of erosion-type NPS pollution in the Majiagou watershed, and (3) evaluate subtractive effects of returning farmland on loss of soil nitrogen and phosphorus. Results may provide scientific reference for the quantitative estimation of NPS pollution load and decision making of NPS pollution control in the Loess Plateau.

## Material and methods

### Study area

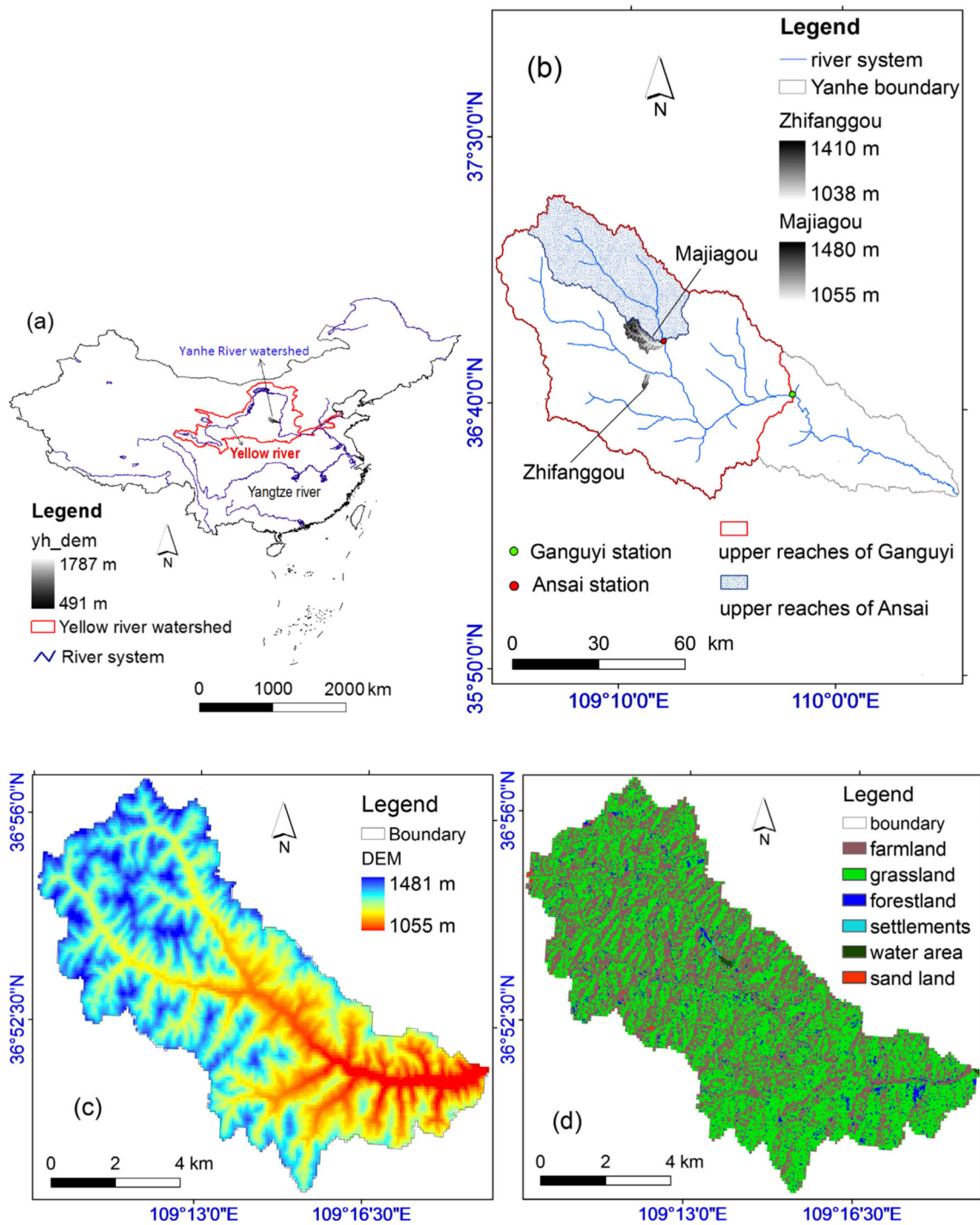
Majiagou river, which is located in the western Ansai County of Yanan city, Northern Shaanxi Province, is one of the first grade tributaries of the Yanhe River. It flows into the Yanhe River in Ansai County from the northwest to the southeast; the main channel is about 17.4 km in length, and the average gully slope is about 6.5‰ (Chen et al. 2011). The watershed, which belongs to the severe soil erosion area (Fu et al. 2010), is a typical hilly and gully region of the Loess Plateau (109°9'30"~109°18'59"E longitude and 36°49'42"~36°56'42"N latitude); the total catchment area is 73.83 km<sup>2</sup> (Jia et al. 2014). Before the implementation of returning farmland policy in 1997, the soil erosion modulus in the Majiagou watershed reached 8740 t/km<sup>2</sup>/a; the soil erosion area was 72.31 km<sup>2</sup>, which accounted for 98 % of the total area (Dang et al. 2013). After the implementation of returning farmland for nearly 10 years, the soil erosion modulus of the Majiagou watershed in 2008 decreased to 5700 t/km<sup>2</sup>/a (Wu et al. 2010).

### Chinese returning farmland policy

For a long time, blind deforestation and unreasonable reclamation in China result in frequent occurrence of serious soil erosion, blown sand hazard, floods, droughts, sandstorms, and other natural disasters, which has seriously affected people's production and life, and also threatened the ecological security. In order to fundamentally improve the sharp deterioration of ecological environment, in 1999, Chinese government determined to first pilot the returning farmland to forest (grass) project in three provinces including Sichuan, Shaanxi, and Gansu, which precluded to the returning farmland project of China. In 2002, the Western Development Office of State Council held a conference to fully implement the project. The returning farmland to forest/grass is a major ecological project which has the biggest investment, the widest involved aspects, and the highest participation of the masses in China and even the world. In other words, the returning farmland to forest/grass project takes the ecological environment protection as starting point to restore vegetation by stopping farming (the cultivated land with serious soil erosion, desertification, salinization, desertification, and low and unstable grain yield) step by step and planting tree/grass according to local conditions. In this study, the Majiagou watershed in the hilly and gully region of the Loess Plateau is one of the main implementation areas of the returning farmland policy.

### Environmental database

The data included in this study include digital elevation model (DEM), daily precipitation data, runoff, soil properties, and land use types (Fig. 1; Table 1).



**Fig. 1** The study area. **a** The relative location between the Yanhe River watershed and the Yellow River/Yellow River basin of China. **(b)** The geographical location sketch of the upper reaches of Ganguyi hydrological station, upper reaches of Ansai hydrological station, the

Majiagou watershed, and the Zhihanggou watershed in the river system of Yanhe River watershed. **c** Digital elevation model (DEM), longitude and latitude coordinates of the study area. **d** Reclassified land use types of the Majiagou watershed

**Dynamic model of sediment yield**

*Model establishment*

The loss of adsorbed NPS pollutants is associated with the sediment yield process in a watershed, so the dynamic

modeling studies on the processes of sediment yield are very critical and necessary for accurately estimating annual adsorbed NPS load. Previous study showed that the shallow gully erosion (ephemeral gully erosion) was one of the main ways of soil erosion in the middle and lower part of the Chinese Loess Plateau sloping land (Li et al.

**Table 1** Descriptions and sources of the environmental database for the Majiagou watershed

Data layer	Format	Description	Source
DEM	Raster	30-m spatial resolution DEM data of the Majiagou watershed	Computer Network Information Center, Chinese Academy of Sciences <a href="http://datamirror.csdb.cn/index.jsp">http://datamirror.csdb.cn/index.jsp</a>
Land use	Raster	Farmland, grassland, forest land, residential area, water area, sand (30-m spatial resolution)	Data Center for Cold and Arid Region Sciences <a href="http://westdc.westgis.ac.cn/">http://westdc.westgis.ac.cn/</a>
Precipitation	DBF	Daily values in Ansai and Yanan rain-gauge stations (1957–2012)	China Meteorological Data Sharing Service Network <a href="http://www.cdc.sciencedata.cn">http://www.cdc.sciencedata.cn</a>
Soil	DBF	Physical and chemical properties	National Science and Technology Infrastructure Center—Data Sharing Infrastructure of Earth System Science ( <a href="http://loess.geodata.cn/">http://loess.geodata.cn/</a> )
Runoff and sediment	Excel	Time series of daily observed values in Ganguyi hydrological stations (1954–1989)	

2009); therefore, based on the CSLE equation (Cheng et al. 2009; Zhu et al. 2012), the soil erosion model considering the shallow gully erosion factor was established to quantitatively evaluate sediment yield of the Majiagou watershed; its expression is as follows:

$$Q = A \times R \times K \times L \times S \times G \times B \times E \times T \quad (1)$$

where  $Q$  is the annual soil erosion modulus, ( $t/hm^2 \cdot a$ );  $A$  is the catchment area,  $hm^2$ ;  $R$  is the rainfall erosivity factor, ( $MJ \cdot mm/hm^2 \cdot h \cdot a$ );  $K$  is the soil erodibility factor, ( $t \cdot hm^2 \cdot h/hm^2 \cdot MJ \cdot mm$ );  $L$  is the slope length factor;  $S$  is the slope gradient factor;  $G$  is the shallow gully erosion factor;  $B$  is the biological measure factor;  $E$  is the engineering measure factor;  $T$  is the tillage measure factor; and  $L$ ,  $S$ ,  $G$ ,  $B$ ,  $E$ , and  $T$  are all dimensionless.

As not all eroded soil is actually delivered to the basin outlet, based on the CSLE equation and the sediment delivery ratio (SDR,  $\lambda$ ) factor, the annual average sediment yield can be estimated by the following Eq. (2),

$$Q_s = A \times R \times K \times L \times S \times G \times B \times E \times T \times \lambda \quad (2)$$

Because the Eq. (2) is the average sediment transport amount over a long time period, it is not a dynamic changing process. On the basis of dynamic estimation methods of NPS pollution at watershed scales studied by Long et al. (2008) and Liu (2009), the rainfall erosivity factor and the sediment delivery ratio factor affected by the hydrological factors were designed into the hydrological dynamic factor; the biological measures, engineering measures, tillage measures, and the sediment delivery ratio factor affected by the land management factors were designed for the dynamic influencing factor of human activities, so the dynamic model of sediment yield suitable for hilly and gully region of the Loess Plateau was put forward. The formula is as follows:

$$Q_{s,i} = A \times K \times LS \times G \times (R_i \times \lambda_{q,i}) \times (B_i \times E_i \times T_i \times \lambda_{m,i}) \quad (3)$$

where subscript  $i$  represents the  $i$ -th year, supposing that the factor  $\lambda_i$  can be divided approximately into the product of  $\lambda_{q,i}$  related only to rainfall-runoff conditions and  $\lambda_{m,i}$  related only to land management measures.

Impacts of hydrological factors on sediment transport are mainly manifested in the moving action of sediment from erosion occurrence to the river course by rainfall runoff.  $\lambda_{q,i}$  can be estimated by the sediment transport capacity that is widely used in hillslope and fluvial geomorphology (Prosser and Rustomji 2000). The widely used equation is as follows:

$$TC = k \times q^a \times s^b \quad (4)$$

where  $TC$  is the average sediment transport capacity per unit width of slope ( $kg \cdot m^{-3}$ );  $q$  is the average runoff amount per unit width ( $m^{-3}$ );  $k$ ,  $a$ , and  $b$  are coefficients; and  $s$  is the surface gradient factor. Those coefficients and the surface gradient factor are constants when there are no changes in underlying surfaces of runoff. Prosser and Rustomji (2000) reported a median value of 1.4 for  $a$  based on an extensive review of previous experiments. According to the definition for  $\lambda_{q,i}$  and general situation of the study area,  $\lambda_{q,i}$  can be supposed as follows:

$$\frac{\lambda_{q,i}}{\lambda_q} = \frac{TC_i}{TC} = \left( \frac{q_i}{q} \right)^{1.4} \quad (5)$$

Impacts of human land management activities on sediment transport are mainly demonstrated in water, and sediment reduction affects of all kinds of water conservation measures. Under the annual changing conditions of  $\lambda_{m,i}$ ,  $B$ ,  $E$ , and  $T$ , the dynamic influencing factor of human activities was introduced and defined as follows:

$$\alpha_i = \frac{B_i \times E_i \times T_i \times \lambda_{m,i}}{B \times E \times T \times \lambda_m} \quad (6)$$

In order to quantitatively determine impacts of land management activities on sediment yield, according to Xu et al.

(2012) research results of runoff and sediment characteristics from 1956 to 2009 in the Yanhe River watershed, the year of 1956–1969 is a sporadic governance stage with little intervention of human activities; the intervention is only 0.9–3.9 % and fluctuations of runoff and sediment mainly are caused by rainfall changes; after this stage, human land management activities gradually became the main driving force for changes of runoff and sediment; returning farmland was the main factor leading to fluctuations of runoff and sediment (Gao et al. 2010; Li et al. 2011). So, this study took the year of 1956–1969 as a baseline period, and the year after the 1970s could be defined as the governance period. Based on the related literatures (Wang and Fan 2002), respectively, the fitting relationship expression ( $R^2=0.912$ ) of runoff and sediment in Ganguyi hydrological station in 1954–1969 was taken as the denominator, and the fitting relationship expression ( $R^2=0.857$ ) of runoff and sediment in 1954–1989 as the molecular, then the ratio of sediment during the governance period and the base period was defined as the dynamic influencing factor of human activities reflecting effects of human land management activities on yearly changes of the watershed sediment transport; the expression is follows:

$$\alpha_i = \frac{0.449x_i - 5062.6}{0.4436x_i - 4559.9} \tag{7}$$

where  $x_i$  represents the runoff amount in the  $i$ -th year ( $10^4 \text{ m}^3$ ), and  $n$  is the number of years. In summary, the dynamic model of erosion and sediment yield was determined as follows:

$$Q_{s,i} = \alpha_i \times \left(\frac{q_i}{q}\right)^{1.4} \times R_i \times \lambda \times A \times K \times LS \times G \times B \times E \times T \tag{8}$$

Where  $\lambda = \lambda_q \cdot \lambda_m$  represents the average sediment delivery ratio;  $B$ ,  $E$ , and  $T$  represent the average value of the watershed for many years.

*Determination of model factors*

In this study, a modified Richardson daily rain erosivity model (Zhang et al. 2003) is used to calculate spatial and temporal distributions of  $R$  factor; the  $K$  value and its spatial distribution is calculated by the modified method of soil erodibility

proposed by Zhang et al. (2007a); spatial distributions of the topography factor ( $LS$ ) are respectively calculated using the formulas put forward by Wischmeier and Smith (1978), McCool et al. (1987) and Liu et al. (2010); the shallow gully erosion factor is determined by the previous research results (Jiang et al. 2008); the existing research results of the biological measure factor, the engineering measure factor, and tillage practice factor in the Loess Plateau (Xie 2008) are used to spatially calculate the  $BET$  factor; the  $SDR$  factor ( $\lambda$ ) is given as a watershed average (Zhu et al. 2007). Based on spatial variations of different land uses and soil types in the Majiagou watershed, the average values and spatial distribution of the related factors in this study are shown in Table 2 and Fig. 2.

**Erosion-type NPS pollution model**

Erosion-type NPS pollution is the pollution process of coupling eroded soil into the receiving water based on the migration of soil erosion (Shi 1997). In this study, based on the pollution load models used by Shi et al. (2002), Xue et al. (2005), and Meng (2005), the dynamic model of erosion-type NPS pollution was established as follows:

$$L_{n,p,i} = Q_{s,i} \times C_{n,p} \times \eta_{n,p} \tag{9}$$

where  $L_{n,p,i}$  is the total nitrogen (TN) and total phosphorus (TP) pollution load in the  $i$ -th year (t/a);  $Q_{s,i}$  is the annual sediment yield amount (t/a);  $C_{n,p}$  is the background content of TN and TP in topsoil ( $\text{g kg}^{-1}$ );  $\eta_{n,p}$  is the enrichment ratio of TN and TP in sediments (-). Because the study area is located in the hilly and gully region of Loess Plateau, soil nutrient content is generally low due to serious soil loss. Based on the study results of Han et al. (2006) in six tributaries of the Yellow River including Huangfuchuan River, Kuye River, Wuding river, Weihe, Jinghe, and Luohe, the soil TN and TP background contents were respectively determined as 400 and 410 g/t, and the enrichment ratios of TN and TP were measured as 0.671 and 0.871.

**Model validation and sensitivity analysis**

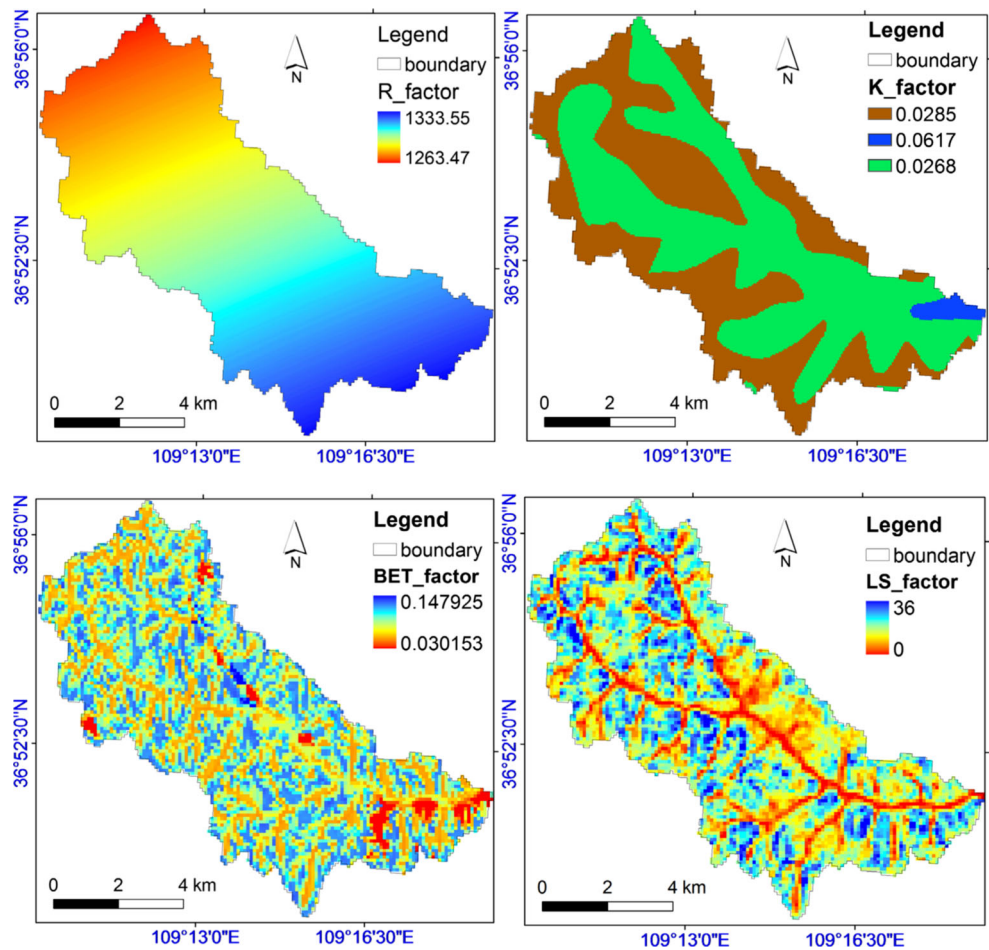
Firstly, the existing simulation result of the annual average erosion modulus from 2001 to 2010 in the Yanhe River watershed is  $5812.28 \text{ t/km}^2/\text{a}$  (Li and Zheng 2012); it has little difference with the average simulated value of  $5803.23 \text{ t/km}^2/$

**Table 2** The average value of factors for the dynamic sediment yield model

Parameter	$K$	$LS$ (Wang 2007)	$G$	$B$	$E$	$T$	$\lambda$ (Zhu et al. 2007)
Value	0.0542	12.9	$G = 1 + (\alpha - \theta_c) \frac{1.003(RI_{30})^{0.103} - 1}{30 - \theta_c}$	0.1562	0.497	0.712	0.92

Notes for the equation:  $G$  is the shallow gully erosion factor;  $\alpha$  is the ground surface slope ( $^\circ$ );  $\theta_c$  is the critical slope gradient ( $15^\circ$ );  $R$  is the individual rainfall (mm);  $I_{30}$  is the maximum 30 min rain intensity (mm/min); when the ground surface slope is less than  $15^\circ$ ,  $G = 1$

**Fig. 2** Spatial distributions of annual average *R* factor, *K* factor, *LS* factor, and *BET* factor in the Majiagou watershed



a from 1995 to 2012 in this study; the relative error is  $-0.16\%$ ; the annual erosion modulus in 2008 is  $2485.46 \text{ t/km}^2/\text{a}$ ; the calculated value in 2008 is  $2278.2 \text{ t/km}^2/\text{a}$ ; the relative error is  $8.34\%$ . Secondly, the observed values of sediment in Ganguyi hydrological station from 1961 to 2008 and the simulated values in this study both showed a decreasing trend although there were slight fluctuations in individual years (Ren et al. 2012); it indicates that the overall changing trends of sediment yield in the study area are consistent with the background of returning farmland. Besides, due to lack of measured sediment data of the Majiagou watershed, the measured sediment data from 1981 to 2010 in Ansai hydrological station (Fig. 1b) was used to estimate the average sediment transport modulus of the watershed by the hydrological analogy method; the estimated value is  $5222.7 \text{ t/km}^2/\text{a}$ ; the average simulated value from 1995 to 2012 in this study is  $5721.9 \text{ t/km}^2/\text{a}$ ; the relative

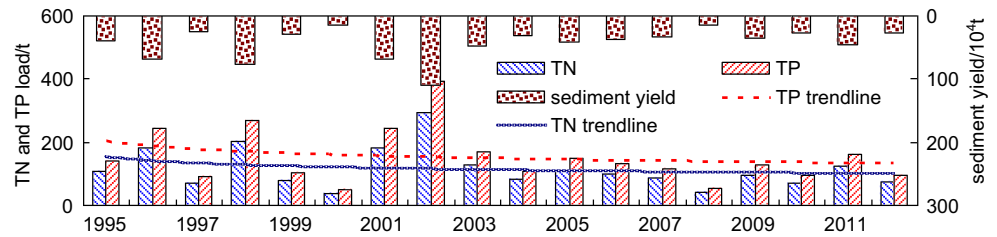
error is  $8.7\%$ . Thirdly, taking into account the similarity of the underlying surface and soil nutrients between the Majiagou watershed (Fig. 1b) and the Zhifanggou watershed (Fig. 1b) in loess hilly and gully region, taking TN load as an example, the research results of annual average TN loss rules in the Zhifanggou watershed by Zhang and Shao (2000) were used to verify the simulation results. Table 3 shows that the annual average TN loss modulus in the Zhifanggou watershed is between  $0.81$  and  $1.98 \text{ t/km}^2$ ; the average value is  $1.32 \text{ t/km}^2$ ; it is covered the TN loss level of  $1.59 \text{ t/km}^2$  in the Majiagou watershed; the relative error is  $-20.5\%$ . The above results demonstrate that the sediment yield and NPS pollution model have scientific rationality and good performance. The model can be used for erosion-type NPS pollution load estimation.

In this study, the integrated dynamic model of erosion-type NPS pollution includes many influential factors including the

**Table 3** Comparative verification of average erosion-type total nitrogen load between the Majiagou watershed and the Zhifanggou watershed

Basin	Zhifanggou watershed			Majiagou watershed
	20 %	40 %	60 %	
Vegetation coverage				
Adsorbed TN load modulus( $\text{t/km}^2$ )	1.98	1.18	0.81	1.59

**Fig. 3** Variations of adsorbed TN, TP, and sediment yield in the Majiagou watershed from 1995 to 2012



catchment area, the rainfall erosivity factor, the soil erodibility factor, the slope length factor, the slope gradient factor, the shallow gully erosion factor, the biological measure factor, the engineering measure factor, the tillage measure factor, the sediment delivery ratio, the runoff amount, the background content of TN and TP in topsoil, and the enrichment ratio of TN and TP in sediments. These meteorological, hydrological, and underlying surface factors are all important for the spatio-temporal characteristics of erosion-type NPS pollution in the loess hilly and gully region; however, sensitivity analysis results in accordance with model and regional characteristics demonstrate that the annual rainfall erosivity factor, the annual runoff amount, and the annual sediment delivery ratio factor related to rainfall runoff and land management are the three foremost sensitivity factors in the established erosion-type NPS pollution model.

the Majiagou watershed; they have similar fluctuations with sediment yield. The overall trend of the NPS pollution in the river basin is gradually decreasing year by year. In the late 1990s, soil erosion has not been effectively controlled in the Majiagou watershed; the corresponding erosion-type pollution is serious. With the continuous increase of watershed management efforts, the sediment transport volume is decreasing year by year, and the benefits of reducing water and sediment are becoming more and more prominent. Although TN and TP pollution loads are bigger than normal due to the individual wet year, the overall shows an obvious downward trend; the average TN and TP pollution loads from 2009 to 2012 were respectively 90.65 and 120.61 t/a; they are reduced by about 35.4 % compared with the first four years (1995–1998); the implementation of water and soil conservation projects played a key role for NPS pollution control.

**Results and discussion**

**Temporal distributions of NPS pollution load**

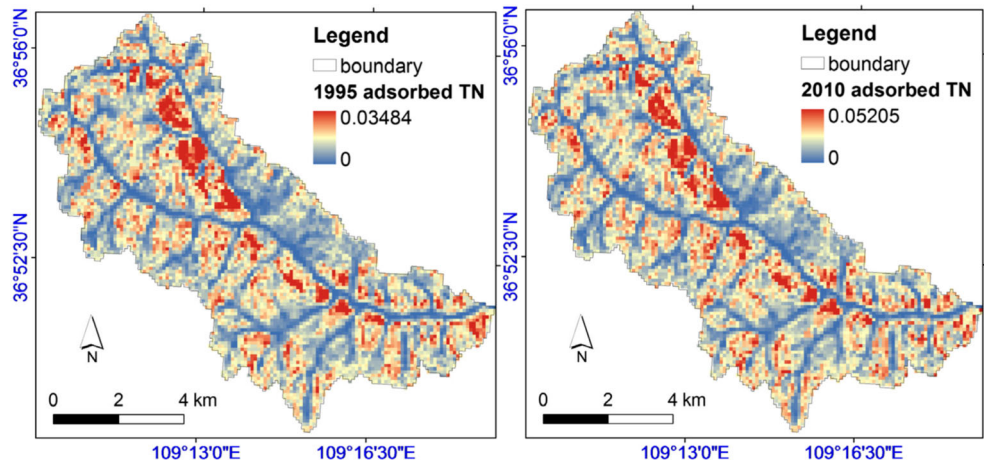
TN and TP in the soil are adsorbed by fine sediment particles and then carried into the receiving waters; after decomposition, they may cause adsorbed NPS pollution and pollute natural waters. Therefore, it is very important to quantitatively evaluate erosion-type NPS pollution for the protection of water ecological environment of the Loess Plateau.

Figure 3 shows that the annual trends of TN and TP load are basically consistent with the sediment transport amount in

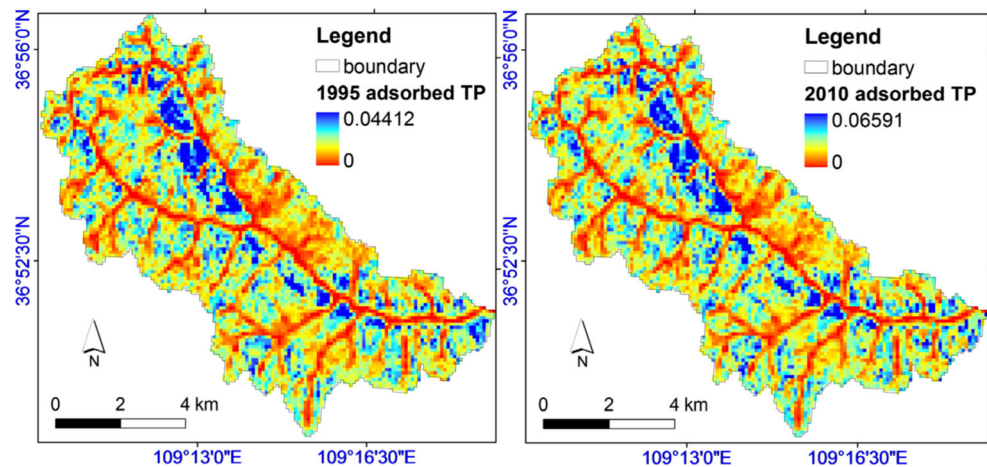
**Spatial distributions of NPS pollution load**

Figures 4 and 5 show spatial distribution of NPS nitrogen and phosphorus loss load modulus in the Majiagou watershed in 1995 and 2010. It can be seen that spatial distributions of NPS nitrogen and phosphorus loss are similar to spatial distributions of sediment transport modulus; the peak region of TN and TP load mainly occurs along the main river banks of the whole Majiagou watershed from northeast to southeast and gradually decreases to the left and right river banks respectively. The difference of TN and TP loss in two typical years mainly depends on the distribution pattern of soil erosion in

**Fig. 4** Spatial distribution of NPS TN loss modulus of Majiagou watershed in 1995 and 2010 (t/hm<sup>2</sup>·a)



**Fig. 5** Spatial distribution of NPS TP loss modulus of the Majiagou watershed in 1995 and 2010 ( $t/hm^2 \cdot a$ )



the corresponding years. The results indicate that the loss of TN and TP is closely related to soil erosion. Therefore, it is very important to retard soil erosion in the loess hilly and gully region, and to subtractive NPS pollution load, and to improve water environment quality by strengthening the research on the mechanism of soil erosion and carrying out the construction of soil and water conservation projects.

Spatial distributions of NPS pollution load and sediment yield are closely related to land use types of the Majiagou watershed. Figure 6 shows area ratio of reclassified land use of the Majiagou watershed in 1995 and 2010. It can be seen that area of slope cropland and grassland represents a significant share; it accounts for more than 95 % of the total area; it is the main source of soil and water loss in the Majiagou watershed. Although the returning farmland project has been implemented in the Majiagou watershed since 1999, a lot of farming land changed into waste grassland; soil and water conservation measures did not catch up with in time; the soil erosion in this watershed was still serious. The field survey results indicate that the slope-cultivated land within the basin accounted for 73.46 % of the total area of farmland; it is mainly distributed on both sides of the river; because the minority slope farmland did not execute returning farmland policy, farmland is still one of the main sources of soil and water loss. A large amount of farmland was also developed to orchard land for apple, but they did not implement soil and water conservation measures; soil and water loss was still serious. Therefore, strengthening agricultural land management can fundamentally solve the problem of soil and water loss. In addition, there are some contiguous returning farmlands in

the Majiagou watershed, especially for the gully head position; it needs to adopt banned measures to governance.

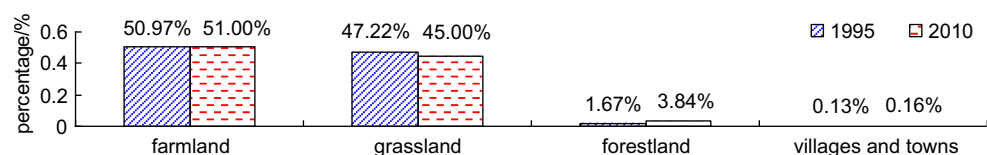
### Relationship between soil erosion and erosion-type NPS pollution

Soil erosion and NPS pollution are inseparable symbiotic phenomena; soil erosion is the major occurrence form especially in agricultural NPS pollution of the loess hilly and gully region in China, so soil erosion is an important NPS pollution. The sediment caused by the soil erosion is not only a kind of non-point source pollution but also the pollutants carried by sediment (especially fine sand) may bring a negative impact on water quality of the receiving waters. At the same time, not all of the sediments will enter into receiving waters; there will be a variety of losses in the transport process of sediment from erosion happened places to receiving waters; and the relationship between soil erosion and NPS pollution load is also relatively complex, so many scholars have developed a lot of integrated NPS pollution models embedded by sub model of erosion and sediment yield. Because people pay more and more attention to the relationship between soil erosion and NPS pollution, currently, the research method of NPS pollution based on soil loss equation has been developed.

### Control strategies of erosion-type NPS pollution

Throughout the research progress of soil erosion and NPS pollution, regardless of the proposal of the concept or the development of research methods and means, soil erosion

**Fig. 6** Area ratio of reclassified land use of the Majiagou watershed in 1995 and 2010





may be earlier than NPS pollution. China's soil and water conservation measures have been carried out for many years and have made plentiful and substantial achievements; rich experiences on prevention and control of soil loss have been accumulated, and massive soil erosion prevention measures have been formed, which play a positive role in aspects of controlling soil erosion (Li et al. 1999). Because of the comparatively significant correlation between soil erosion and NPS pollution, these measures have positive effects on the control of NPS pollution. Therefore, the research of soil and water conservation has a certain guiding significance for the planning of NPS pollution control strategies.

Generally, water quality affected by excess runoff, sediment, and nutrient losses from agricultural areas can be improved by implementing best management practices (BMPs) that control the movement of NPS pollutant loads (Maringanti et al. 2009). BMPs are effective in reducing the transport of agricultural nonpoint source pollutants to receiving water bodies (Wang et al. 2009). The effectiveness is mainly manifested in stagnating runoff, depositing sediment, and controlling non-point source pollution. NPS pollution prevention and control can be divided into three stages as follows: source reduction, process control, and terminal treatment (Wu and Ma 2015). Based on the meteorological and underlying surface characteristics of Loess Plateau, the control measures of erosion-type NPS pollution in the Chinese Loess Plateau can be summarized as such contour planting technology, terracing, warping dam, returning farmland to forest (grass), seasonal ponds, vegetative filter strips, riparian buffer zone, diversion and storage facilities, green agriculture, etc.

## Conclusions

In order to reveal the erosion-type NPS pollution process in a small watershed of Chinese Loess Plateau, a dynamic and distributed model of erosion-type NPS pollution based on the CSLE equation was established to investigate the distributed coupling responses of sediment yield and erosion-type NPS pollution from 1995 to 2012. Validation results indicate that the established model has practical application value and can be used to forecast annual erosion-type NPS pollution load. Main results can be drawn as follows:

1. Since the extensive development of the returning farmland from 1997, the erosion-type NPS TN and TP load showed an overall downward trend; the average TN and TP load modulus in the last four years (2009–2012) were 1.23 and 1.63 t/km<sup>2</sup>/a, respectively, which were both decreased by about 35.4 % compared with the initial period of treatment (1995–1998). The implementation of water and soil conservation measures such as returning farmland to forest or grassland is the key to control NPS

pollution, but the pollution situation is still severe, and the severe soil erosion is the main reason for the high TN and TP load in the study area.

2. The spatial distribution patterns of TN and TP loss were basically consistent with sediment yield, both sides of the river are the peak areas of TN and TP loss load, and the closer the distance to the river, the greater the loss of sediment and nutrients. The water and soil conservation projects at present have obvious mitigation effects on micro and mild soil erosion, but the effects on the higher erosion intensity are not ideal. It is necessary to further intensify the construction of soil and water conservation projects. Therefore, the soil and water conservation measures such as returning sloping farmland to grassland or forestland, closing hillsides to facilitate afforestation, building warping dam and fish scale pits, etc. are of great significance for reduction of erosion-type NPS pollution and improvement of water environment quality.

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