Control Effects of Different Agronomic Practices on Runoff Losses of Different Phosphorus Forms from Sloping Cropland along Chaohu Lake: A Postprint

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Abstract

To determine the impacts of different agronomic measures on ecological protection and water environment management in sloping farmlands along Chaohu Lake, a long-term fixed monitoring station for agricultural non-point source pollution was used as the platform to continuously monitor soil and water losses and various phosphorus forms transported via surface runoff under four agronomic measures—conventional tillage (CK), hedgerow (daylily, PH), hedgerow plus straw mulching (PHS), and contour ridge tillage (CR)—for two consecutive years from 2014 to 2015. The results showed that compared with conventional tillage, PH, PHS, and CR effectively reduced runoff and sediment yield ($P<0.05$), with the reduction effects following the order: PHS>PH>CR. Compared with CK, PH, PHS, and CR reduced runoff loss by 23.5%, 36.5%, and 19.7%, and soil loss by 29.5%, 45.2%, and 26.3%, respectively, demonstrating significant soil and water conservation benefits. Under CK conditions, the total phosphorus (TP) concentration in runoff was 0.612–1.220 mg · L ^{1}, of which particulate phosphorus (PP) accounted for 71.5%–81.7% of total phosphorus, constituting the primary form of phosphorus loss via surface runoff. In dissolved total phosphorus (DTP), dissolved orthophosphate (D-Ortho-P) constituted a large proportion of 87.4%–90.7%, while dissolved organic phosphorus (DOP) accounted for a small proportion of only 9.3%–12.6%. Compared with CK, PHS, PH, and CR significantly reduced the concentrations of PP and TP in runoff ($P<0.05$), but increased the concentrations of DTP and D-Ortho-P to varying degrees, while exerting no significant influence on DOP concentration ($P>0.05$). Under CK conditions, the annual phosphorus loss load averaged 0.706 kg · hm ^{2}, accounting for 0.98% of the phosphorus application rate for the crop that year. Compared with the CK treatment, the annual phosphorus loss load under PH, PHS, and CR treatments was reduced by 38.4%, 53.8%, and 33.4%, respectively ($P<0.05$), and their control efficacy was primarily realized through reducing runoff volume and decreasing the PP concentration in runoff. In summary, hedgerow (daylily), hedgerow plus straw mulching, and contour ridge tillage are effective measures for controlling soil, water, and phosphorus runoff losses from sloping farmlands along Chaohu Lake, with hedgerow combined with straw mulching demonstrating the greatest efficacy. This study can provide a scientific basis for controlling soil erosion and non-point source pollution in sloping farmlands within the Chaohu Lake basin.

Full Text

Introduction

Agricultural non-point source pollution represents a primary cause of water quality degradation [1]. To mitigate this issue, Yang et al. [2] proposed a theoretical and technical framework of "source reduction—process interception—nutrient reuse—ecological restoration," with source control being the most effective and fundamental strategy for preventing agricultural non-point source pollution. Phosphorus (P) is not only one of the three essential macronutrients for plant growth and development but also a critical limiting factor for eutrophication in water bodies [3-5]. Numerous studies have demonstrated that substantial P export from agricultural soils constitutes a major contributor to agricultural non-point source pollution. In natural and wastewater systems, phosphorus exists in various forms including orthophosphate, condensed phosphates, organic phosphorus, and particulate phosphorus. Different P forms contribute differently to algal growth: dissolved orthophosphate phosphorus (D-Ortho-P) can be directly assimilated by algae and bacteria, and its concentration increase directly intensifies eutrophication [6]; however, D-Ortho-P represents only a small fraction of total phosphorus (TP). Particulate phosphorus (PP) and dissolved organic phosphorus (DOP) are typically not directly available to algae, yet they constitute a considerable proportion of TP, with approximately 70% potentially convertible to bioavailable phosphorus through extracellular enzymatic degradation [7]. Therefore, systematic investigation of the characteristics of different P forms lost via runoff from agricultural soils is crucial for source control of agricultural non-point source pollution. Chaohu Lake ranks among the most severely eutrophic freshwater lakes in China. In recent years, government agencies and numerous scholars have invested substantial resources in remediation projects and research, implementing various countermeasures that have achieved notable results. Nevertheless, the eutrophication trend in Chaohu Lake has not been fundamentally reversed, with summer cyanobacterial blooms remaining common in the western lake area. Consequently, eutrophication has become a "bottleneck" constraining regional economic and social sustainable development. Current research on P loss from farmland in this watershed has primarily focused on rice-wheat (or rice-rapeseed) rotation systems [5,8], with limited reports on sloping croplands experiencing severe soil erosion. Thus, further research in this area is urgently needed.

Previous studies have shown that agronomic practices altering microtopography (contour tillage, furrow-ridge planting, etc.), increasing surface cover (straw mulching, plastic film mulching, etc.), modifying soil physical properties (reduced or no-tillage), and hedgerow technology can effectively reduce and prevent soil erosion while controlling nutrient loss from farmland [9-16]. Hedgerow technology demonstrates excellent performance in soil and water conservation, nutrient loss control, and economic benefits. Contour ridging improves field microclimate, effectively increases soil temperature, intercepts runoff, reduces soil and nutrient loss, and achieves water harvesting, moisture retention, and warming effects. Additionally, straw return, as a critical component of low-carbon and organic agriculture, positively impacts soil organic matter content, fertility improvement, and reduction of farmland nutrient loss. However, the effectiveness of hedgerows, contour ridging, and straw return in conserving soil and water and reducing nutrient loss is influenced by comprehensive factors including climatic conditions, topographic characteristics, soil properties, and hedgerow features [12,14-15]. The efficacy of these agronomic measures in controlling P loss from sloping croplands in the Chaohu Lake watershed remains unclear. Therefore, this study utilized a long-term fixed observation station for agricultural non-point source pollution along Chaohu Lake to investigate the control effects of three agronomic measures—hedgerow (*Hemerocallis citrina* Baroni), hedgerow with straw mulching, and contour ridging—on soil, water, and different P forms in runoff under natural rainfall conditions in a wheat (*Triticum aestivum* L.)-sesame (*Sesamum indicum* L.) rotation system, aiming to provide scientific evidence for agricultural non-point source pollution control in the Chaohu Lake watershed.

1.1 Study Area Description

The experiment was conducted at Yingxia Village, Changlinhe Town, Feidong County, Anhui Province (117°27 E, 31°41 N), approximately 1.5 km from Chaohu Lake. This region belongs to the Jianghuai low hilly area, located in the eastern part of the Mesozoic-Cenozoic Hefei Depression, with a landscape dominated by low hills and undulating plains. The study area features a north subtropical monsoon climate with an average annual temperature of 15.5°C and annual precipitation of 940–1,000 mm, concentrated mainly in summer (June–August). The frost-free period ranges from 224 to 252 days. The main crops include rice (*Oryza sativa* L.), winter wheat, maize (*Zea mays* L.), sesame, rapeseed (*Brassica napus* L.), and cotton (*Anemone vitifolia* Buch.). The experimental soil was a yellow-brown soil developed from Xiashu loess parent material. Basic physicochemical properties of the 0–20 cm soil layer before the experiment were: pH 5.95, bulk density 1.23 g · cm^{3}, organic matter 18.22 g · kg^{1}, total nitrogen 1.08 g · kg^{1}, alkali-hydrolyzable nitrogen 87.12 mg · kg^{1}, total phosphorus 0.35 g · kg^{1}, Olsen-P 9.62 mg · kg^{1}, slowly available potassium 624.78 mg · kg^{1}, and available potassium 156.37 mg · kg^{1}.

1.2 Experimental Design

Four treatments were established: 1) conventional downslope tillage (CK); 2) hedgerow of *Hemerocallis citrina* (PH); 3) hedgerow with straw mulching (PHS); and 4) contour ridging (CR). The experiment employed a randomized complete block design with three replications. Correspondingly, twelve runoff plots were established, each oriented north-high-south-low with a 6° slope and an area of 24 m^2 (8 m × 3 m). Each plot was bordered by 25-cm-thick brick-cement barriers, with 30 cm buried underground and 25 cm aboveground to prevent leakage between plots. A runoff collection tank was installed on the southern side of each plot to collect water and sediment samples after rainfall events. The tanks were 1 m deep below ground surface, with graduated scales on the walls for water volume measurement. Asbestos tiles covered the tanks to prevent rainwater and dust entry and to protect against accidental falls. A standard rain gauge was installed near the experimental area for precipitation monitoring.

The PH treatment utilized *Hemerocallis citrina*, a perennial herbaceous plant from the Liliaceae family with strong drought resistance, tolerance to poor soils and low temperatures, and disease resistance. Its well-developed root system, with fine roots extending up to 50 cm, provides excellent soil conservation and runoff interception capabilities. Additionally, it offers economic value as its flowers are edible and medicinal. The hedgerow was established in June 2008, with three strips per plot, each consisting of two rows spaced 20 cm apart within and between plants, with 280 cm between strips.

The PHS treatment involved applying straw mulch from the previous crop between hedgerow strips at a rate of 3,000 kg · hm ^{2}, with straw cut to 20–30 cm lengths.

The CR treatment involved constructing six contour terraces within each plot, with ridges 1 m wide, 0.14 m high, and spaced 0.4 m apart.

All plots except the hedgerow strips were cropped with a sesame-winter wheat rotation following local planting methods and densities. Fertilizer application rates were: sesame season—N 150 kg · hm ^{2}, P O 90 kg · hm ^{2}, K O 120 kg · hm ^{2}; wheat season—N 180 kg · hm ^{2}, P O 75 kg · hm ^{2}, K O 90 kg · hm ^{2}. Sixty percent of nitrogen (urea) was applied as basal fertilizer and 40% as topdressing (sesame at budding stage, wheat at jointing stage). All phosphorus (superphosphate) and potassium (potassium chloride) were applied as basal fertilizers.

1.3 Sample Collection and Analysis

During 2014–2015, runoff volume was measured by recording water levels in collection tanks after each rainfall event that generated runoff. Mixed water-sediment samples were collected from multiple points in each tank, combined in a clean bucket, and 1 L of water sample was taken. The tanks were then cleaned for subsequent events. Samples were immediately divided into two portions: one for sediment content determination and another for chemical analysis. For sediment measurement, at least 500 mL of mixed sample was allowed to settle for over 20 hours, then filtered, oven-dried at 105°C for 24 hours, cooled, and weighed to calculate sediment yield [17].

Chemical analyses included total phosphorus (TP), dissolved total phosphorus (DTP), and dissolved orthophosphate phosphorus (D-Ortho-P), following the *Water and Wastewater Monitoring Analysis Methods* (4th edition) [18]. TP was determined by potassium persulfate oxidation-molybdate colorimetry. DTP was measured using the same method after filtration through 0.45 m membrane filters. D-Ortho-P was measured directly by molybdate colorimetry after 0.45 m filtration. Particulate phosphorus (PP) and dissolved organic phosphorus (DOP) were calculated by difference: PP = TP − DTP and DOP = DTP − D-Ortho-P.

1.4.1 Calculation of Phosphorus Loss Load per Unit Area (Q)

The average concentration of each phosphorus form in runoff from a single rainfall event represents the mean concentration discharged throughout the runoff process. This average runoff concentration (C) for each phosphorus form in a plot can be calculated using Equation (1):

$$C = \frac{M}{V} = \frac{\int_0^t C(t) \cdot V(t)\, dt}{\int_0^t V(t)\, dt}$$

where C is the runoff concentration of each phosphorus form (mg · L ^{1}), M is the flux of each phosphorus form (g), V is the runoff flux (L), *C(t)* is the runoff concentration at time t (mg · L ^{1}), *V(t)* is the surface runoff volume at time t (L), and t is rainfall duration.

Phosphorus loss from a single runoff event can be calculated using Equation (2):

$$Q_i = \frac{C_i \cdot V_i}{2,400}$$

where Q is the loss of each phosphorus form from the ith rainfall event, C is the concentration of each phosphorus form in runoff (mg · L ^{1}), and V is the runoff volume from the 24 m² plot (L).

Annual phosphorus loss load represents the cumulative loss from all rainfall events in a year and serves as an important indicator for evaluating soil and water conservation and agricultural non-point source pollution control effectiveness. It can be calculated using Equation (3):

$$Q = \sum_{i=1}^{n} Q_i$$

where Q is the cumulative loss load of each phosphorus form (kg · hm ^{2}) and n is the number of runoff-generating rainfall events per year.

1.4.2 Data Analysis

Data processing and analysis were performed using Microsoft Excel 2007 and SPSS 19.0. Least significant difference (LSD) tests were used for mean separation at the 5% significance level.

2 Results and Analysis

2.1 Runoff and Sediment Production Effects Under Different Agronomic Measures

Five rainfall events generated runoff during the 2014–2015 experimental period: July 4 and July 24, 2014; and June 16, June 26, and August 9, 2015, with precipitation amounts of 89.5 mm, 126.2 mm, 96.2 mm, 78.9 mm, and 48.6 mm, respectively. Annual runoff and sediment yields for each treatment are summarized in Figure 1 [Figure 1: see original paper]. Runoff and sediment production followed the order CK > CR > PH > PHS. ANOVA revealed significant differences between the three agronomic measures and local conventional downslope tillage ($P < 0.05$). Compared with CK, PH reduced surface runoff by 20.4% and 26.5% (averaging 23.5%) and sediment yield by 26.0% and 32.9% (averaging 29.5%). PHS reduced runoff by 33.0% and 39.9% (averaging 36.5%) and sediment by 42.7% and 47.7% (averaging 45.2%). CR reduced runoff by 17.2% and 22.1% (averaging 19.7%) and sediment by 22.8% and 29.7% (averaging 26.3%). These results demonstrate that all three agronomic measures effectively reduced runoff and sediment production in sloping croplands around Chaohu Lake, with effectiveness decreasing in the order: PHS > PH > CR. Comparison of reduction magnitudes indicates that sediment reduction exceeded runoff reduction for all three measures.

2.2 Effects of Different Agronomic Measures on Phosphorus Concentrations in Runoff

Concentrations of TP, DTP, PP, D-Ortho-P, and DOP in runoff from each rainfall event under different agronomic measures are presented in Table 1 . Under conventional downslope tillage, TP concentrations in runoff ranged from 0.612 to 1.220 mg · L ^{1}, all exceeding the Class V surface water quality standard limit of 0.4 mg · L ^{1} (GB3838—2002), indicating that each runoff event from sloping croplands around Chaohu Lake poses a potential threat to nearby water quality. Compared with CK, PHS significantly reduced TP and PP concentrations ($P < 0.05$) by 19.1–33.5% and 43.4–54.9%, respectively. However, PHS significantly increased DTP and D-Ortho-P concentrations ($P < 0.05$) by 33.2–60.3% and 34.8–65.8%, respectively. Similarly, PH significantly reduced TP and PP concentrations compared with CK ($P < 0.05$) by 13.6–24.8% and 26.6–37.2%, respectively, while increasing DTP and D-Ortho-P concentrations, though not significantly ($P > 0.05$). CR reduced TP and PP concentrations by 13.9-19.8% and 22.6-30.1%, respectively. ANOVA indicated significant differences in PP concentrations, with TP concentrations reaching significance in three of five runoff events ($P < 0.05$). DTP and D-Ortho-P concentrations showed slight increases but no significant differences ($P > 0.05$). DOP concentrations were relatively low (0.012-0.044 mg • L ^{1}) and showed no significant differences among treatments. These findings demonstrate that PHS, PH, and CR reduced TP and PP concentrations to varying degrees but increased DTP and D-Ortho-P concentrations, with PHS showing the greatest effects.

2.3 Effects of Different Agronomic Measures on Phosphorus Forms in Runoff

The proportions of different phosphorus forms in runoff are shown in Table 2 . Under conventional tillage, PP accounted for 71.3-81.7% of TP, indicating that particulate matter (0.45 m) transported by runoff serves as the primary carrier for P migration in sloping croplands, with PP being the dominant form of P loss via surface runoff—consistent with previous research [19-20]. Within DTP, D-Ortho-P represented the major fraction (87.4-90.7%), while DOP constituted a minor proportion (9.3-12.6%). The study also found that compared with CK, the three agronomic measures not only effectively reduced PP concentrations ($P < 0.05$) but also significantly decreased the PP/TP ratio ($P < 0.05$), particularly under PHS, where PP/TP decreased to 50.1-55.8%.

2.4 Control Effects of Different Agronomic Measures on Phosphorus Runoff Loss

Due to the combined influence of rainfall conditions and agricultural management practices, phosphorus loss loads fluctuated considerably among individual runoff events. Therefore, annual phosphorus loss load (i.e., flux) provides a more representative indicator and is commonly used to characterize phosphorus loss status in watersheds. Annual loss loads of different phosphorus forms for each treatment are summarized in Table 3 . Under conventional tillage (CK), average annual TP loss load was 0.706 kg • hm ^{2}, equivalent to 0.98% of applied P fertilizer and exceeding the environmentally acceptable P loss threshold of 0.44 kg • hm ^{2} • a ^{1} proposed in previous research [21], further demonstrating that P migration from sloping croplands along Chaohu Lake could threaten nearby water quality. PP, DTP, D-Ortho-P, and DOP accounted for 75.0%, 25.0%, 22.3%, and 2.8% of TP, respectively. Different agronomic measures significantly affected annual TP and PP loss loads ($P < 0.05$), substantially reducing TP and PP transport via surface runoff. Compared with CK, PH, PHS, and CR reduced annual TP loss loads by 38.4%, 53.8%, and 33.4% ($P < 0.05$), and PP by 49.0%, 67.6%, and 41.0% ($P < 0.05$), respectively, while also reducing DTP, D-Ortho-P, and DOP loads to varying degrees. These results demonstrate that hedgerow, hedgerow with straw mulching, and contour ridging can effectively control phosphorus loss from sloping croplands along Chaohu

Lake, with hedgerow plus straw mulching being the most effective.

3 Discussion

3.1 Control Effects of Different Agronomic Measures on Phosphorus Runoff Loss

Literature findings on whether agronomic measures reduce phosphorus concentrations in runoff compared with conventional tillage have been inconsistent. Wang et al. [22] reported that alfalfa-maize intercropping and daylily-maize intercropping increased TP and bioavailable phosphorus concentrations while decreasing PP compared with conventional maize monoculture. In contrast, Zhang et al. [20] found that three-strip contour mulberry with cross-slope tillage significantly reduced TP, PP, and DTP concentrations. This study demonstrated that hedgerow, hedgerow with straw mulching, and contour ridging significantly reduced PP and TP concentrations while increasing DTP and D-Ortho-P concentrations to varying degrees. Phosphorus loss from soil is essentially a process of interaction between surface soil and rainfall/runoff, with runoff phosphorus concentrations depending on both the dilution effect of runoff on surface soil phosphorus and the interaction between runoff and phosphorus during downslope transport. Under this study' s conditions, the three agronomic measures increased DTP and D-Ortho-P concentrations primarily by reducing runoff velocity, which intensified interaction between runoff and surface soil, thereby increasing the amount of TDP and D-Ortho-P dissolved and desorbed per unit runoff. Additionally, long-term straw return (including returned straw and cut hedgerow biomass) increased soil phosphorus reserves and enhanced soil P supply capacity [23], while organic acids from straw decomposition may have increased soil phosphorus mobility and facilitated P transport in soil [24]. In contrast, PP content is mainly influenced by raindrop splash and runoff erosion. The three agronomic measures significantly reduced runoff and sediment, weakening erosion of surface soil PP by rainfall-runoff processes and consequently reducing PP content per unit runoff.

This study showed that compared with conventional tillage, all three agronomic measures significantly reduced TP loss loads, indicating effective control of phosphorus migration from sloping croplands—consistent with previous reports [13-16,25]. For example, in 20° purple soil sloping croplands in Zigui County, Three Gorges Reservoir area, vetiver hedgerow with wheat-maize rotation reduced annual TP loss to 20.51 $\mathrm{mg \cdot m^{2}}$, only 56.95% of the control [16]. In the Danjiangkou Reservoir area, daylily hedgerows reduced runoff phosphorus by 78.3% compared with the control [25]. In brown soil sloping croplands in Liaoning Province, ridging reduced runoff phosphorus loss by 34.9% and sediment-associated phosphorus by 12.1% compared with the control [14]. In the Chaohu Lake watershed, straw mulching in upland fields under rice-upland rotation reduced TP loss by 32.3% compared with the control [13]. Soil phosphorus loss load via surface runoff is determined by both runoff volume and TP concentration, with TP concentration comprising DTP and PP. Although the three agronomic measures increased DTP concentrations to varying degrees, PP represents the dominant form of phosphorus loss via runoff from sloping lands. The reduction in PP by these measures far exceeded their impact on DTP, thereby decreasing overall TP concentration. Considering runoff volume, sediment yield, and phosphorus concentrations, the control effects on phosphorus output were achieved primarily through reducing runoff volume and decreasing PP concentration in runoff.

3.2 Phosphorus Runoff Loss Levels in Chaohu Watershed Sloping Croplands

Phosphorus loss from sloping lands is influenced by comprehensive factors including soil properties, climatic conditions, vegetation cover, agricultural management, and topography. Liu et al. [26] studied nitrogen and phosphorus losses from citrus orchards on sloping lands in the Danjiang Reservoir area under different mulching practices, reporting annual P loss loads of 1.6–1.7 kg · hm ^{2} under conventional management. Lin et al. [27] investigated soil and nutrient losses from purple hilly region sloping croplands in Sichuan under different tillage and mulching practices, finding average seasonal P loss of 27.18 kg · hm ^{2} under conventional downslope ridging. Zhang et al. [20] studied nitrogen and phosphorus losses from dry sloping lands in the Three Gorges Reservoir area, reporting annual P flux of 0.23 kg · hm ^{2} under maize-mustard rotation. Lu et al. [28] monitored nitrogen and phosphorus loss characteristics from sloping red soil fields in Yunnan, finding annual P loss loads of 1.45–6.78 kg · hm ^{2} under conventional fertilization and downslope tillage. This study showed that conventional downslope tillage in Chaohu watershed sloping croplands resulted in average annual P loss of 0.706 kg · hm ^{2}. Thus, phosphorus runoff loss levels vary considerably across regions. Compared with other areas, Chaohu watershed sloping croplands exhibit moderate P loss levels. Chu et al. [29-30] studied nutrient export from polder areas along Chaohu Lake during summer rice and winter rapeseed-wheat seasons, reporting annual P export loads of 0.27 kg · hm ^{2} and 0.48 kg · hm ^{2} for rice-rapeseed and rice-wheat rotation systems, respectively. Phosphorus loss from sloping croplands along Chaohu Lake exceeds that from rice-wheat (or rice-rapeseed) rotation systems in the same region, and its potential long-term impact on Chaohu Lake water quality cannot be ignored. Additionally, rainfall variability causes substantial differences in annual farmland phosphorus loss, necessitating long-term monitoring for more accurate assessment of soil phosphorus runoff loss loads in the Chaohu watershed.

Hedgerow (PH), hedgerow with straw mulching (PHS), and contour ridging (CR) effectively control soil erosion risk in Chaohu watershed sloping croplands, with effectiveness decreasing in the order: PHS > PH > CR. Particulate phosphorus represents the dominant form of phosphorus transported via surface runoff from Chaohu watershed sloping croplands. Within DTP, D-Ortho-P constitutes the major fraction while DOP represents a minor proportion. PH, PHS, and CR significantly reduced PP and TP concentrations in runoff while increasing DTP and D-Ortho-P concentrations to varying degrees, without significantly affecting DOP concentration.

These three agronomic measures effectively reduce phosphorus loss loads from sloping croplands, with the primary mechanisms being runoff volume reduction and PP concentration decrease. Hedgerow combined with straw mulching demonstrated the best performance and can serve as an effective source control measure for phosphorus export from agricultural non-point source pollution in sloping croplands along Chaohu Lake.

This study focused on phosphorus loss and load calculations in surface runoff without considering phosphorus leaching losses, which should be addressed in future research.

References

[1] Zhang W L, Wu S X, Ji H J, et al. Estimation of agricultural non-point source pollution in China and the alleviating strategies . Estimation of agricultural non-point source pollution in China in early 21st century[J]. Scientia Agricultura Sinica, 2004, 37(7): 1008-1017

[2] Yang L Z, Shi W M, Xue L H, et al. Reduce-retain-reuse-restore technology for the controlling the agricultural non-point source pollution in countryside in China: General countermeasures and technologies[J]. Journal of Agro-Environment Science, 2013, 32(1): 1-8

[3] Gburek W J, Sharpley A N, Heathwaite L, et al. Phosphorus management at the watershed scale: A modification of the phosphorus index[J]. Journal of Environmental Quality, 2000, 29(1): 130-144

[4] Sharpley A N. Soil mixing to decrease surface stratification of phosphorus in manured soils[J]. Journal of Environmental Quality, 2003, 32(4): 1375-1384

[5] Wang J, Lü G A, Guo X S, et al. Conservation tillage and optimized fertilization reduce winter runoff losses of nitrogen and phosphorus from farmland in the Chaohu Lake region, China[J]. Nutrient Cycling in Agroecosystems, 2015, 101(1): 93-106

[6] Zieliński P, Jekatierynczuk-Rudczyk E. Comparison of mineral and organic phosphorus forms in regulated and restored section of a small lowland river (NE Poland)[J]. Ecohydrology & Hydrobiology, 2015, 15(3): 125-135

[7] Qin C, Liu H Z, Liu L, et al. Bioavailability and characterization of dissolved organic nitrogen and dissolved organic phosphorus in wastewater effluents[J]. Science of the Total Environment, 2015, 511: 47-53

[8] Wang L T, Ma Y H, Chu Y, et al. Study of nitrogen and phosphorus losses and yield of rice in different fertilizations of Chaohu Lake Basin[J]. Journal of Soil and Water Conservation, 2011, 25(5): 40-43

[9] Stevens C J, Quinton J N, Bailey A P, et al. The effects of minimal tillage, contour cultivation and in-field vegetative barriers on soil erosion and phosphorus loss[J]. Soil and Tillage Research, 2009, 106(1): 145-151

[10] Xiao J B, Sun Z X, Jiang C G, et al. Effect of technique of ridge film mulching and furrow seeding on soil erosion and crop yield on sloping farmland in western Liaoning[J]. Scientia Agricultura Sinica, 2016, 49(20): 3904-3917

[11] Lal R. Agroforestry systems and soil surface management of a tropical alfisol: . Water runoff, soil erosion, and nutrient loss[J]. Agroforestry Systems, 1989, 8(2): 97-111

[12] Cai Q G, Li S L. Effect of contour hedgerows on control of soil erosion[J]. Journal of Soil and Water Conservation, 1998, 4(2): 54-60

[13] Wang J, Guo X S, Wang Y Q. Effect of straw mulch on nitrogen and phosphorus loss from farmlands in Chaohu Lake region under natural rainfall condition[J]. Chinese Journal of Eco-Agriculture, 2010, 18(3): 492-495

[14] Xin Y, Wang X, Qiu Y, et al. Effects of different tillage modes on soil, water and N, P nutrient loss on sloping croplands in Liaoning Province[J]. Journal of Soil and Water Conservation, 2013, 27(1): 27-30

[15] Xiao B, Wang Q H, Wang H F, et al. The effects of grass hedges and micro-basins on reducing soil and water loss in temperate regions: A case study of Northern China[J]. Soil and Tillage Research, 2012, 122: 22-35

[16] Xia L Z, Ma L, Yang L Z, et al. Effects of hedgerows and ridge cultivation on losses of nitrogen and phosphorus of slope land in Three Gorges Reservoir area[J]. Transactions of the CSAE, 2012, 28(14): 104-111

[17] Guo S Y. Theory and Method of Soil and Water Conservation Monitoring[M]. Beijing: China Water & Power Press, 2010: 202-205

[18] State Environmental Protection Administration of China (SEPA). Water and Wastewater Monitoring Analysis Method[M]. 4th ed. Beijing: China Environmental Science Press, 2002: 243-250

[19] Zhou M H, Zhu B, Wang T, et al. Phosphorus losses and effects of fertilization on sloping cropland of purple soil[J]. Journal of Hydraulic Engineering, 2010, 41(11): 1374-1381

[20] Zhang Y, Fan F L, Zhou C, et al. Effects of crop/mulberry intercropping on surface nitrogen and phosphorus losses in Three Gorges Reservoir Area[J]. Acta Pedologica Sinica, 2016, 53(1): 189-201

[21] Van der Molen D T, Breeuwsma A, Boers P C M. Agricultural nutrient losses to surface water in the Netherlands: Impact, strategies, and perspectives[J]. Journal of Environmental Quality, 1998, 27(1): 4-11

[22] Wang T, Zhu B, Xia L Z. Effects of contour hedgerow intercropping on nutrient losses from the sloping farmland in the three gorges area, China[J].

Journal of Mountain Science, 2012, 9(1): 105-114

[23] Wu J, Guo X S, Lu J W, et al. Effects of continuous straw mulching on supply characteristics of soil inorganic nitrogen and crop yields[J]. Scientia Agricultura Sinica, 2012, 45(9): 1751-1759

[24] Peng N, Wang K R, Buresh R J, et al. Effect of rice straw incorporation on concentration of organic acids and available phosphorus in soil under different water regimes[J]. Acta Pedologica Sinica, 2006, 43(2): 347-351

[25] Yao G Z, Liu Z Y. Preliminary study on the effects of different hedgerow on the runoff and nutrient loss on slope farmland in Danjiangkou reservoir[J]. Journal of Anhui Agricultural Sciences, 2010, 38(6): 3015-3016

[26] Liu Y, Tao Y, Wan K Y, et al. Runoff and nutrient losses in citrus orchards on sloping land subjected to different surface mulching practices in the Danjiangkou Reservoir area of China[J]. Agricultural Water Management, 2012, 110: 34-40

[27] Lin C W, Luo C Y, Pang L Y, et al. Effects of different cultivation and mulching methods on soil erosion and nutrient losses from a purple soil of sloping land[J]. Acta Ecologica Sinica, 2010, 30(22): 6091-6101

[28] Lu Y, Hu W L, Lei B K, et al. The monitoring of nitrogen and phosphorus loss by surface runoff in sloping red soil fields of Yunnan Province, China[J]. Journal of Agro-Environment Science, 2012, 31(8): 1544-1553

[29] Chu Y, Wang L T, Ma Y H, et al. Nutrient export from a typical polder area around Chao Lake during rice growing period in the summer[J]. Journal of Soil and Water Conservation, 2010, 24(5): 135-140

[30] Chu Y, Wang L T, Ma Y H, et al. Nutrient export from a typical polder area around Lake Chao during rape and wheat growing period[J]. Journal of Soil and Water Conservation, 2013, 27(2): 36-41

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