

ISSN 1000-0933
CN 11-2031/Q

生态学报

Acta Ecologica Sinica



第 33 卷 第 24 期 Vol.33 No.24 **2013**

中国生态学学会
中国科学院生态环境研究中心
科学出版社

主办
出版



中国科学院科学出版基金资助出版

生态学报

(SHENGTAI XUEBAO)

第 33 卷 第 24 期 2013 年 12 月 (半月刊)

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期刊基本参数:CN 11-2031/Q * 1981 * m * 16 * 296 * zh * P * ¥ 90.00 * 1510 * 33 * 2013-12



封面图说: 黄土丘陵农牧交错带——黄土丘陵是中国黄土高原的主要地貌形态,由于黄土质地疏松,加之雨季集中,降水强度较大,地表流水冲刷形成很多沟谷,斜坡所占的面积很大。这里千百年来的农牧交错作业,地表植被和生态系统均遭受了严重的破坏。利用高精度影像对小流域景观的研究表明,这里耕地、林地和水域景观相对比较规则简单,荒草地和人工草地景观比较复杂。农牧交错带小流域景观形态具有分形特征,各类景观斑块的分维数对粒度变化的响应不同,分维数随粒度的增大呈非线性下降趋势。

彩图及图说提供: 陈建伟教授 北京林业大学 E-mail: cites.chenjw@ 163.com

DOI: 10.5846/stxb201304210764

解成杰, 郭雪莲, 余磊朝, 许静. 滇西北高原纳帕海湿地土壤氮矿化特征. 生态学报, 2013, 33(24): 7782-7787.

Xie C J, Guo X L, Yu L C, Xu J. Net nitrogen mineralization in soils of Napahai wetland in Northwest Yunnan. Acta Ecologica Sinica, 2013, 33(24): 7782-7787.

滇西北高原纳帕海湿地土壤氮矿化特征

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摘要: 采用树脂芯原位培育法, 研究了纳帕海沼泽、沼泽化草甸和草甸土壤氮的矿化特征。结果表明, 铵态氮($\text{NH}_4^+\text{-N}$)为沼泽、沼泽化草甸土壤中无机氮的主要存在形式, 分别占无机氮含量的 96.76% 和 75.24%, 而硝态氮($\text{NO}_3^-\text{-N}$)为草甸土壤中无机氮的主要存在形式, 占无机氮含量的 58.77%。植物生长期中, 纳帕海湿地土壤的净氮矿化速率表现为沼泽化草甸>草甸>沼泽, 表明干湿交替的土壤环境更利于土壤氮矿化作用的进行, 土壤中氮素有效性和维持植物可利用氮素的能力更强。整个生长季, 沼泽和草甸土壤氮矿化为硝化作用, 而沼泽化草甸土壤氮矿化为氨化作用。土壤硝态氮含量、有机质含量、碳氮比和含水量均对纳帕海沼泽、沼泽化草甸和草甸土壤的氮矿化产生显著影响。

关键词: 纳帕海; 高原湿地; 净氮矿化率

Net nitrogen mineralization in soils of Napahai wetland in Northwest Yunnan

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Abstract: Nitrogen (N) is an essential nutrient of special importance for plant growth while it is often deficient in soils because of low phytoavailability. Shifts in soil N status can be caused by variations in the N transformation. Soil N mineralization is of prime importance in ecosystem productivity, N potential availability and losses from ecosystems. Using resin-core incubation method, we examined the net N mineralization rates in swamp, swamp meadow and meadow soils (0—15 cm) in situ. The soils located along a water level gradient in Napahai wetland, which are sensitive to the changes of hydrological regimes, and reflect the different stage of wetland succession. The objective was to provide insight into the mechanism that how wetland ecosystem evolution constraining net N mineralization in soils. The results indicated that the inorganic N concentrations were significantly different among the three soils (0—10 cm), swamp > swamp meadow > meadow, during the growth season. The $\text{NH}_4^+\text{-N}$ concentrations showed the same decrease trend as inorganic N while the $\text{NO}_3^-\text{-N}$ concentrations showed a significant increase trend in the three soils. The inorganic N was mainly in the form of $\text{NH}_4^+\text{-N}$ in swamp and swamp meadow soils, which accounted for 96.76% and 75.24% respectively. In contrast, $\text{NO}_3^-\text{-N}$ was the main form of inorganic N in meadow soil and accounted for 58.77%. The net N mineralization rates were significantly different during the growth season, ranking in order of swamp meadow > meadow > swamp. The results indicated that wet and dry alternation is beneficial to the net N mineralization in the wetland soils, and favors higher N effectiveness and greater phytoavailability. The net N mineralization rate in swamp soil was negative during the growth season. The rates in swamp meadow and meadow soils were negative from May to September while positive from September to November. The net

基金项目: 国家自然科学基金资助项目(41001332); 云南省科技厅科研专项资助项目(212005); 西南林业大学重点科研基金资助项目(110913, 110924)

收稿日期: 2013-04-21; **修订日期:** 2013-10-09

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ammonization rates in the soils showed a significant decrease as meadow > swamp meadow > swamp from May to September, but showed a significant increase as swamp < meadow < swamp meadow from September to November. The net nitrification rates in soils among the three wetland types showed a significant decrease as swamp > swamp meadow > meadow from May to September, but showed a significant increase as swamp < swamp meadow < meadow from September to November. On the whole, the net N mineralization was main in the form of nitrification in the swamp and meadow soils while in the form of ammonization in the swamp meadow soil during the growth season. In addition, the N mineralization in soils was influenced by soil NO_3^- -N concentration, organic material concentration, C/N ratio and soil moisture in the soils. The net N mineralization rate in swamp soil was negatively related to soil NO_3^- -N concentration, organic material concentration, C/N ratio and soil moisture. In swamp meadow soil, the N mineralization rate was negatively related to soil NO_3^- -N concentration and C/N ratio, but was positively related to soil moisture. In contrast, the net N mineralization rate in meadow soil was negatively related to soil NO_3^- -N concentration and bulk density, but was positively related to organic material concentration and soil moisture.

Key Words: Napahai; plateau wetland; net N mineralization rate

氮是植物生长必不可少的大量营养元素之一,是湿地生态系统中最重要限制养分,其含量高低直接影响着湿地生态系统的初级生产力^[1]。湿地土壤中可被植物直接吸收利用的氮素不足土壤全氮的2%^[2],95%以上氮素以有机氮的形式存在^[3],不能直接被植物吸收利用,需要经过微生物的矿化作用将其转化为 NH_4^+ -N 和 NO_3^- -N 形式的有效氮^[4]。土壤氮素的矿化作用作为氮循环的重要过程之一,与微生物活动、植物养分吸收、反硝化过程和氮固定等有着密切联系^[5-6]。研究湿地土壤 NH_4^+ -N 和 NO_3^- -N 的动态和有机氮矿化速率及影响因素对于了解湿地系统氮素循环与转化具有重要意义。

近年来,国际上对湿地土壤有机氮矿化开展了广泛研究,包括不同因素(植物^[7]、土地利用^[8]、水热环境^[9])对湿地土壤氮矿化作用的影响、湿地土壤氮矿化速率及其影响因素^[10-11]、湿地土壤氮矿化对气候变化和氮沉降的响应^[12]等。但现有研究主要针对同一类型湿地生态系统开展研究,对不同湿地生态系统中土壤氮矿化趋势的对比研究还比较缺乏。国内也在该领域开展了大量研究工作,取得了许多重要成果,但这些研究多集中在三江平原^[13]、长江中下游^[14]等湿地区域,对位于重要江河源头的若尔盖高原湿地也有所研究^[15],但对云贵高原这一类独特湿地的研究却较少,特别是滇西北高原湿地尚未开展相关研究。

滇西北是云南高原湿地的集中分布区,受新构造运动差异抬升、断裂陷落、冰川溶蚀以及流水改造等影响,形成了个体面积小、空间异质性高、数量众多、相互间无水道相通的封闭与半封闭的独特湿地类型^[16]。滇西北高原湿地独特的结构特征决定了其生态系统的脆弱性和敏感性。近年来,在气候变化和人类活动影响下,纳帕海湿地面积萎缩,干旱化程度加剧,湿地空间上从湖心向湖岸呈现出由沼泽向沼泽化草甸、草甸的演替格局^[17]。本文选取纳帕海典型沼泽、沼泽化草甸、草甸为研究对象,采用树脂芯原位培育法,研究纳帕海处于不同演替阶段的湿地土壤氮矿化特征,对纳帕海湿地生态演替机理及氮循环的深入研究等具有重要意义。

1 实验材料与方法

1.1 研究区概况

纳帕海湿地位于滇西北横断山脉中段香格里拉县境内(27°49′—27°55′N, 99°37′—99°41′E),海拔 3260 m。本区保留的第三纪末期形成的古夷平面错落分布在不同高度,纳帕海即发育在石灰岩母质的中甸高原上。受喀斯特作用的强烈影响,湖盆底部被蚀穿而形成落水洞,湖水在地下汇集后从北部穿过小背斜出露形成支流汇入金沙江。湖盆四周山岭环绕,从湖盆中心至湖岸生长着大量的水生和陆生植被,湖滨有较大面积的沼泽草甸,周围山上生长着硬叶常绿阔叶林和云杉冷杉针叶林以及灌丛。水量补给主要依靠降雨、冰雪融水和湖东南侧几条短小河流,以及湖两侧沿金沙江一中甸断裂带上涌的泉水^[17]。纳帕海湿地地处青藏高原

与亚热带季风气候区和中南半岛热带季风区的结合部,具有高寒、年均温低、霜期长、气温年较差和日较差大、干湿季节分明等特点。年均温为 5.4 ℃,年降水量为 619.9 mm,主要集中在 6—8 月份^[18]。

1.2 研究方法

依据典型性和代表性原则,选择一条典型的研究样带,样带大小为 10 m×30 m,样带上选择典型的沼泽、沼泽化草甸、草甸样地,样地的人文、植被、土壤等状况见表 1。2011 年于 5—7 月份、7—9 月份和 9—11 月份测定土壤净氮矿化量和土壤净氮矿化速率。土壤氮矿化采用树脂芯原位培养法测定。树脂芯的实验装置包括:PVC 管(内径 5 cm,高 15 cm)、装有 3 g 阴离子交换树脂(二甲苯胺阴离子)和 3 g 阳离子交换树脂(磺酸根型阳离子)的尼龙网(100 目)。装有阴阳离子交换树脂的尼龙网袋放入饱和 NaCl 溶液中浸泡 12h,激活。每个研究样地内随机选 5 个点,去除地表凋落物,每个点打入两支 PVC 管,将其中一支取出,放入 4 ℃ 冰箱带回实验室。另一支尽量不破坏土壤的原状结构,用小刀去除底部约 2 cm 厚的土壤。在 PVC 管顶部放置 1 个尼龙网袋,底部放置 2 个。最后,将处理好的 PVC 管放回原位,野外培养 2 个月。土壤全氮用凯氏定氮法测定,NH₄⁺-N 用纳氏试剂比色法测定,NO₃⁻-N 用酚二磺酸比色法测定。

表 1 研究样地的基本情况
Table 1 Description of study area

样地 Site	优势物种 Dominant species	水文状况 Hydrological condition	土壤类型 Soil types
沼泽 Swamp	杉叶藻(<i>Hippuris vulgaris</i>), 茭草(<i>Zizania caduciflora</i>), 水葱(<i>Scirpus taberna montani</i>), 水蓼(<i>Polygonum hydropiper</i>)等	常年积水	沼泽土
沼泽化草甸 Swamp meadow	无翅苔草(<i>Carex pleistoguna</i>), 华扁穗草(<i>Blysmus sinocompressus</i>), 云雾藁草(<i>Carex nubigena</i>), 发草(<i>Deschamps caespitosa</i>), 矮地榆(<i>Sanguisorba filiformis</i>)等	季节性积水	草甸沼泽土
草甸 Meadow	鹅绒萎陵菜(<i>Potentilla anserine</i>), 斑唇马先蒿(<i>Pedicularis longiflora</i> var. <i>tubiformis</i>), 车前(<i>Plantago asiatica</i>), 牡蒿(<i>Artemisia japonica</i>), 高山紫苑(<i>Aster tataricus</i>), 蒲公英(<i>Taraxacum mongolicum</i>) 肉果草(<i>Lancea tibetica</i>)等	地表无积水,地下水位埋藏较深	草甸土

1.3 数值计算与统计分析

土壤净氮矿化量=培养后的无机氮(NH₄⁺-N + NO₃⁻-N) + 淋溶无机氮(NH₄⁺-N + NO₃⁻-N) - 培养前的无机氮(NH₄⁺-N + NO₃⁻-N)

土壤净氮矿化速率=[培养后的无机氮(NH₄⁺-N + NO₃⁻-N) + 淋溶无机氮(NH₄⁺-N + NO₃⁻-N) - 培养前的无机氮(NH₄⁺-N + NO₃⁻-N)] / 培养时间

土壤净氨化速率=(培养后的 NH₄⁺-N + 淋溶 NH₄⁺-N-培养前的 NH₄⁺-N) / 培养时间

土壤净硝化速率=(培养后的 NO₃⁻-N + 淋溶 NO₃⁻-N-培养前的 NO₃⁻-N) / 培养时间

数据统计分析软件和作图工具分别采用 SPSS18. 0 和 Excel 2003。

2 结果与分析

2.1 纳帕海湿地土壤无机氮含量季节动态

纳帕海湿地土壤中无机氮含量的季节动态见图 1。纳帕海湿地 0—10 cm 土壤无机氮(NH₄⁺-N + NO₃⁻-N) 总量平均值大小为沼泽(110.95 mg/kg)>沼泽化草甸(92.99 mg/kg)>草甸(64.38 mg/kg)。其中,土壤 NH₄⁺-N 含量表现为沼泽>沼泽化草甸>草甸;NO₃⁻-N 含量表现为草甸>沼泽化草甸>沼泽。NH₄⁺-N 为沼泽、沼泽化草甸土壤中无机氮的主要存在形式,其含量占总无机氮含量的比例分别为 96.76%、75.24%。NO₃⁻-N 为草甸土壤中无机氮的主要存在形式,其含量占总无机氮含量的 58.77%。NH₄⁺-N 含量的季节变化幅度,沼泽湿地土壤为 54.0%,沼泽化草甸湿地土壤为 19.3%,草甸土壤为 58.5%。NO₃⁻-N 含量的季节变化幅度,沼泽湿地土壤为 52.3%,沼泽化草甸湿地土壤为 88.7%,草甸土壤为 96.6%。

2.2 纳帕海湿地土壤氮矿化特征

纳帕海不同类型土壤氮的矿化特征差异显著 ($P < 0.05$) (表 2), 3 种类型土壤氮的净矿化速率不同时期均表现为沼泽化草甸 > 草甸 > 沼泽, 沼泽湿地土壤氮的净矿化速率在整个生长季均为负值, 而沼泽化草甸和草甸土壤在 5—7 月份和 7—9 月份为负值, 9—11 月份为正值。3 种类型土壤氮的净氨化速率在 5—7 月份和 7—9 月份表现为草甸 > 沼泽化草甸 > 沼泽, 在 9—11 月份表现为沼泽化草甸 > 草甸 > 沼泽。3 种类型土壤氮的净硝化速率在 5—7 月份和 7—9 月份表现为沼泽 > 沼泽化草甸 > 草甸, 在 9—11 月份表现为草甸 > 沼泽化草甸 > 沼泽。整个生长季, 沼泽和草甸土壤氮矿化为硝化作用, 铵态氮向硝态氮转化; 而沼泽化草甸土壤氮矿化为氨化作用。

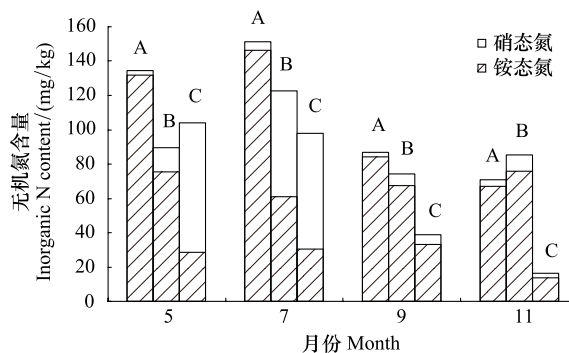


图 1 纳帕海湿地土壤中无机氮含量的季节动态 (A. 沼泽; B. 沼泽化草甸; C. 草甸)

Fig.1 The seasonal dynamics of inorganic N content in soils of swamp (A), swamp meadow (B) and meadow (C) in Napahai wetland

表 2 纳帕海湿地土壤氮矿化特征

Table 2 The N mineralization characteristics in soils of swamp, swamp meadow and meadow in Napahai wetland

项目 Item	培养期 (月) Incubation stage (Month)	沼泽 Swamp	沼泽化草甸 Swamp meadow	草甸 Meadow
净氮矿化速率 / (mg·kg ⁻¹ ·d ⁻¹)	5—7	-0.69 (0.03) c	-0.21 (0.09) a	-0.41 (0.19) b
Net nitrogen mineralization rate	7—9	-1.24 (0.24) a	-0.88 (-0.11) a	-1.05 (0.14) a
	9—11	-0.58 (0.25) c	1.00 (0.56) a	0.11 (0.03) b
净氨化速率 / (mg·kg ⁻¹ ·d ⁻¹)	5—7	-0.73 (0.01) c	-0.21 (0.12) b	-0.16 (0.11) a
Net ammonification rate	7—9	-1.24 (0.27) c	-0.03 (0.01) b	-0.01 (0.01) a
	9—11	-0.61 (0.24) c	0.94 (0.59) a	-0.09 (0.06) b
净硝化速率 Net nitrification rate	5—7	0.04 (0.02) a	0.01 (0.00) b	-0.25 (0.09) c
/(mg·kg ⁻¹ ·d ⁻¹)	7—9	-0.01 (0.00) a	-0.85 (0.27) a	-1.04 (0.21) a
	9—11	0.037 (0.02) a	0.06 (0.06) a	0.19 (0.07) a

括号内的数值为标准差; 同行内含有相同上标字母表示差异不显著 ($P < 0.05$)

2.3 纳帕海湿地土壤氮矿化与土壤环境的关系

纳帕海不同类型土壤氮矿化特征与土壤环境因子的相关关系如表 3 所示。沼泽湿地土壤净氮矿化速率与土壤的硝态氮含量、有机质含量、碳氮比和含水量均呈显著的负相关关系; 沼泽化草甸湿地土壤的净氮矿化

表 3 纳帕海湿地土壤氮矿化速率与土壤环境因子的相关性

Table 3 The relationships between net N mineralization and environmental factors in soils of swamp, swamp meadow and meadow in Napahai wetland

类型 Type	指数 Index	铵态氮 Ammonium nitrogen	硝态氮 Nitrate nitrogen	有机质 Organic matter	碳氮比 C/N	容重 Bulk density	含水量 Moisture content
沼泽 Swamp	相关性 Pearson correlation	-0.787	-0.999 *	-0.916	-0.963	-0.287	-0.897
	显著性 Significance	0.423	0.024	0.262	0.173	0.815	0.292
沼泽化草甸 Swamp meadow	相关性 Pearson correlation	0.279	-0.843	-0.568	-0.890	0.620	0.783
	显著性 Significance	0.820	0.362	0.616	0.302	0.574	0.428
草甸 Meadow	相关性 Pearson correlation	0.575	-0.774	0.954	-0.551	-0.992	0.768
	显著性 Significance	0.610	0.436	0.195	0.629	0.081	0.442

* 在 0.05 水平上显著相关

速率与土壤的硝态氮含量、碳氮比呈显著的负相关关系,与含水量呈显著正相关关系;草甸土壤的净氮矿化速率与土壤的硝态氮含量和容重均呈显著的负相关关系,与有机质含量和含水量呈显著的正相关关系。可见,土壤硝态氮含量、有机质含量、碳氮比和含水量均对纳帕海沼泽、沼泽化草甸和草甸土壤的氮矿化产生显著影响。

3 讨论

3.1 不同湿地类型对土壤净氮矿化速率的影响

5—7 月份和 7—9 月份,纳帕海沼泽、沼泽化草甸和草甸土壤净氮矿化速率在均为负值,土壤无机氮向有机氮转化,系统净消耗无机氮。这可能由于植物处于快速生长阶段,植物大量吸收无机氮,土壤无机氮减少,表现为固持状态。9—11 月份,沼泽湿地土壤净氮矿化速率在均为负值,而沼泽化草甸和草甸土壤净氮矿化速率均为正值。即,沼泽湿地土壤无机氮向有机氮转化,系统净消耗无机氮;而沼泽化草甸和草甸土壤有机氮向无机氮转化,无机氮为净积累。这可能与土壤环境有关。沼泽湿地地表常年积水,土壤水分过饱和,土壤透气性差,导致厌氧微生物和反硝化细菌生长活跃,部分无机氮以气体形式散失,由反硝化作用引起的氮损失可能是导致净氮矿化速率出现负值的主要原因。相比而言,沼泽化草甸和草甸土壤透气性好,有利于好氧微生物和硝化细菌生长,促进了土壤氮的矿化。植物生长期,纳帕海湿地土壤的净氮矿化速率表现为沼泽化草甸>草甸>沼泽。说明干湿交替的土壤环境更利于土壤氮矿化作用的进行,土壤中氮素有效性和维持植物可利用氮素的能力更强。

3.2 环境因子对土壤净氮矿化速率的影响

土壤氮矿化作用与土壤环境密切相关,土壤的氮矿化速率受土壤水热条件^[19]、养分条件^[20]、微生物^[21]等因素综合影响。Kader 等^[22]研究表明土壤氮矿化速率与矿质氮含量呈负相关。本研究发现沼泽、沼泽化草甸和草甸土壤的氮矿化速率均与土壤的矿质氮含量呈显著负相关。这表明土壤中存在一个控制氮矿化的反馈机制,即较高的矿质氮初始值限制了土壤氮矿化。这种关系随土壤水分含量而变化,当土壤水分较充足时上述关系明显,而水分含量较低时不太明显,原因是低水分限制了土壤氮矿化^[23]。本研究也表明土壤水分含量对沼泽、沼泽化草甸和草甸土壤的氮矿化均产生显著影响。Kader 等^[22]研究表明厌氧环境下,土壤氮矿化速率与培养前土壤有机质含量呈负相关关系。本研究中,沼泽和沼泽化草甸常年或季节性淹水,土壤透气性差,处于厌氧环境,其土壤氮矿化速率与培养前有机质含量呈负相关关系。而草甸土壤透气性好,处于有氧环境,其土壤氮矿化速率与培养前有机质含量呈正相关关系。可见,土壤有机质含量对氮矿化作用的影响受土壤透气性的制约。

References:

- [1] Mitsch W J, Gosselink J G. Wetlands. New York: Van Nostrand Reinhold Company Inc., 2000: 89-125.
- [2] Bai J H, Li X W, Cui B S, Wang Q G. Nitrogen in wetland soils: a review. *Soil*, 2006, 38(2): 143-147.
- [3] Guo X L. Study on the Characteristics of Nitrogen Cycling in Plant-Soil System in Wetlands Along a Water Level Gradient in the Sanjiang Plain [D]. Changchun: Northeast Normal University, 2008.
- [4] Lang M, Cai Z C, Mary B, Hao X Y, Chang S X. Land-use type and temperature affect gross nitrogen transformation rates in Chinese and Canadian soils. *Plant and Soil*, 2010, 334(1/2): 377-389.
- [5] Bannert A, Kleinedam K, Wissing L, Mueller-Niggemann C, Vogelsang V, Welzl G, Cao Z H, Schlöter M. Changes in diversity and functional gene abundances of microbial communities involved in nitrogen fixation, nitrification, and denitrification in a Tidal Wetland versus paddy soils cultivated for different time periods. *Applied and Environmental Microbiology*, 2011, 77(17): 6109-6116.
- [6] Geurts J J M, Smolders A J P, Banach A M, van de Graaf J P M, Roelofs J G M, Lamers L P M. The interaction between decomposition, net N and P mineralization and their mobilization to the surface water in fens. *Water Research*, 2010, 44(11): 3487-3495.
- [7] Maltais-Landry G, Maranger R, Brisson J, Chazarenc F. Nitrogen transformations and retention in planted and artificially aerated constructed wetlands. *Water Research*, 2009, 43(2): 535-545.
- [8] Bedard-Haughn A, Matson A L, Pennock D J. Land use effects on gross nitrogen mineralization, nitrification, and N₂O emissions in ephemeral

- wetlands. *Soil Biology and Biochemistry*, 2006, 38(12): 3398-3406.
- [9] Yu S, Ehrenfeld J G. The effects of changes in soil moisture on nitrogen cycling in acid wetland types of the New Jersey Pinelands (USA). *Soil Biology & Biochemistry*, 2009, 41(12): 2394-2405.
- [10] Bohlen P J, Gathumbi S M. Nitrogen cycling in seasonal wetlands in subtropical cattle pastures. *Soil Science Society of America Journal*, 2007, 71(3): 1058-1065.
- [11] Noe G B. Measurement of net nitrogen and phosphorus mineralization in wetland soils using a modification of the resin-core technique. *Soil Science Society of America Journal*, 2011, 75(2): 760-770.
- [12] Turner M M, Henry H A L. Net nitrogen mineralization and leaching in response to warming and nitrogen deposition in a temperate old field: the importance of winter temperature. *Oecologia*, 2010, 162(1): 227-236.
- [13] Sun Z G, Liu J S. Soil nitrogen net mineralization and nitrification in typical *Calamagrostis angustifolia* wetlands in Sanjiang Plain. *Chinese Journal of Applied Ecology*, 2007, 18(8): 1771-1777.
- [14] Zhao Q Q. Study of Nitrogen Mineralization Dynamics in Soil of Taihu Lake Zone [D]. Nanjing: Nanjing Forest University, 2011.
- [15] Gao J Q, Ouyang H, Zhang F, Wang C M. The response of soil nitrogen mineralization to soil temperature and soil moisture in Zoige Alpine Wetland. *Wetland Science*, 2008, 6(2): 229-234.
- [16] Tian K, Lu M, Chang F L, Mo J F, Li L C, Yang Y X. The ecological environment degradation and degradation mechanism of Napahai Karst Wetland in southwestern Yunnan Plateau. *Journal of Lake Sciences*, 2004, 16(1): 35-42.
- [17] Tian K, Mo J F, Lu M, Chang F L, Yang Y X. Human disturbances on the ecological environment degradation of Napahai Wetland in the upstream of Yangtze river. *Resource and Environment in the Yangtze Basin*, 2004, 13(3): 292-295.
- [18] Zhang K, Tian K, Lü X G, Tong S Z. Response of meadow soil nitrogen to hydro-periods in Napahai Plateau Wetland. *Environmental Science*, 2009, 30(8): 2216-2220.
- [19] Noe G B, Hupp C R, Rybicki N B. Hydrogeomorphology influences soil nitrogen and phosphorus mineralization in floodplain wetlands. *Ecosystems*, 2013, 16(1): 75-94.
- [20] Vernimmen R R E, Verhoef H A, Verstraten J M, Bruijnzeel L A, Klomp N S, Zoomer H R, Wartenbergh P E. Nitrogen mineralization, nitrification and denitrification potential in contrasting lowland rain forest types in Central Kalimantan, Indonesia. *Soil Biology and Biochemistry*, 2007, 39(12): 2992-3003.
- [21] Sparrius L B, Kooijman A M. Nitrogen deposition and soil carbon content affect nitrogen mineralization during primary succession in acid inland drift sand vegetation. *Plant and Soil*, 2013, 364(1/2): 219-228.
- [22] Kader M A, Sleutel S, Begum S A, Moslehuddin A Z M, de Neve S. Nitrogen mineralization in sub-tropical paddy soils in relation to soil mineralogy, management, pH, carbon, nitrogen and iron contents. *European Journal of Soil Science*, 2013, 64(1): 47-57.
- [23] Haramoto E R, Brainard D C. Strip tillage and oat cover crops increase soil moisture and influence N mineralization patterns in cabbage. *Hortscience*, 2012, 47(11): 1596-1602.

参考文献:

- [2] 白军红, 李晓文, 崔保山, 王庆改. 湿地土壤氮素研究概述. *土壤*, 2006, 38(2): 143-147.
- [3] 郭雪莲. 三江平原不同水位梯度湿地植物-土壤系统氮循环特征研究 [D]. 长春: 东北师范大学, 2008.
- [13] 孙志高, 刘景双. 三江平原典型小叶章湿地土壤氮素净矿化与硝化作用. *应用生态学报*, 2007, 18(8): 1771-1777.
- [14] 赵琦齐. 太湖湖滨带湿地土壤氮矿化动态研究 [D]. 南京: 南京林业大学, 2011.
- [15] 高俊琴, 欧阳华, 张锋, 王春梅. 若尔盖高寒湿地土壤氮矿化对温度和湿度的响应. *湿地科学*, 2008, 6(2): 229-234.
- [16] 田昆, 陆梅, 常凤来, 莫剑锋, 黎良才, 杨永兴. 云南纳帕海岩溶湿地生态环境变化及驱动机制. *湖泊科学*, 2004, 16(1): 35-42.
- [17] 田昆, 莫剑锋, 陆梅, 常凤来, 杨永兴. 人为活动干扰对纳帕海湿地环境影响的研究. *长江流域资源与环境*, 2004, 13(3): 292-295.
- [18] 张昆, 田昆, 吕宪国, 佟守正. 纳帕海湖滨草甸湿地土壤氮动态对水文周期变化的响应. *环境科学*, 2009, 30(8): 2216-2220.

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《生态学报》主要报道生态学及各分支学科的重要基础理论和应用研究的原始创新性科研成果。特别欢迎能反映现代生态学发展方向的优秀综述性文章;研究简报;生态学新理论、新方法、新技术介绍;新书评价和学术、科研动态及开放实验室介绍等。

《生态学报》为半月刊,大 16 开本,280 页,国内定价 90 元/册,全年定价 2160 元。

国内邮发代号:82-7,国外邮发代号:M670

标准刊号:ISSN 1000-0933 CN 11-2031/Q

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生 态 学 报

(SHENGTAI XUEBAO)

(半月刊 1981 年 3 月创刊)

第 33 卷 第 24 期 (2013 年 12 月)

ACTA ECOLOGICA SINICA

(Semimonthly, Started in 1981)

Vol. 33 No. 24 (December, 2013)

编 辑	《生态学报》编辑部 地址:北京海淀区双清路 18 号 邮政编码:100085 电话:(010)62941099 www.ecologica.cn shengtaixuebao@rcees.ac.cn	Edited by	Editorial board of ACTA ECOLOGICA SINICA Add: 18, Shuangqing Street, Haidian, Beijing 100085, China Tel: (010)62941099 www.ecologica.cn shengtaixuebao@rcees.ac.cn
主 编	王如松	Editor-in-chief	WANG Rusong
主 管	中国科学技术协会	Supervised by	China Association for Science and Technology
主 办	中国生态学学会 中国科学院生态环境研究中心 地址:北京海淀区双清路 18 号 邮政编码:100085	Sponsored by	Ecological Society of China Research Center for Eco-environmental Sciences, CAS Add: 18, Shuangqing Street, Haidian, Beijing 100085, China
出 版	科 学 出 版 社 地址:北京东黄城根北街 16 号 邮政编码:100717	Published by	Science Press Add: 16 Donghuangchenggen North Street, Beijing 100717, China
印 刷	北京北林印刷厂	Printed by	Beijing Bei Lin Printing House, Beijing 100083, China
发 行	科 学 出 版 社 地址:东黄城根北街 16 号 邮政编码:100717 电话:(010)64034563 E-mail: journal@cspg.net	Distributed by	Science Press Add: 16 Donghuangchenggen North Street, Beijing 100717, China Tel: (010)64034563 E-mail: journal@cspg.net
订 购	全国各地邮局	Domestic	All Local Post Offices in China
国外发行	中国国际图书贸易总公司 地址:北京 399 信箱 邮政编码:100044	Foreign	China International Book Trading Corporation Add: P.O.Box 399 Beijing 100044, China
广告经营 许 可 证	京海工商广字第 8013 号		



ISSN 1000-0933
CN 11-2031/Q

国内外公开发行

国内邮发代号 82-7

国外发行代号 M670

定价 90.00 元