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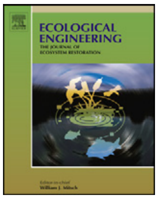

Soil nitrogen dynamics following short-term revegetation in the water level fluctuation zone of the Three Gorges Reservoir, China

Chen Ye[a,b], Xiaoli Cheng[a,*], Yulong Zhang[a,b], Zhixi Wang[a], Quanfa Zhang[a]

[a] *Key Laboratory of Aquatic Botany and Watershed Ecology, Wuhan Botanical Garden, Chinese Academy of Sciences, Wuhan 430074, China*
[b] *Graduate School of the Chinese Academy of Sciences, Beijing 100049, China*

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ABSTRACT

With the completion of the Three Gorges project, native vegetation in the water level fluctuation zone between the elevations of 145 m to175 m disappeared due to the inundation with a hydrological regime with flooding in winter instead of summer, a reversal of the natural one. We conducted a field experiment in the riparian ecosystem in the Three Gorges Reservoir to study nitrogen (N) dynamics under short-term revegetation and flooding during the period from 2008 to 2009. Soil chemical and physical characteristics, net mineralization potential rate (NMPR), net nitrification potential rate (NNPR), and denitrification potential rate (DPR) were determined in the laboratory. These results showed a significant decrease in inorganic N (NH_4^+-N and NO_3^--N) following the short-term revegetation and flooding, which was probably related to the interactions between surface flow, flooding, plant N uptake, and N transformation. Plants in conjunction with flooding increased the NMPR and NNPR, and increased the DPR only at the beginning of the revegetation and then decreased DPR after the flooding by regulating the concentration of soil organic carbon (SOC) and C:N ratios in soil, and decreasing the soil bulk density. Vegetation types affected N dynamics by changing SOC, soil N availability, and C:N ratios. The inorganic N, NMPR, and NNPR were higher in shrub soil than those in herb and tree soils due to higher SOC, whereas the DPR in tree soils was lower compared to shrub and herb soils because of lower C:N ratios together with the lower SOC. These results imply that soil inorganic N declined following the revegetation and flooding, and the revegetation in the riparian zone could potentially improve water quality.

1. Introduction

Riparian areas, the intersection of terrestrial and aquatic ecosystems, play an important role in removing nutrients, particularly nitrogen (N), from water flowing through riparian soils (Schade et al., 2001). Nitrogen cycling in the riparian zone is particular interesting due to (1) mineralization, which produces inorganic N (NH_4^+-N and NO_3^--N) from the soil organic N pool; (2) nitrification, which produces NO_3^--N from the NH_4^+-N and organic N and emits N_2O as a by-product; and (3) denitrification, the reduction of soil NO_3^--N to N_2 and N_2O (Bedard-Haughn et al., 2006). Mineralization and nitrification are typical favored in well aerated soils with more available soil organic N and NH_4^+-N; however, denitrification is generally favored in poorly aerated soils with high NO_3^--N (Booth et al., 2005).

Vegetation plays an important role in regulating N cycling (Karjalainen et al., 2001; Menyailo et al., 2002; Cheng, 2009). Plants can reduce N concentrations in riparian soils by absorbing mineral N for plant growth and hence reduce N concentrations in the water flowing through riparian soils to improve water quality (Bardgett et al., 2007). Wetlands dominated by plant communities tend to remove nitrate more effectively than non-vegetated wetlands due to plant N uptake and higher denitrification (Zhu and Sikora, 1995; Schade et al., 2001). Different vegetation types can also affect the N cycle in ecosystems by changing plant carbon (C) substrate, root growth, and available N in soil (Bardgett and Wardle, 2003; Knoepp and Vose, 2007). For example, Hefting et al. (2005) have found that different vegetation types (forest *versus* herbaceous) can impact the N retention efficiency in riparian buffer zones, which is related to the differences in root biomass, plant uptake, and soil nutrient addition.

A number of studies have been carried out to relate soil N dynamics to environmental changes in the riparian zone (Xu et al., 2007; Cheng et al., 2007). Environment changes including the

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Abbreviations: NMPR, net mineralization potential rate; NNPR, net nitrification potential rate; DPR, denitrification potential rate; N, nitrogen; SOC, soil organic carbon; TC, total carbon; TN, total nitrogen.

* Corresponding author. Tel.: +86 27 87510881; fax: +86 27 87510251.
E-mail address: xlcheng@fudan.edu.cn (X. Cheng).

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changes in soil aeration condition and soil N induced by flooding can also affect soil N dynamics in riparian areas (Venterink et al., 2002; Gergel et al., 2005; Hernandez and Mitsch, 2007). Flooding creates the aerobic and anaerobic conditions, which has an important influence on soil mineralization and nutrient cycling (De Jonge and Van Beusekom, 1995; Antheunisse et al., 2007). Hou et al. (2007), for instance, have reported that the duration of emersion and inundation have a significant influence on the nitrification process in the intertidal sediments. Collectively, these studies suggest that N dynamics in riparian areas can be greatly influenced by vegetation and flooding.

With the implement of the Three Gorges Dam project, the newly formed water level fluctuation zone results in various ecological problems such as loss of previous vegetation and soil erosion in an area of 350 km^2 in the Three Gorges Reservoir (New and Xie, 2008). To restore and protect the riparian ecosystem, revegetation has been carried out for recent years. A number of species (*Cynodon dactylon*, *Hemathria sibirica*, *Hibiscus syriacus*, *Morus alba, Salix variegate*, *Salix chaenomeloides*, and *Taxodium distichum*) with a high tolerance to summer exposure and winter inundation were transplanted to adapt to new conditions in the water level fluctuation zone of the Reservoir. However, very little information is available about the changes in soil N dynamics and how revegetation and flooding affect N dynamics in the water level fluctuation zone.

In this study, the hypothesis is that revegetation, vegetation types, and flooding would influence N dynamics in the water level fluctuation zone of the Three Gorges Reservoir. The specific objectives of this study were to: (1) estimate the temporal variations in N dynamics following the short-term revegetation and flooding and (2) investigate how vegetation types affect the N dynamics.

2. Materials and methods

2.1. Site description

The study was carried out in Zhongxian (108°11′N, 30°26′E), Chongqing, China (Fig. 1). The southeast sub-tropic monsoon climate has a daily mean temperature range from −4 to 44 °C. The annual mean precipitation ranges from 886 mm to 1614 mm with 80% taking place from April to October. The purple soil developed from purple gritstone in the study area is the typical soil type in the water level fluctuation zone of Three Gorges Reservoir (Zhao et al., 2007) and the soil slope is 32.5°. The average soil pH in the study region is 6.22 ± 0.09 and average soil water content is 19.99 ± 0.71%. The water level of the study region was controlled by the Three Gorges Reservoir. In the winter (October to April) of 2008, the water level of the Three Gorges Reservoir reached a maximum of 172 m above sea level, and would fluctuate from 145 m in summer to 175 m in winter thereafter.

Before submergence, vegetation in the water level fluctuation zone of the Three Gorges Reservoir was dominated by annuals, i.e., *Setaria viridis*, *Digitaria ciliaris*, and *Leptochloa Chinensis*, perennials including *Cynodo dactylon*, *Hemarthria altissima*, and *Capillipedium Assimile*, and woody plants such as *Ficus tikoua*, *Pterocarya stenoptera*, and *Vitex negundo* (Lu et al., 2010). After the prolonged submergence, annual plants such as *Setaria viridis, Digitaria ciliaris,* and *Leptochloa Chinensis* are the dominant species, and a few alien invasive plants, such as *Eupatorium adenophorum* and *Alternanthera philoxeroides*, are present in the inundation areas (Zhong and Qi, 2008). In the study area, revegetation was carried out along the elevation from 155 m to 175 m in March 2008 (Fig. 1). Herbs were planted between the elevations of 155–165 m, with the mean coverage of 95% and the dominant species were *Cynodon dactylon* and *Hemathria sibirica*. Shrubs were planted between the elevations of 165–172 m with the mean planting density of 8 stems per square meters and the species were *Hibiscus syriacus*, *Morus alba*, and *Salix variegate*. Trees were planted between the elevations of 172–175 m with the same planting density as shrubs and the species included *Salix chaenomeloides* and *Taxodium distichum*. All the plant species tolerate summer exposure and winter submergence.

2.2. Soil sampling

Field surveys were conducted in March 2008, September 2008, June 2009, and September 2009 when the water level of the study

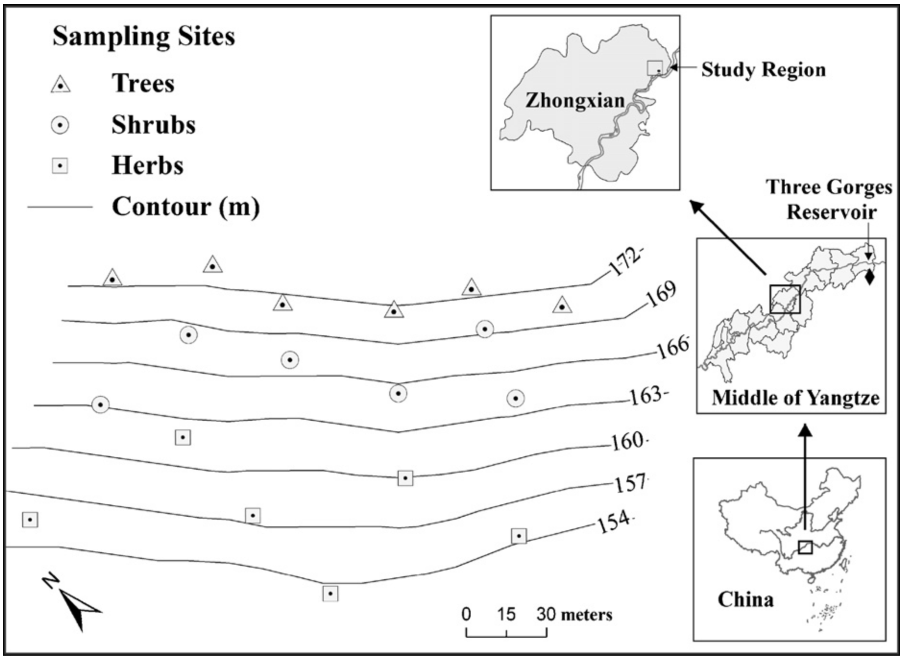

Fig. 1. Sampling sites in Zhongxian County, Chongqing, China.

area was about 145 m. From October 2008 to May 2009, the study area was flooded and water level fluctuated from 145 m to 172 m. The first sampling time, March 2008, was conducted before the revegetation to investigate conditions before planting, while the other three sampling times were after the revegetation in April 2008. Eighteen sampling plots (1 m × 1 m each) in the revegetation area were randomly selected in the three communities of herbs, shrubs, and trees (Fig. 1). Soil samples of the 0–20 cm soil layer were collected, sealed in plastic bags, and stored at 4 °C for analysis. The roots were sampled using a root corer with a diameter of 16 cm and length of 20 cm. Root samples were washed by hand over a 0.5 mm sieve and separated into living and dead roots according to color and elasticity (Hefting et al., 2005).

2.3. *Sample analysis*

Net N mineralization potential rate (NMPR) and net nitrification potential rate (NNPR) were estimated from 21-d soil incubations conducted in laboratory (Hart et al., 1994). For these incubations, air-dried soil was sorted to remove roots and rocks, passed through a 1 mm sieve, homogenized by hand and then placed in loosely capped polyethylene bottles. Soil samples were uniformly moistened with deionized water to water content corresponding to 70% water holding capacity and then placed in a 28 °C incubator. The difference between nitrification incubation and N mineralization incubation was that the former was amended with 70 mg NH_4^+-N kg^{-1}. For the amended treatment the soil was moistened with a $(NH_4)_2SO_4$ solution to obtain the required soil moisture and NH_4^+-N concentration. Each incubation bottle with 10 g of soil was opened every 3 d, aerated for 5 min, and water content was checked by weighing and adjusted as needed (Sierra, 2002). Two subsamples were removed and measured for exchangeable NH_4^+-N and NO_3^--N as described above after 0 d, 7 d, 14 d, and 21 d of incubation (Robertson and Vitousek, 1981).

Denitrification potential rate (DPR) was measured using the acetylene block technique (Tiedje et al., 1989). Three replicate 150-mL bottles with about 150 g wet mass of soil were amended with carbon and nitrogen by adding 40 mL of a solution containing 200 mg NO_3^--N/L and 3.3 g C/L. Bottles were filled with N_2 gas to keep the soil anoxic. These conditions were made for measurement of the maximum denitrification rate under near ideal condition. Each bottle was added with 10 mL of acetylene and then was shaken for 15 min to equilibrate acetylene between water and vapor phases. Bottles were incubated in the dark for 4 h and the initial and final headspace gas samples were collected in 3-mL containers (Schade et al., 2001).

Soil organic carbon (SOC), total carbon (TC) and total nitrogen (TN) were analyzed with an N C Soil Analyzer (Flash, EA, 1112 Series, Italy). Exchangeable NH_4^+-N and NO_3^--N were determined with a spectrophotometer using the indophenol blue colorimetric method and phenol disulfonic acid colorimetry, respectively. The root biomass was determined gravimetrically after drying the fresh roots at 70 °C for 48 h (Hefting et al., 2005).

2.4. *Calculation of net N mineralization potential rate (NMPR), net nitrification potential rate (NNPR), and denitrification potential rate (DPR)*

The NMPR was calculated as the final inorganic N (NH_4^+-N and NO_3^--N) minus initial inorganic N divided by incubation time, and NNPR as final NO_3^--N minus initial NO_3^--N divided by incubation time (Robertson and Vitousek, 1981). The DPR was calculated from the difference between final and initial headspace nitrous oxide content divided by incubation time (Schade et al., 2001).

2.5. *Statistical analyses*

We used one-way analysis of variance (ANOVA) to compare the differences in soil inorganic N, NMPR, NNPR, and DPR between sampling times and to investigate the effects of vegetation types on root biomass. Statistical significance of vegetation type effects on NH_4^+-N, NO_3^--N, TC, SOC, C:N ratios, NMPR, NNPR, and DPR was evaluated with repeated measures ANOVA, where multiple measurements on a given treatment through time represented the repeated variables. Pearson correlation analysis was used to test the relationships between rates of N dynamics and soil characteristics. All the processes were performed using SPSS 13.0 for windows.

3. Results

3.1. *Changes in nitrogen dynamics following short-tem revegetation*

Soil inorganic N concentrations and soil N transformation showed clear dynamics following revegetation (Table 1). The NO_3^--N and soil bulk density significantly decreased, and NH_4^+-N concentrations increased following revegetation. Overall, inorganic N including NH_4^+-N and NO_3^--N concentrations significantly decreased after the short-term revegetation (probability < 0.05) (Table 1). The NMPR and NNPR significantly increased after revegetation, but DPR significantly increased only at the beginning of the revegetation (i.e., September 2008). The NO_3^--N significantly increased and NH_4^+-N, soil bulk density, and DPR decreased after flooding by comparing September 2008 with June 2009 (probability < 0.05) (Table 1).

3.2. *Effect of vegetation types on nitrogen dynamics, soil carbon and root biomass*

Variabilities occurred in N dynamics among the different vegetation types, herbs, shrubs, and trees (Figs. 2 and 3; Table 2). Annual mean (March 2008–September 2009) inorganic N concentrations were higher in soils supporting shrubs compared to soils supporting herbs and trees (Fig. 2). The highest values of annual mean NMPR and NNPR were found in soils supporting shrubs and the lowest in soils supporting herbs (Fig. 3d and e). The annual mean

Table 1

Dynamic soil inorganic N, net mineralization potential rate (NMPR), net nitrification potential rate (NNPR) and denitrification potential rate (DPR) during monitoring. Values are the mean ± SE in which SE is the standard error. Different letters indicate statistical significances between the four sampling times at probability (level of significance) = 0.05, and number of samples $n = 18$ for each sampling time.

Soil characteristic	March 2008	September 2008	June 2009	September 2009
NO_3^--N (mg kg^{-1})	30.76 ± 3.14^a	0.73 ± 0.09^c	6.44 ± 0.64^b	5.37 ± 0.49^b
NH_4^+-N (mg kg^{-1})	7.10 ± 0.47^c	17.53 ± 1.63^a	8.15 ± 0.45^b	11.38 ± 0.48^b
Bulk density (g cm^{-3})	2.31 ± 0.03^a	1.92 ± 0.02^b	1.38 ± 0.02^d	1.54 ± 0.03^c
NMPR (mg kg^{-1} d^{-1})	1.02 ± 0.11^b	$1.17 \pm 0.10^{a,b}$	1.33 ± 0.09^a	1.35 ± 0.07^a
NNPR (mg kg^{-1} d^{-1})	1.21 ± 0.43^b	1.61 ± 0.25^b	3.07 ± 0.47^a	3.81 ± 0.39^a
DPR (mg kg^{-1} h^{-1})	0.18 ± 0.02^b	8.79 ± 0.57^a	0.76 ± 0.34^b	0.16 ± 0.05^b

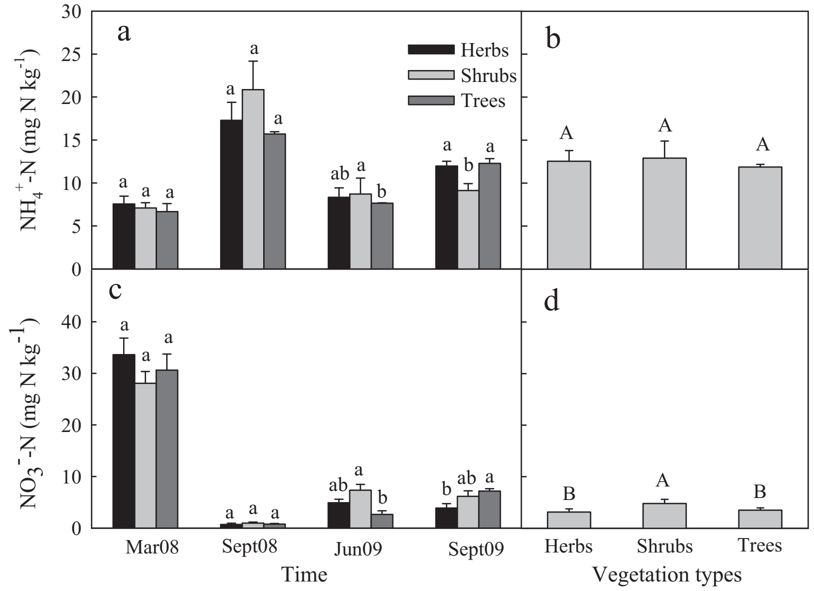

Fig. 2. Temporal variations of soil NH_4^+-N and NO_3^--N concentrations (a and b), and annual averages of NH_4^+-N and NO_3^--N concentrations (c and d) (mean ± standard error) in plant zone of each vegetation type. Different letters over the bars indicate statistically significant differences at the 0.05 level of significance. Vegetation types: herbs, shrubs and trees. Sampling times: March 2008, September 2008, June 2009, and September 2009.

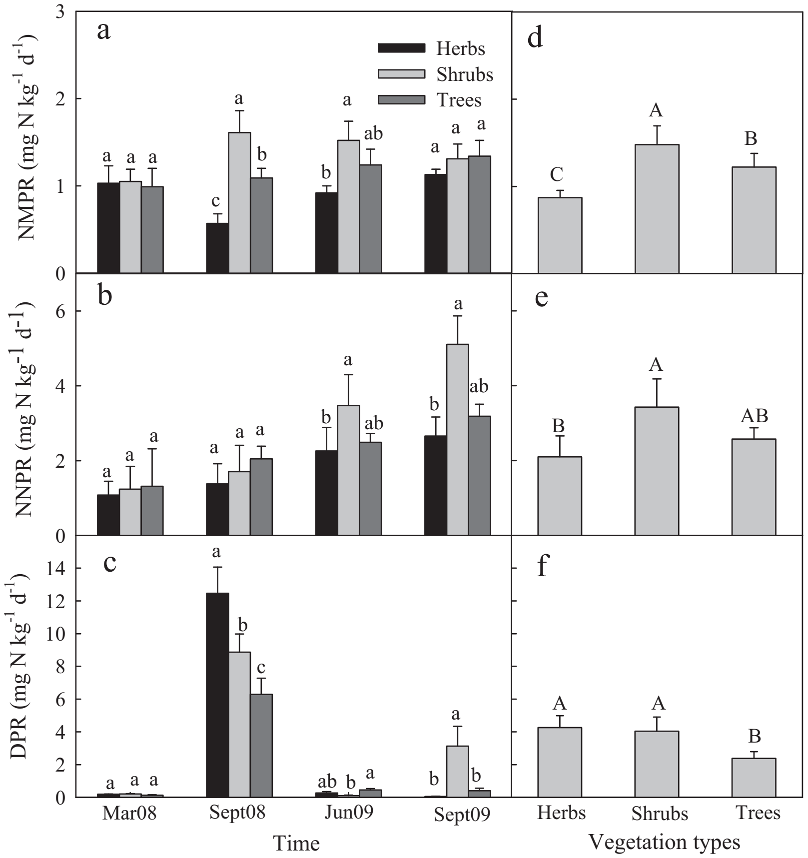

Fig. 3. Dynamic (a) net nitrogen mineralization potential rate (NMPR), (b) net nitrogen nitrification potential rate (NNPR), (c) denitrification potential rate (DPR), (d) annual averages of NMPR, (e) NNPR, and (f) DPR (mean ± standard error) of each vegetation type. Different letters over the bars indicate statistically significant differences at the 0.05 level of significance for vegetation types.

Table 2
Statistically significant differences of soil inorganic N, net mineralization potential rate (NMPR), net nitrification potential rate (NNPR), denitrification potential rate (DPR), soil total carbon (TC), soil organic carbon (SOC), and C:N ratios based on two-way ANOVA.

Variable	NH_4^+-N	NO_3^--N	NMPR	NNPR	DPR	TC	SOC	C:N ratios
Vegetation types	n.s.	***	*	*	n.s.	*	***	***
Time	***	***	n.s.	**	***	n.s.	n.s.	***
Vegetation types × Time	n.s.	***	n.s.	n.s.	*	n.s.	n.s.	***

n.s. = not significant.
[*] Probability < 0.05.
[**] Probability < 0.01.
[***] Probability < 0.001.

DPR was lower in soils supporting trees than soils supporting herbs and shrubs (Fig. 3f).

The mean TC, SOC, C:N ratios, biomasses of living roots and dead roots were not always significantly different in the soils supporting the three plant communities, with higher TC and SOC in soils supporting shrubs compared to the soils supporting trees (Figs. 4 and 5). The C:N ratios decreased after revegetation (i.e., September 2008 and June 2008) and the lowest C:N ratios was found in soils supporting trees (Fig. 4). The highest living root biomass and dead root biomass were found in soils supporting shrubs and trees, respectively (Fig. 5).

3.3. Main controls on nitrogen dynamics

The NMPR and NNPR showed a significantly positive relationship with NO_3^--N and SOC and significantly negative relationship with NH_4^+-N and soil bulk density ($probability < 0.05$). The DPR was significantly and directly correlated to C:N ratios and soil bulk density, and inversely correlated with NO_3^--N ($probability < 0.05$). The NH_4^+-N concentration was significantly and directly correlated with C:N ratios and inversely correlated with NO_3^--N ($probability < 0.05$) (Table 3).

4. Discussion

This study showed clear N dynamics following the revegetation and flooding in the water level fluctuation zone of the Three Gorges Reservoir (Table 1). These patterns might be related to interactions of plant N uptake, N transformation, and soil environmental condition (DeLaune et al., 2005; Hefting et al., 2005). Soil inorganic N concentrations (NO_3^--N and NH_4^+-N) significantly decreased ($probability < 0.05$) following the short-term revegetation and flooding (Table 1), which was probably related to the interactions among surface flow, recharge, flooding, N transformation, and plant N uptake (Casey and Klaine, 2001; Schade et al., 2001; Zhao et al., 2007). From March 2008 to September 2008, the variation in

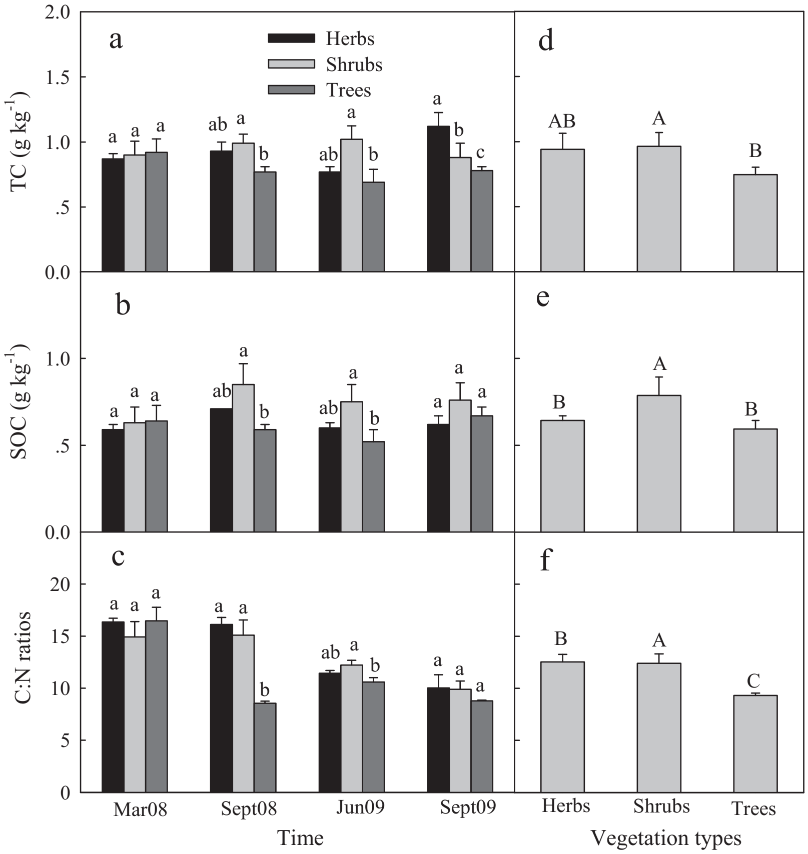

Fig. 4. Dynamic (a) soil total carbon (TC), (b) soil organic carbon (SOC), (c) C:N ratios, (d) annual averages of TC, (e) SOC, and (f) C:N ratios (mean ± standard error) of each vegetation type. Different letters over the bars indicate statistically significant differences at the 0.05 level for vegetation types.

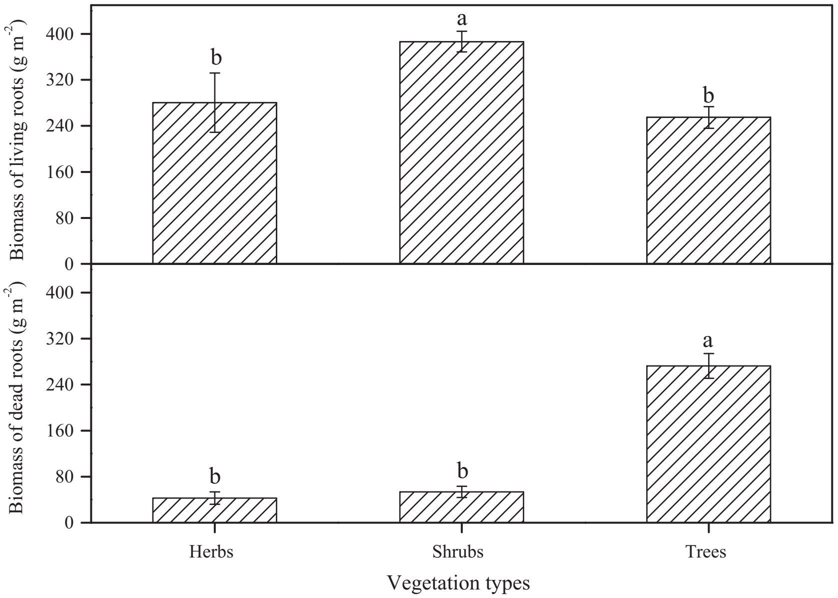

Fig. 5. Biomass of living roots and dead roots for each plant community. Different letters over the bars indicate statistically significant differences at the 0.05 level for vegetation types.

inorganic N (Table 1) was probably related to the surface flow, recharge, plant uptake, and denitrification (Casey and Klaine, 2001; Schade et al., 2001). Many studies have reported large declines in NO_3^--N concentration due to the surface flow and recharge in riparian zones (Casey and Klaine, 2001). For the Three Gorges Reservoir, 80% of annual precipitation takes place from April to October and the soil slope is 32.5%, which would result in large surface runoff and infiltration, and decreased NO_3^--N in the soil from March 2008 to September 2008 (Table 1). After the revegetation, plants regulate soil inorganic N by plant N uptake and impacting soil N transformation (Knoepp and Vose, 2007). Denitrification, the process by which bacteria reduce NO_3^--N to primarily N_2 gas, has been identified as the primary mechanism of NO_3^--N removal in riparian zones (Schade et al., 2001). The increased denitrification after revegetation (i.e., September 2008) could also lead to the decline in NO_3^--N (Table 1). After flooding, plant uptake, flooding, and denitrification regulated soil inorganic N. Plants can absorb soil inorganic N for growth and hence reduce N concentrations in soil (Table 1; Knoepp and Vose, 2007). This study found a distinct reduction of soil NH_4^+-N concentration with soil drying after the flooding (i.e., June 2009) (Table 1), being coincidental with increases in plant biomass during the growth season. Moreover, during the flooding period, the frequent material exchanges between floodwater and riparian zone could also lead to the variation in soil inorganic N (NH_4^+-N and NO_3^--N) when comparing September 2008 with June 2009 (Table 1; Hou et al., 2007). The decreased denitrification after flooding (i.e., June 2009) would also increase NO_3^--N (Table 1; Schade et al., 2001). Additionally, increased nitrification (Table 1) could also reduce the soil NH_4^+-N and increase NO_3^--N during reservoir drawdown (Zaman and Chang, 2004).

Dynamics of NMPR, NNPR, and DPR after revegetation (Table 1) were related to plants and flooding (Knoepp and Vose, 2007; Hou et al., 2007). Plants can affect soil N transformation directly through root N uptake and indirectly through regulating soil nutrient availability and ambient conditions (Knoepp and Vose, 2007; West et al., 2006). The decreased soil bulk density could increase NMPR and NNPR after the revegetation (Table 1). The soil bulk density was significantly negative with the NMPR and NNPR (probability < 0.05) (Table 3). The short-term revegetation can improve the soil porosity by decreasing the soil bulk density and then increasing soil mineralization and nitrification, which were favored in well aerated soils (Baldwin and Mitchell, 2000; Booth et al., 2005). Meanwhile, with the absence of plant uptake during sample laboratory incubations, the nitrifiers were probably able to compete more for available NH_4^+-N, resulting in increased observed NNPR (Arnold et al., 2008). Moreover, this study found a significant increase in DPR at the beginning of the revegetation (i.e., September 2008) (Table 1), which was likely attributed to the non-statistically

Table 3
Pearson correlation coefficients among net nitrogen mineralization potential rate (NMPR), net nitrogen nitrification potential rate (NNPR), denitrification potential rate (DPR) and soil parameters.

Characteristic	NMPR	NNPR	DPR	NH_4^+-N	NO_3^--N	C:N	TC	TN	SOC	Soil bulk density
NMPR	1.00	0.38^{**}	0.13	-0.28^{**}	0.27^{**}	0.02	0.17	0.02	0.35^{**}	-0.31^{**}
NNPR		1.00	−0.03	-0.36^{**}	0.52^{**}	−0.11	0.28^{**}	0.10	0.45^{**}	-0.39^{**}
DPR			1.00	0.16	-0.36^{**}	0.50^{**}	0.19	−0.10	0.12	0.05
NH_4^+-N				1.00	-0.36^{**}	0.29^{**}	0.02	−0.07	0.07	−0.12
NO_3^--N					1.00	-0.21^{*}	0.11	0.09	0.32^{**}	0.48^{**}
C:N						1.00	0.21^{*}	-0.39^{**}	0.34^{**}	0.37^{**}
TC							1.00	0.68^{**}	0.44^{**}	−0.07
TN								1.00	0.03	-0.23^{*}
SOC									1.00	-0.25^{**}
Soil bulk density										1.00

* Probability < 0.05.
** Probability < 0.01.

significant increase of soil organic matter (i.e., with 0.62 ± 0.04 g/kg SOC in March 2008 and 0.72 ± 0.03 g/kg in September 2009) provided by plant materials especially in soils supporting shrubs (Fig. 4). This finding is consistent with other high rates of denitrification due to higher soil organic matter in soils (Dodla et al., 2008). The new hydrological regime with flooding in summer induced by the reservoir operation is opposite of the natural rhythms of the Yangtze River (Wang et al., 2005; Bai et al., 2005). Also, the regulated water level fluctuation zone with a 30 m difference in water levels dramatically alters the conditions in the riparian zone. Nevertheless, flooding often affects soil N dynamics in riparian zone soils (Hernandez and Mitsch, 2007; Hou et al., 2007). Thus, the variations in N transformation between September 2008 and June 2009 were probably attributed to the interaction of plants and flooding. After flooding, as desiccation and oxidation of the soils proceeded, an expanded habitat for aerobic microbiota will be created and an increase in the mineralization rate of carbon would be expected (Baldwin and Mitchell, 2000). Although the laboratory assays in this study did not show significant decreases in TC and SOC, or an increase in NMPR, significant decrease in soil C:N ratios could be found after the flooding (Fig. 4). The concentration of SOC was related to the interaction between the organic matter production and flooding. During flooding, senescing plant material could provide organic matter for the soil, but flooding would flush N, in the form of organic debris and dissolved solutes, from riparian ecosystems (Adair et al., 2004). Therefore, the changes of the SOC and C:N ratios in soil due to plant productions and flooding have a great impact on N transformation (Rückauf et al., 2004; Dodla et al., 2008). Moreover, the increase in NNPR and decrease in DPR after flooding occurred (Table 1) were also related to plant production and flooding. The increased plant biomass and rooting into drying soil after flooding creates aerated zones and promotes nitrification but inhibits denitrification (Jennifer et al., 2006). Additionally, the increased soil porosity induced by the decreased soil bulk density after the flooding may also increase NNPR and decrease DPR (Table 1; Baldwin and Mitchell, 2000; Oehler et al., 2007).

Differences in vegetation communities influence N dynamics by changing the root N uptake, organic matter productions, soil C:N ratios, and N concentrations in soil (Hefting et al., 2005). In this study, soil NO_3^--N concentrations, soil organic carbon, and C:N ratios varied significantly among the different communities of vegetation (probability < 0.05) (Figs. 2 and 4). Higher biomass of living roots and lower biomass of dead roots in soils supporting shrubs, together with higher TC and SOC in shrubs when compared to trees (Figs. 4 and 5) could indicate that shrubs may provide soil organic matter more quickly than trees (Osborne and Kovacic, 1993). Pearson correlation analysis showed that SOC was positively correlated with NO_3^--N, NMPR, and NNPR (Table 3). Higher SOC production in soils supporting shrubs (Fig. 4) enhanced the NMPR and NNPR (Fig. 3) and hence led to the increased NO_3^--N in soils supporting shrubs compared to the soils supporting the other two plant communities (Fig. 2; Hefting et al., 2005). Moreover, higher N availability in soils supporting shrubs can in turn promote the NMPR and NNPR (Booth et al., 2005). Additionally, the lower C:N ratios in soils supporting trees induced by lower organic carbon production (Fig. 4) could lead to the lower DPR compared to the soil supporting shrubs (Fig. 3f and Table 3), which was similar to other studies in which soil displayed low rates of denitrification under low C:N ratios and low N availability (Rückauf et al., 2004; Greenan et al., 2006).

5. Conclusions

The soil N dynamics were significantly dynamic in the revegetated areas in the water level fluctuation zone of the Three Gorges Reservoir, China. Inorganic N (NO_3^--N and NH_4^+-N) concentrations significantly decreased following the short-term revegetation and flooding, which probably was related to the interactions between surface flow, flooding, plant N uptake, and N transformation. Plant productions in conjunction with flooding increased NMPR and NNPR, and increased DPR only at the beginning of revegetation and then decreased DPR after the flooding by regulating the concentration of SOC and C:N ratios in soil, and decreasing the soil bulk density. Types of plant communities affected inorganic N, NMPR, NNPR, and DPR by changing SOC, soil N availability, and C:N ratios. This study implies that soil inorganic N decreases following the revegetation and flooding and the revegetation in the water level fluctuation zone could potentially improve water quality and reduce the risk of eutrophication in the Three Gorges Reservoir. Finally, the short-term revegetation in this study may not sufficiently address the effects of vegetation on N dynamics in the riparian ecosystem. Long-term revegetation studies are still necessary to extrapolate the vegetation effect on N dynamics combined with environmental factors (i.e., flooding) in riparian ecosystems.

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