# ESTIMATION OF ATMOSPHERIC NITROGEN DEPOSITION TO TAIHU LAKE FROM TAIHU WATERSHED, CHINA

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**Abstract.** In this study, the catchment area of Taihu Lake, China, was divided into four parts: water area, farmland area, construction land and vegetation area, and the total amount of atmospheric nitrogen deposition from the catchment area into the Taihu Lake was estimated. The results showed that the total nitrogen deposition from the water area, farmland, urban construction land and vegetation area into the water were 38667.5 t, 124596.1 t, 52653.2 t and 11107.8 t, respectively. The atmospheric nitrogen deposition entering into water was 227024.6 t eventually, accounting for 80.5% of total atmospheric nitrogen deposition, which has exceeded the nitrogen content of agricultural non-point source pollution, industrial sewage, domestic sewage and other exogenous pollution. Nitrogen deposition in farmland area is the main source of entering Taihu Lake. Atmospheric nitrogen deposition may be the main pollution source into the Taihu basin. Atmospheric nitrogen deposition plays an important role in the input of exogenous nitrogen in Taihu Lake, which is an important source of nitrogen and plays an important role in eutrophication. It is recommended to take necessary measures to control atmospheric nitrogen deposition, for example, reduce energy-intensive industries, build buffer strips, ecological ditches, and three- dimensional greening.

**Keywords:** *water area, farmland, vegetation, agricultural production, buffer strips, three-dimensional greening*

## Introduction

Reactive nitrogen (Nr) has significantly increased over the past 150 years because of emissions from fossil fuels burning, industry and fertilizer and transportation development, at the rate of about 10 times higher than a century ago (Meunier et al., 2016). Excessive atmospheric nitrogen (N) deposition resulted in the negative impacts on the function and biodiversity of terrestrial ecosystems (Porter et al., 2013; Stevens et al., 2018). Atmospheric N deposition is also an important reason for water eutrophication (Xu et al., 2018), especially in some plateau and mountain lakes (Hundey et al., 2015). Compared with other pollution sources, atmospheric N deposition also affected food production, environmental quality and climate change from the regional to global scales, and further threat to human health especially in highly populated regions (Yu et al., 2019). However, it is difficult to observe and quantify atmospheric N deposition, especially dry deposition (Ti et al., 2018).

In the temperate terrestrial ecosystems, constant anthropogenic N input accelerated plant growth, but N over-enrichment would result in N loss eventually, which has changed the species composition and caused ecosystem degradation (Gilliam et al.,


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2016). Anthropogenic N emissions lead to acid rain and soil acidification, which damages plants through leaves and soil, and leads to nutrient deficiency and forest decline (Abrahamsen et al., 2012; Zheng et al., 2018). In addition, soil acidification increased the activity of soil aluminum ion and elements in soil, which was toxic to plants and humans (Fujii et al., 2018; Meng et al., 2019).

Atmospheric N deposition is an important source of lakes pollution (Xie et al., 2007; Ellis et al., 2105; Chen et al., 2018). It has resulted in acidification and eutrophication of freshwater ecosystems (Brittain and Strecker, 2018). It changed abundance and composition of phytoplankton in lakes (Lepori and Keck, 2012; Benavides-Ordillo et al., 2019). It also affected biogeochemical cycle, trophic dynamics and biological diversity (Meunier et al., 2015). Excess N deposition resulted in acidification of water and soil, eutrophication of water in lakes and rivers, depleted or wiped out the fish stocks, which also affected the aquatic animals and plants, and the structure and function of aquatic ecosystem (Gao et al., 2014; Geng et al., 2021; Mcdonnell et al., 2021).

In China, N deposition amount was 13.2 kg N $ha^{-1}$ in 1980s, and reached 21.1 kg N $ha^{-1}$ in the 2000s (Liu et al., 2013). Taihu Lake is the third largest freshwater lake in China. Taihu Lake basin is one of the most densely populated and urbanized areas in China. Industry, agriculture and transportation are well developed in this area. Atmospheric N deposition is also an important N input source of the Taihu Lake, which would affect the water quality of the lake and the growth of plankton (Di et al., 2015). Taihu basin has been a hotspot for atmospheric N deposition. In 1980s, the total amount of N deposition was less than 3000 t $yr^{-1}$ in the Taihu basin because of less industrial development, and less N emissions during industrial and agricultural production (Xu et al., 2019). N emissions and deposition have also increased with the development of industrial and agricultural production since the 1990s. Total N deposition entering into the lake was 9981 t $yr^{-1}$ from 2002 to 2003, which represents about 48.8% of total annual N inputs via inflow rivers (Yang et al., 2007). In the Taihu basin, the total N deposition was 20978 t $yr^{-1}$ in 2011 (Liu et al., 2012). The N wet deposition from 2003 to 2004 was 7329.5 t $yr^{-1}$ (Wang et al., 2009), from 2009 to 2010 was up to 10868 t $yr^{-1}$ (Yu et al., 2011) and was up to 12062 t $yr^{-1}$ in 2012 (Li et al., 2015). N deposition was 50-60 kg N $ha^{-1}$ $yr^{-1}$ in 2013, but the same latitude of Sichuan was only 15-21 kg N $ha^{-1}$ $yr^{-1}$, the Tibetan Plateau without industrial pollution only 10-14 kg N $ha^{-1}$ $yr^{-1}$ (Zhu et al., 2015), the N deposition in Taihu Lake would reach 18447.5-22137.0 t $yr^{-1}$ in 2013 according to this result. It is evident that the total amount of atmospheric N deposition in Taihu Lake was increasing, and significantly aggravated lake eutrophication (Luo et al., 2007). Previous studies have shown that the N load transmitted from the atmosphere to water body may be close to the load of rivers and other point sources in Taihu Lake. N deposition in contaminated regions contributed by precipitation may be elevated by 1-2 orders of magnitude compared to uncontaminated regions (Wang et al., 2017).

In the above-mentioned estimation process, the total amount of atmospheric N deposition from the water surface of Taihu Lake was estimated, but the amount of N deposition entering into the lake from the whole watershed was not estimated. The total area of Taihu lake catchment is 36895 $km^2$, but the water area of Taihu is only 2338 $km^2$, accounting for 6.3% of the catchment area. Therefore, the main objective of this study is to analyze the contribution of atmospheric N deposition entering into the Taihu lake from the whole watershed, analyze the total amount of N uptake and leach by different land use, and find out the main source of N deposition entering into the Taihu Lake, and to provide scientific suggestions for controlling lake eutrophication.


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So, the watershed catchment can be divided into different areas depending upon the variability of absorption of N deposition, which fully considers the impact of atmospheric N deposition on water body in the whole watershed, and plays an important role in analyzing the impact of atmospheric N deposition on water body, especially the external sources of N.

## Materials and methods

### *Study area*

Taihu Lake is located in the Yangtze River delta, the most developed area of China in industry and agriculture (*Fig. 1*). A large amount of N is released in the process of industrial, agricultural production and transportation. The water quality of Taihu Lake is deteriorating gradually. In recent decades, with the deterioration of water quality, the algal bloom outbreaks are frequent. Taihu Lake has brought a great impact on economic and social development within the Taihu basin. Since the 1980s, the amount of pollutants discharged into the Taihu Lake has increased dramatically, which resulted in deterioration of the lake ecosystem and appearance of harmful algal blooms. Many studies have been taken to restore the lake ecosystem since the 1990s. However, the lake water quality has not shown any significant improvement.

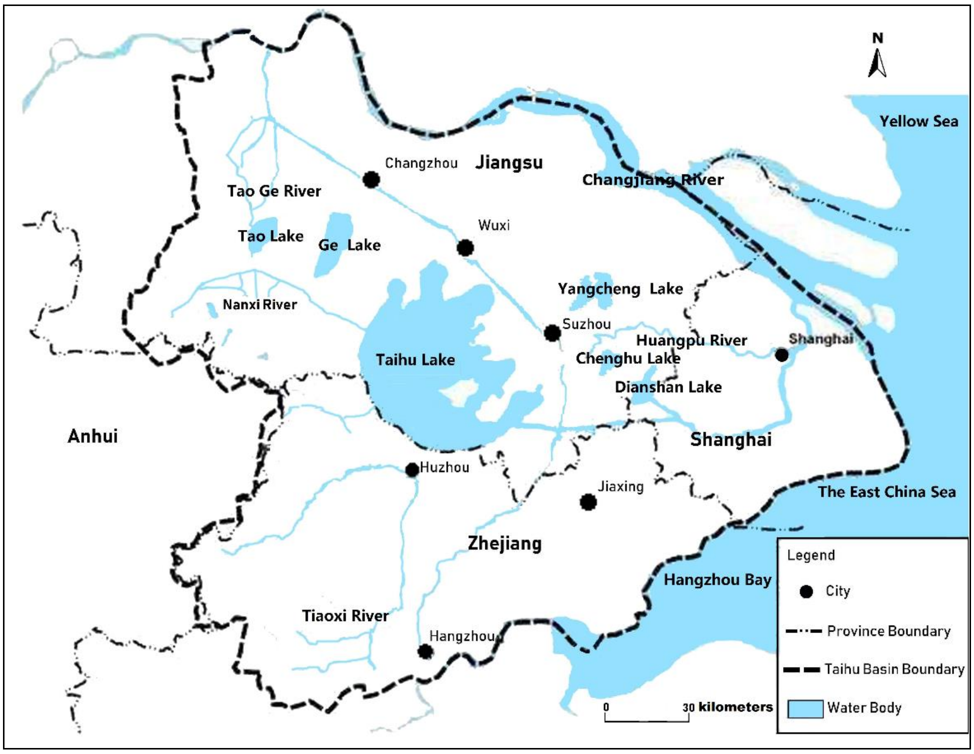


***Figure 1.*** *Lake and city distribution in Taihu basin*

### *Data sources*

Some important cities and water areas in the Taihu basin are shown in *Figure 1*. Precipitation N ion content was obtained from environmental monitoring stations in


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Suzhou, Wuxi and Changzhou in 2014, and the value of the dry deposition rate in 2014 is referenced by Ti et al. (2018). N ion concentration of precipitation (from Aug. 2013 to Aug. 2014) in Hangzhou, Jiaxing and Huzhou was acquired from the research of Wang et al. (2015). N ion of precipitation (from Sep. 2014 to Sep. 2015) in Shanghai was obtained from a study of Deng et al. (2016). Precipitation data came from Statistical Yearbooks of the cities in 2014 (Suzhou, Wuxi, Changzhou, Hangzhou, Jiaxing, Huzhou, Shanghai (excluding Chongming)). Data on vegetation and land use in Taihu basin was taken from land use map at the scale of 1:100,000 (2015) (*Fig. 2*). The data of the agricultural output, poultry and livestock output, chemical fertilizer, population were obtained from Statistical Yearbooks of Suzhou, Wuxi, Changzhou, Jiaxing, Huzhou, Hangzhou and Shanghai (excluding Chongming) respectively.

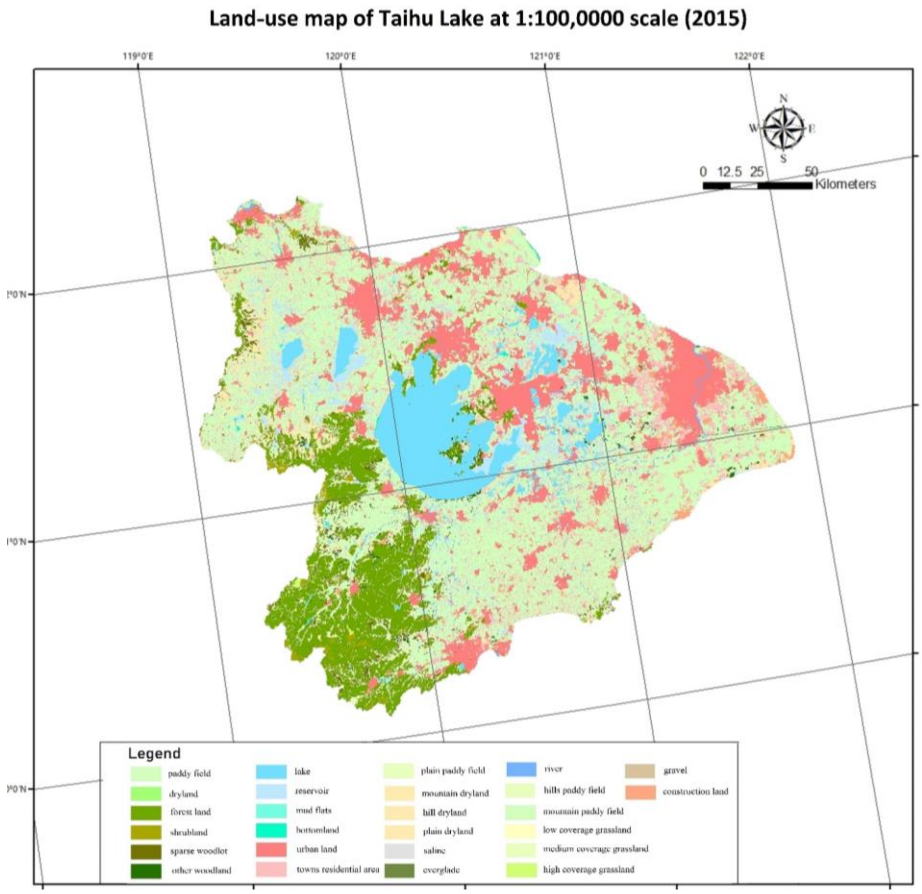


***Figure 2.*** *Land-use map of Taihu Lake basin at 1:100,000 scale (2015)*

## *Estimation method of N deposition*

### *Estimation method of N deposition from catchment into Taihu Lake*

According to the landuse vectorgraph in Taihu basin at the scale of 1:100,000 (2015) (*Fig. 2*), Taihu Lake basin was divided into four sections in accordance with the land-use classification, those are water area (lake, river, reservoir and everglade), farmland (paddy field, plain paddy field, hills paddy field, mountain paddy field, dryland, mountain dryland, hill dryland, plain dryland), vegetation area (forest land, shrubland, sparse woodlot, low-coverage grassland, medium-coverage grassland, high-coverage


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grassland), urban construction land (UCL) (urban land and towns residential area), respectively. Some gravel and saline were not included in the statistics, because their area was less than 0.003%. There are great differences in atmospheric N deposition in different land-use patterns. The atmospheric N can be directly accepted by the water area, while the atmospheric N deposition will be absorbed by crops in the farmland and then discharged into the Taihu Lake. In forest and grassland, N deposition is absorbed by vegetation. If N cannot be absorbed completely by the vegetation, the excessive N will be discharged into the Taihu Lake, if N is absorbed completely, the total amount of N deposition entering into the Taihu Lake will be zero. When the atmospheric N deposition is only absorbed by the urban green space in the urban area, the remaining part will afflux into the Taihu Lake.

Therefore, N deposition from catchment entering into Taihu Lake can be expressed as:

$$N_{\mathrm{input}} = N_{\mathrm{wat}} + N_{\mathrm{far}} + N_{\mathrm{veg}} + N_{\mathrm{urb}} \qquad \text{(Eq.1)}$$

where $N_{\mathrm{wat}}$ represents N deposition from water area, $N_{\mathrm{far}}$ represents N deposition from farmland into the lake, $N_{\mathrm{veg}}$ represents N deposition from vegetation area, and $N_{\mathrm{urb}}$ represents N deposition from UCL into the lake.

*Estimation method of each component*

(1) Estimation of total N deposition ($N_{\mathrm{total}}$)

The estimation method of wet deposition is the precipitation collection method. The total amount of wet deposition is calculated using N deposition in each precipitation, so the wet N deposition is expressed as:

$$F_w = \sum_{i=1}^{n} Ci \times Pi \qquad \text{(Eq.2)}$$

where $F_{\mathrm{w}}$ represents the total amount of wet N deposition (kg N·hm$^{-2}$); $C_{\mathrm{i}}$ represents the average concentration of N deposition (mg N·L$^{-1}$) in every area; $P_{\mathrm{i}}$ represents per precipitation (mm).

Dry N deposition is calculated according to particulate ammonium and nitrate concentrations in the aerosols. It can be expressed as:

$$F_{\mathrm{dry}} = F_{\mathrm{d}} \times A = C_{\mathrm{a}} \times V_{\mathrm{d}} \times A \qquad \text{(Eq.3)}$$

where $F_{\mathrm{d}}$ is the dry deposition rate of N (kg N km$^{-2}$·d$^{-1}$), $C_{\mathrm{a}}$ is the concentration of N in aerosol particles, $V_{\mathrm{d}}$ is the dry deposition rate of aerosol particles. $A$ represents the basin area. So the total N deposition is equal to the sum of dry deposition and wet deposition.

$$N_{\mathrm{total}} = F_{\mathrm{w}} + F_{\mathrm{dry}} \qquad \text{(Eq.4)}$$

(2) Estimation method of N deposition in water area ($N_{\mathrm{wat}}$)

There are many water areas in Taihu watershed, including Taihu Lake, Ge Lake, Yangcheng Lake etc., they are scattered in the Taihu basin. The dry N deposition and wet N deposition can be deposited into water portion.


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N deposition in water area is expressed as:

$$N_{wat} = (R_{wat} / R_{tot}) \times N_{total} \quad \text{(Eq.5)}$$

where $R_{wat}$ is the water area, $R_{tot}$ is the total basin area.

(3) Estimation method of N deposition from farmland entering into the lake ($N_{far}$)

The N absorption rate is used to estimate the N deposition from farmland into Taihu Lake. There are four main ways of N input in farmland in the Taihu Lake basin, i.e. chemical fertilizer ($N_{fert}$), N input from human and livestock excreta ($N_{exc}$), biological N fixation ($N_{fix}$) and atmospheric N deposition ($N_{dep}$) in farmland. In this study, it is assumed that all forms of N input are equally absorbed by the crops. Therefore, the rest of the atmospheric N deposition is considered to enter into the lake after absorption by all plants.

① The chemical fertilizer is the most important N input in the process of agricultural production in Taihu basin. The final N input amount of chemical fertilizer ($N_{fert}$) is calculated as follows:

$$\mathrm{N}_{fert} = \sum_{\mathrm{i}=1}^{\mathrm{m}} \mathrm{N}_{\mathrm{fert_i}} \quad \text{(Eq.6)}$$

where $N_{fert}$ represents the total N amount of chemical fertilizer to farmland, $N_{ferti}$ represents the *i* kind N chemical fertilizer to farmland (pure N).

② N input from human and livestock excreta ($N_{exc}$): The N input of excreta mainly comes from the agricultural population, livestock and poultry in the Taihu basin. The data of agricultural population, the amount of livestock and poultry in the Taihu basin is obtained by the Statistical Yearbooks of all regions. The calculation equation of livestock and poultry quantity is as follows (Yan et al., 2010):

$$Lpp = Bs + S \times 0.542 \quad \text{(Eq.7)}$$

where *Lpp* represents livestock and poultry population, *Bs* represents breeding stock, *S* represents slaughter capacity.

The N input is calculated as follows:

$$N_{exctotal} = \sum_{i=1}^{m} N_{exci} \quad \text{(Eq.8)}$$

where $N_{exci}$ is N input from all types of human or livestock waste, $N_{exctotal}$ is the total amount of N in excreta.

Because the rate of excrements as a fertilizer to fields is low in Taihu basin, therefore, the N input from excrement does not return to the fields completely, the amount of N to fields is calculated as the following:

$$N_{exc} = r_{exc} \times N_{exctotal} \quad \text{(Eq.9)}$$

where $r_{exc}$ is the coefficient ($r_{exc}$) from excrement to fields.


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③ N fixation by crop ($N_{fix}$): The N fixation rate of crops is quite different between various crops. The yield of main crops is obtained from the local Statistical Yearbooks, and the total N fixation amount of crops is calculated according to the N fixation coefficient of various crops. Therefore, the N fixation of crops can be calculated by the following equation:

$$N_{fix} = \sum_{i=1}^{n} A_i \times Ci \quad \text{(Eq.10)}$$

where $N_{fix}$ represents the N fixation amount of the crops, $A_i$ represents the plant area of certain crops, $C_i$ represents the N fixation coefficient of a certain crop.

④ Atmospheric N deposition of farmland ($N_{dep}$): The amount of N deposition in farmland can be calculated by the following equation:

$$N_{dep} = R_2 \times N_{total} \quad \text{(Eq.11)}$$

where $R_2$ represents the ratio of the farmland area to the Taihu basin area.

⑤N assimilation in crops ($N_{ass}$): The N content of the main crops in the Taihu Lake area is calculated according to the N absorption rate of the main crops. The N uptake ($N_{ass}$) can be calculated by the following equation:

$$N_{ass} = \sum_{i=1}^{m} O_i \times Ri \quad \text{(Eq.12)}$$

where $N_{ass}$ represents the N uptake amount of the crops, $O_i$ represents the output of certain crops, $R_i$ represents the absorption coefficients of N of certain crop.

If the crops absorb all forms of N uniformly, the absorption coefficients of crops to various forms of N can be obtained by the following equation:

$$r = N_{ass} / (N_{fert} + N_{exc} + N_{fix} + N_{dep}) \quad \text{(Eq.13)}$$

Therefore, the calculation equation of N entering into the Taihu basin through atmospheric N deposition is as follows:

$$N_{farm} = (1 - r \times N_{dep} / (N_{fert} + N_{exc} + N_{fix} + N_{dep})) \times N_{dep} \quad \text{(Eq.14)}$$

(4) Estimation method of N deposition from UCL entering into the lake （$N_{urb}$）

The afforestation rate of UCL is rather higher in the Taihu basin, so atmospheric N deposition in UCL does not all enter into the water body. Some of N deposition is absorbed by the urban green spaces, while the rest of N deposition can be regarded as entering into the lake. So the calculation equation is the following:

$$N_{urb} = R_3 \times N_{total} - \sum_{i=1}^{n} A_i \times f_{gb} \quad \text{(Eq.15)}$$

where $R_3$ represents the ratio of UCL in Taihu basin. $A_i$ represents the urban green space ， $f_{gb}$ represents N absorption rate of green space ($kg \cdot hm^{-2}$).


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(5) Estimation method of N deposition from vegetation area entering into the lake ($N_{veg}$)

In the vegetation area, when the atmospheric N deposition is absorbed and saturated by vegetation and soil, the excess N will be discharged to the lake. Therefore, it is necessary to consider the critical point of different soil types when estimating the N deposition entering into water bodies. Therefore, the important step is to estimate whether the regional atmospheric N deposition exceeded the N critical loads. If it exceeds the N critical loads, the excess part is regarded as entering into the water; if it does not exceed the loads, it is regarded as being absorbed and utilized by vegetation (Song et al., 2014).

At present, the simple mass balance method (SMB) is widely used to estimate the critical load of atmospheric N deposition. The basic equation is as follows:

$$CL_N = N_i + N_{up} + N_{de} + N_{le,crit} \quad \text{(Eq.16)}$$

where $CL_N$ represents the critical loads of N deposition; $N_i$ represents the mineralization rate of soil N; $N_{up}$ represents the rate of N uptake by vegetation; $N_{de}$ represents the denitrification rate of N in soil; $N_{le,erit}$ represents the critical point of soil N leaching rate (Posch et al., 2015).

$N_{de}$ is the denitrification rate of N, the denitrification rate is linear with the net N input, Therefore, the calculation equation is as follows (Posch et al., 2015):

$$N_{de} = \begin{cases} f_{de}(N_d - N_i - N_{up}) & N_d > N_i + N_{up} \\ 0 & N_d \le N_i + N_{up} \end{cases} \quad \text{(Eq.17)}$$

where $N_d$ represents N deposition in the vegetation area of Taihu basin. According to the calculation of total N deposition in the region, the calculation equation is:

$$N_d = R_4 \times N_{total} \quad \text{(Eq.18)}$$

where $R_4$ is the percentage of vegetation area in the watershed.

$N_{de}$ can be ignored in well-drained vegetation cover areas. According to the above calculation, *Equation 16* can be simplified as follows:

$$CL_N = N_i + N_{up} + \frac{N_{le,crit}}{1 - f_{de}} \quad \text{(Eq.19)}$$

where $f_{de}$ represents the denitrification rate, $N_{le,erit}$ represents the critical leaching rate.

The calculation equation of the critical leaching rate ($N_{le,erit}$) of N is as follows:

$$N_{le,erit} = Q \times [N]_{crit} \quad \text{(Eq.20)}$$

where $Q$ represents the runoff, $[N]_{crit}$ represents the critical leaching concentration of N. The calculation equation of $N_{veg}$ is as follows:

$$N_{veg} = \begin{cases} N_d - CL_N \times A_f & N_d > CL_N \times A_f \\ 0 & N_d \le CL_N \times A_f \end{cases} \quad \text{(Eq.21)}$$


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where $A_f$ represents the vegetation area. When the N deposition ($N_d$) is larger than the critical loads in natural vegetation area, the excess part of N deposition can be regarded as entering into the basin. When $N_d$ in vegetation area is less than the critical load, it can be regarded as 0.

## Results

### *Watershed division of the Taihu Lake basin*

According to the land-use vectorgraph in Taihu basin at the scale of 1:100,000 (2015) (*Fig. 2*), the water area accounts for 13.70%, farmland 46.71%, vegetation area 13.91% (forest 13.44%, grassland 0.47%) and UCL 25.67%.

### *Total N deposition ($N_{total}$)*

The concentration of N deposition, the rate of wet N deposition and dry N deposition rate and total amount of wet N deposition and dry N deposition are listed in *Table 1*.

***Table 1.*** *Wet N deposition and dry N deposition rate and the total amount in every city*

| City | Concentration of N deposition (mg N •L$^{-1}$) | Wet N deposition (Kg/km$^2$ yr) | Rainfall (mm) | Total amount of wet N deposition (t) | Dry deposition rate of N (Kg/km$^2$ yr) | Total amount of dry N deposition (t) |
|---|---|---|---|---|---|---|
| Suzhou | 3.82 | 4840.5 | 1265.7 | 41088.6 | 2693.9 | 20582.8 |
| Wuxi | 4.45 | 5885.7 | 1322.5 | 27235.7 | 2858.2 | 41238.0 |
| Changzhou | 4.19 | 5504.1 | 1313.0 | 24135.5 | 2712.3 | 11893.4 |
| Hangzhou | 2.48 | 2561.6 | 1359.9 | 6045.3 | 2474.3 | 5839.3 |
| Jiaxing | 2.72 | 3170.3 | 1580.8 | 12411.5 | 2415.6 | 9457.0 |
| Huzhou | 2.69 | 3506.7 | 1443.6 | 20401.6 | 1444.1 | 8401.7 |
| Shanghai | 3.84 | 4972.4 | 1295.3 | 25747.1 | 5560.4 | 27714.2 |
| Total | | | | 157065.2 | | 125126.5 |

In this study, the total amount of wet N deposition ($Fw$) is 157065.2 t according to *Equation 2*, the total dry N deposition is 125126.5 t according to *Equation 3*, the total N deposition ($N_{total}$) 282191.8 t according to *Equation 4*.

### *N deposition in water area ($N_{wat}$)*

The ratio of $R_{wat}/R_{tot}$ is 0.1370 in this study, so the amount of N deposition ($N_{wat}$) directly from the Taihu basin into the lake is 38667.5 t according to *Equation 5*.

### *Total N deposition from farmland entering into the lake ($N_{far}$)*

① $N_{fert}$: The N fertilizer ($N_{fert}$) in the Taihu basin in 2014 is listed in *Table 2* according to the Statistical Yearbooks of Suzhou, Wuxi, Changzhou, Jiaxing, Huzhou, Hangzhou and Shanghai (excluding Chongming). So $N_{fert}$ is about 213263.6 t by *Equation 6*.

***Table 2.*** *N amount of chemical fertilizer in Taihu basin (pure N)*

| City | Suzhou | Wuxi | Changzhou | Hangzhou | Jiaxing | Huzhou | Shanghai | Summation |
|---|---|---|---|---|---|---|---|---|
| N amount of chemical fertilizer (t) | 3977 | 3160 | 22739 | 46800 | 29200 | 78100 | 29287 | 213263 |


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② $N_{exc}$: The number of agricultural population, the amount of livestock and poultry in the Taihu basin is obtained from the Statistical Yearbooks of the Taihu basin, and as shown in *Table 3*. The livestock and poultry population is calculated according to *Equation 7,* the N coefficient of people and animal excreta is referenced by the study from Zhang in 2014 (Zhang et al., 2014), the results are listed in *Table 3*. The total amount of N in excreta ($N_{exc}$) according to *Equation 8* is 342506.7 t according to *Equation 8*. The value of $r_{exc}$ is 0.1 in Taihu basin according to the study from Zhang in 2014 (Zhang et al., 2014), so the actual amount of N through excrement into farmland is 34250.7 t.

***Table 3.*** *N excretion rates and total content by human and domestic animals*

| Parameters | People (N kg/person·year) | Pig (N kg/each·year) | Cattle (N kg/each·year) | Sheep (N kg/each·year) | Rabbit (N kg/each·year) | Poultry (N kg/each·year) | Summation (t) |
|---|---|---|---|---|---|---|---|
| N discharge coefficient* | 4.0 | 4.5 | 61.1) | 2.28 | 1.0 | 0.275 | |
| Amount (10000) | 1863.5 | 1452.9 | 215.0 | 268.7 | 189.0 | 22925.2 | |
| N discharge amount (t) | 74539.2 | 65524.6 | 131382.2 | 6126.3 | 1890.1 | 63044.3 | 342506.7 |

*N discharge coefficient refers to the research results of Zhang et al. (2014)

③ $N_{fix}$: The planting area and the N fixation rate of the main crops in Taihu Lake Basin are shown in *Table 4*. The N fixation amount of the crops ($N_{fix}$) is 36350.3 t according to *Equation 10*.

***Table 4.*** *N fixation coefficient and the quantity of N fixation of staple crops*

| Parameters | Wheat | Rice | Maize | Soybean | Potatoes | Oil-bearing | Cotton | Vegetable and fruits | Other crops | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Acreage (×1000 $hm^2$) | 263.9 | 447.7 | 28.7 | 39.6 | 18.7 | 75.2 | 2.2 | 367.0 | 113.4 | |
| Fixed N coefficient (N kg/$hm^2$)* | 15.0 | 45.0 | 15.0 | 80.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | |
| Amount of fixed N (Nt) | 3958.7 | 20148.3 | 431.0 | 3165.6 | 279.8 | 1128.0 | 33.5 | 5505.0 | 1700.6 | 36350.3 |

*Fixed N coefficient refers to the research results of Zhang et al. (2014)

④ $N_{dep}$: In this study, $R_2$ is 0.4671, $N_{total}$ is 282191.8. Therefore, the calculation result of $N_{dep}$ is 131811.1 t according to *Equation 11*.

⑤ $N_{ass}$: The main agricultural output and their N absorption coefficient are shown in *Table 5,* the absorption coefficients of N can be referenced from some researches (Xu et al., 2006; Zhang et al., 2014; Gao et al., 2014). Ultimately, the N uptake ($N_{ass}$) of the crop in the Taihu Lake basin can be calculated through *Equation 12.* The total N uptake of crops is calculated as 217634.6 t.

According to the above calculation, $N_{ass}$ is 217634.6 t, $N_{fert}$ is 213263.0 t, $N_{exc}$ is 342506.7 t, $N_{fix}$ is 36350.3 t, $N_{dep}$ is 131811.1 t, and $r$ is equal to 0.2981 by *Equation 13*.

According to the calculation, the N deposition entering into the Taihu Lake from farmland is 124596.1 t by *Equation 14*, it accounts for 94.5% of N deposition in the farmland area, only 5.70% is absorbed by crops in Taihu basin, which is only 7215.0 t.


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***Table 5.** Absorption coefficient and absorptive amount of staple crops*

| Parameters | Rice | Wheat | Maize | Soybean | Potato | Oil-bearing | Cotton | Vegetables | Total |
|---|---|---|---|---|---|---|---|---|---|
| N absorption coefficient (kg/t)* | 19 | 28 | 14 | 45 | 25 | 35 | 30 | 3.5 | |
| Output ($10^4$t) | 4615141 | 1300441 | 176803 | 1268147 | 115441 | 222467 | 3057 | 6636749 | |
| N uptake amount (t) | 87687.7 | 36412.3 | 2475.2 | 57066.6 | 2886.0 | 7786.3 | 91.7 | 23228.6 | 217634.6 |

*N absorption coefficient refers to the research results of Xu et al. (2006), Zhang et al. (2014) and Gao et al. (2014)

### *Total N deposition from UCL entering into the lake ($N_{urb}$)*

UCL of every region is shown in *Table 6, $R_3$* is equal to 0.2567 in this study, so the product of $R_3$ and $N_{total}$ is 72446.3 t. The value of $f_{gb}$ in this study is 0.116 t N·hm$^{-2}$ (Zhang et al., 2019). The amount absorbed N is 19793.1 t. $N_{urb}$ is 52653.2 t by *Equation 15*.

***Table 6.** The area of UCL in Taihu basin*

| UCL | Suzhou | Wuxi | Changzhou | Hangzhou | Jiaxing | Huzhou | Shanghai | Total |
|---|---|---|---|---|---|---|---|---|
| Area/hm$^2$ | 34909 | 18543 | 8813 | 18386 | 5659 | 4792 | 80041 | 160692 |

### *Total N deposition from vegetation area entering into the lake ($N_{veg}$)*

① It is difficult to obtain the average annual mineralization rate of the soil ($N_i$), the value of $N_i$ in the Taihu basin is 0.25 keq·hm$^{-2}$·a$^{-1}$ according to Duan and Liu's researches (Duan et al., 2015; Liu et al., 2020). So $N_i$ is 0.25 keq·hm$^{-2}$·a$^{-1}$.

② The rate of N uptake by forest vegetation types ($N_{up}$) is 2.06 keq·hm$^{-2}$·a$^{-1}$ in the Taihu basin according to Sun and Duan's researches (Sun and Xie, 2014; Duan et al., 2015).

③ $R_4$ is 0.1391. $N_{total}$ is 282191.8 t, the final calculation of $N_d$ is 39252.9 t by *Equation 18*.

④ The average runoff depth in Taihu basin is 553 mm in 2014 according to the Taihu Basin and Southeast Rivers Water Resources Bulletin, so $Q$ = 553 mm. Based on considerations to protect groundwater, a lower limit of $[N]_{crit}$ = 20.0 mg/L is suggested as the critical limit (Vries et al., 2015). The value of $N_{le,erit}$ can be calculated by *Equation 20*. The value of $f_{de}$ is 0.5 according to Duan's research in 2015 (Duan et al., 2015) in the calculation *Equation 17*. Finally, $CL_N$ is 5.446 gN·m$^{-2}$·a$^{-1}$ by *Equation 19*.

$A_f$ is 5168.04 km$^2$ in this study, the maximum N load in vegetation area is calculated as 28145.1 t according to this critical load ($CL_N$), and less than the actual N deposition ($N_d$, 39252.9 t). So, the amount of N deposition entering into Taihu Lake through the vegetation area is 11107.8 t by *Equation 21*.

### *Total N deposition from the entire Basin entering into the lake ($N_{input}$)*

The N deposition in each region and the total N deposition entering into Taihu Lake is shown in *Table 7*. The final contribution of atmospheric N deposition entering into the water body is calculated by *Equation 1*. The N amount directly into the water ($N_{wat}$) is 38667.5 t. The final amount of N into the water after the crops absorption ($N_{far}$) is


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124596.1 t. The total amount of N into the water after the absorption of urban green plants ($N_{urb}$) is 52653.2 t. The amount of N after the absorption of vegetation area ($N_{veg}$) is 11107.8 t. The final N deposition entering into the basin ($N_{input}$) is 227024.6 t.

***Table 7.*** *The total amount of N deposition entering the lake from the different regions*

| Parameter | $N_{wat}$ | $N_{far}$ | $N_{urb}$ | $N_{veg}$ | $N_{input}$ |
|---|---|---|---|---|---|
| N deposition/t | 38667.5 | 124596.1 | 52653.2 | 11107.8 | 227024.6 |
| Percentage/% | 17.0 | 54.9 | 23.2 | 4.9 | 100.0 |

## Discussion

According to the above calculation, the total N deposition in the catchment area of Taihu Lake was 282191.8 t. After absorption by vegetation, soil and crops and so on, the 227024.6 t of N will eventually enter into the lake, accounted for 80.5% of the total deposition. The least N deposition was absorbed by farmland, most of N entered into Taihu Lake. It has become the main source of entering into Taihu Lake, accounted for 54.9%. The most N deposition was absorbed by vegetation, and thus few N into the water from the vegetation areas, only accounted for 4.9%. UCL reduced the N deposition entering into the water body because of the absorption of urban green space.

The improper or excessive fertilization is becoming more and more serious in Taihu Lake, and causes the environmental pollution from the non-point pollution of farmland, not only less N deposition is absorbed by it, but also becomes an important source of N emission. The agricultural production was the most contributor (62–69%) in China, especially in the developed and coastal regions that have high population densities (Xian et al., 2018). The livestock excrement is also an important source of atmospheric N emissions from the livestock production (Ti et al., 2019). There are not enough buffer strips around the farmland to absorb N deposition, which may eventually result in large amounts of N entering the water (Li et al., 2019). Therefore, the least of N deposition was absorbed by crops and most entered into the water.

Taihu basin covers only 0.38 percent of the country, but the population accounts for 10.2% of China's population, and GDP accounts for 9.9% which is 2.2 times the national average. Industry, agriculture and transportation are very developed in the Taihu Lake area in China and the number of automobiles is very high. In 2012, the proportion of urbanization in Taihu Lake has reached 77.6%. The coal burning, power production, and car ownership will all be the source of N emissions. Some models predict that China's NOx emissions decreased by 9.11% on average during 2019–2030 because of the decline in the proportion of industry (Yu and Liu, 2020). The coal consumption, electricity production, electricity production and car ownership are the source of N emissions (Wei et al., 2018), they will directly affect the level of N deposition. Continuing urbanization will reduce the vegetation area in Taihu basin, UCL is up to 24.95% in Taihu Basin, and there is little absorption of N deposition by natural vegetation in this area. Only 27.3% of the N deposition is absorbed by the urban green space, therefore, it is necessary to increase urban green space.

There are many water bodies in Taihu Basin, for example, Taihu Lake, Ge Lake, Yangcheng Lake, Dingshan Lake, etc., they can directly accept N deposition. Although the area of these lakes is only 2,838 $km^2$, accounting for 7.7% of the entire basin, and the area of other ponds and rivers only accounts for 13.7% of the entire basin. Since this


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water area is not covered by any vegetation or other objects, there will be no conversion and interception of N deposition. N from the atmosphere can enter the water body through atmospheric (rain, snow) and occult (dew, frost) precipitation, etc. (Kurzyca and Frankowski, 2019), or directly enter the water body through dry deposition. Therefore, a large amount of N can get into the water directly, the amount of N deposition in water area has reached 17.0%. Wang et al. (2017) also reported that the annual flux loads of TN from surrounding rivers, atmospheric deposition, and sediment suspension was 29600 t in 2014, and 23.5% of the TN load comes from atmospheric deposition directly entering into the lake. This result is also in agreement with our research.

N deposition can be absorbed by many plants (Gong et al., 2019), but the N deposition is absorbed to a certain extent, and more than the critical loads, N will not be absorbed (Kosonen et al., 2019), and a small amount of excess N is leached out and discharged into the water. Therefore, although the vegetation area only accounts for 13.7% of the Taihu Lake Basin, but it was found that 71.7% of the N deposition in the area was absorbed.

N deposition in the catchment area of Taihu Lake was 282191.8 t in this study, and the 227024.6 t of N deposition entered the lake. The total N emission into the Taihu Lake only reaches 141150.5 t in 2014 according to Wang’s research (Wang et al., 2019), which is only 50.0% of the atmospheric N deposition, and it is difficult to reach the impact caused by atmospheric N deposition. According to the Overall Plan for Integrated Water Environment Management in the Taihu basin (revised in 2013), by the year 2015, the maximum allowance total N emissions will be 100,818 t, but the atmospheric N deposition has exceeded this threshold. Therefore, the atmospheric N deposition may be an important source of N in the Taihu basin, which will seriously affect the development of aquatic ecosystems. The influence degree of atmospheric N deposition may exceed the total of industry, agriculture, domestic sewage.

## Conclusions and prospects

The catchment area of Taihu Lake was divided into four areas (water area, farmland area, UCL and vegetation area) to calculate the atmospheric N deposition. The amount of N deposition entering into the water from the four areas was 38667.5 t, 124596.1 t, 52653.2 t and 11107.8 t, respectively. The total N deposition entering into the lake is 227024.6 t, which contributed to 80.5% of the atmospheric N deposition in the basin. The total N into Taihu Lake through atmospheric N deposition is more than agricultural non-point source pollution, domestic sewage and industrial wastewater. Atmospheric N deposition may be the largest pollution source in Taihu Lake.

It is very important to control the atmospheric N deposition in terms of the external N input in Taihu Basin. After the calculation of agricultural non-point source pollution, domestic sewage, industrial wastewater, internal release and other control measures have achieved results, it is very important to control the atmospheric N emission. But the air pollution from thermal power plants, automobile transportation, petrochemical industry, large-scale application of chemical fertilizers and pesticide problems is becoming more and more serious. The atmospheric reactive N mainly comes from N fertilizer synthesis, fossil fuel combustion, N fertilizer applied in farmland and a large amount of volatilization of human and animal waste, as well as a small number of biological combustions, lightning process. Therefore, it is very important to control N emissions.


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It is a recommended way to popularize control-released fertilizer and optimized N management in the agricultural production, which could effectively improve N utilization efficiency and reduce N release in the course of agricultural production. Some strategies can be used in the livestock excrement treatment, for instance, manure acidification and deep manure placement, urease inhibitor, and so on. It will be effective to reduce high energy consumption industries in the process of industrial production, so the fossil fuel consumption can be decreased. It is necessary to develop clean energy vigorously, and increase the recovery and treatment of N in the combustion process of fossil fuels. In the meantime, control the number and travel of motor vehicles, develop public transport, these measures will effectively reduce N emissions.

In addition, increasing N absorption can significantly reduce the total amount of N deposition entering into the lake. Buffer strips and ecological channels can be build around the farmland, the buffer strips may intercept and retain nutrients from surface runoff, the ecological channels can absorb and remove nutrients such as N and phosphorus, and reduce the concentration of nutrient into the lake. The urbanization of the Taihu Lake Basin is at a relatively high level in China, and the land for urban green space is very limited. Therefore, three-dimensional greening is a very good choice, and can be vigorously developed.

How to accurately determine the dry deposition and more accurately estimate the contribution of the N and phosphorus deposition in the river basin to the water body, and the ability of the above methods to reduce N emissions and increase N absorption are the focus of future research.

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## REFERENCES

[1] Abrahamsen, G., Stuanes, A. O., Tveite, B. (2012): Long-Term Experiments with Acid Rain in Norwegian Forest Ecosystems. – Springer-Verlag, New York.

[2] Benavides-ordillo, S., Farjalla, F., Angélica, L., González, A. L., Romero, G. Q. (2019): Changes in rainfall level and litter stoichiometry affect aquatic community and ecosystem processes in Bromeliad phytotelmata. – Freshwater Biology 64: 1357-1368.

[3] Brittain, J. T., Strecker, A. L. (2018): The interactive effect of multiple stressors on crustacean zooplankton communities in montane lakes. – Water Resources Research 54: 939-954.

[4] Chen, X., Wang, Y. H., Ye, C., Zhou, W., Cai, Z. C., Yang, H., Han, X. (2018): Atmospheric nitrogen deposition associated with the eutrophication of Taihu lake. – Journal of Chemistry 2018: 1-10.

[5] Deng, H. Y. (2016): Chemical characteristics of precipitation and their source analysis in Shanghai. – Dissertation, East China Normal University.

[6] Di, Z. Z., Zhang, H., Shan, B. Q. (2015): Status of internal nutrient loads and their effects on overlying water quality in Taihu Lake. Acta Scientiae Circumstantiae 35: 3872-3882.

[7] Duan, L., Zhao, Y., Hao, J. M. (2015): Critical load assessments for sulphur and nitrogen for soils and surface waters in China. – Critical Loads and Dynamic Risk Assessments 25: 419-438.

[8] Ellis, B. K., Craft, J. A., Stanford, J. A. (2015): Long-term atmospheric deposition of nitrogen, phosphorus and sulfate in a large oligotrophic lake. – PeerJ - the Journal of Life and Environmental Sciences 3: e841.


http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_10851101

[9] Fujii, K., Shibata, M., Kitajima, K., Ichie, T., Kitayama, K., Turner, B. L. (2018): Plant–soil interactions maintain biodiversity and functions of tropical forest ecosystems. – Ecological Research 33: 149-160.
[10] Gao, Y., He, N. P., Zhang, X. Y. (2014): Effects of reactive nitrogen deposition on terrestrial and aquatic ecosystems. – Ecological Engineering 70: 312-318.
[11] Geng, J., Li, H., Chen, D., Nei, X. F., Diao, Y. Q., Zhang, W. S., Pang, J. P. (2021): Atmospheric nitrogen deposition and its environmental implications at a headwater catchment of Taihu Lake Basin, China. – Atmospheric Research 256: 105566.
[12] Gilliam, F. S., Billmyer, J. H., Walter, C. A., Peterjohn, W. T. (2016): Effects of excess nitrogen on biogeochemistry of a temperate hardwood forest: evidence of nutrient redistribution by a forest understory species. – Atmospheric Environment 146: 261-270.
[13] Gong, C., Xian, C., Su, Y., Ouyang, Z. (2019): Estimating the nitrogen source apportionment of Sophora japonica in roadside green spaces using stable isotope. – Science of the Total Environment 689: 1348-1357.
[14] Hundey, E. J., Moser, K. A., Longstaffe, F. J., Michelutti, N., Hladyniuk, R. (2015): Recent changes in production in oligotrophic Uinta Mountain lakes, Utah, identified using paleolimnology. – Limnology & Oceanography 59: 1987-2001.
[15] Kurzyca, I., Frankowski, M. (2019): Scavenging of nitrogen from the atmosphere by atmospheric (rain, snow) and occult (dew, frost) precipitation. Comparison of urban and nonurban deposition profiles. – Journal of Geophysical Research: Biogeosciences 124: 2288-2304.
[16] Kosonen, Z., Schnyder, E., Hiltbrunner, E., Thimonier, A., Thöni, L. (2019): Current atmospheric nitrogen deposition still exceeds critical loads for sensitive, semi-natural ecosystems in Switzerland. – Atmospheric Environment 211: 214-225.
[17] Lepori, F., Keck, F. (2012): Effects of atmospheric nitrogen deposition on remote freshwater ecosystems. – Ambio 41: 235-246.
[18] Li, X. Y., Li, H. B., Yang, G. S., Chen, B. Y. (2015): Spatial variation of domestic water consumption and fate of domestic sewage in rural areas of Taihu region, Jiangsu. – Journal of Ecology and Rural Environment 31: 158-165.
[19] Li, C. H., Wang, Y. K., Ye, C., Wei, W. W., Zheng, B. H., Xu, B. (2019): A proposed delineation method for lake buffer zones in watersheds dominated by non-point source pollution. – Science of the Total Environment 660: 32-39.
[20] Liu, T., Yang, L. Y., Hu, Z. X., Sun, Y. N. (2012): Spatial-temporal features of atmospheric deposition of nitrogen and phosphorus to the Lake Taihu. – The Administration and Technique of Environmental Monitoring 24: 20-24.
[21] Liu, X. J., Zhang, Y., Han, W. X., Tang, A. H., Shen, J. L., Cui, Z. L., Vitousek, P., Erisman, J. W., Goulding, K., Christie, P., Fangmeier, A., Zhang, F. S. (2013): Enhanced nitrogen deposition over China. – Nature 494: 459-462.
[22] Liu, J. Z., Wang, P., Xiao, H. Y., Zhao, J., Su, W. (2020): Soil N mineralization rate and nitrification rate of terrestrial ecosystems in China and its influencing factors - a synthetic analysis of literature data. – Acta Ecologica Sinica 40: 4207-4218.
[23] Luo, L. C., Qin, B. Q., Yuan, L. Y., Song, Y. Z. (2007): Total inputs of phosphorus and nitrogen by wet deposition into Lake Taihu, China. – Hydrobiologia 581: 63-70.
[24] Mcdonnell, T. C., Driscoll, C. T., Sullivan, T. J., Burns, D. A., Baldigo, B. P., Shao, S., Lawrence, G. B. (2021): Regional target loads of atmospheric nitrogen and sulfur deposition for the protection of stream and watershed soil resources of the Adirondack Mountains, USA. – Environmental Pollution 281: 117110.
[25] Meng, C., Tian, D. S., Zeng, H., Li, Z. L., Yi, C. X., Niu, S. L. (2019): Global soil acidification impacts on belowground processes. – Environmental Research Letters 14: 74003-74003.
[26] Meunier, C. L., Gundale, M. J., Sánchez, I. S. (2016): Impact of nitrogen deposition on forest and lake food webs in nitrogen-limited environments. – Global Change Biology 22: 164-179.

[27] Porter, E. M., Bowman, W. D., Clark, C. M., Compton, J. E., Pardo, L. H., Soong, J. L. (2013): Interactive effects of anthropogenic nitrogen enrichment and climate change on terrestrial and aquatic biodiversity. – Biogeochemistry 114: 93-120.
[28] Posch, M., Vries, W. D., Sverdrup, H. U. (2015): Mass balance models to derive critical loads of nitrogen and acidity for terrestrial and aquatic ecosystems. – Critical Loads and Dynamic Risk Assessments 25: 171-205.
[29] Song, H. H., Jiang, C. M., Yu, W. T. (2014): Basic features and monitoring methodologies of atmospheric nitrogen deposition. – Chinese Journal of Applied Ecology 25: 599-610.
[30] Sun, C. L., Xie, S. D. (2014): Study on critical loads of sulfur and nitrogen in the Pearl River Delta. – Environmental Science 35: 250-255.
[31] Stevens, C. J., David, T. I., Storkey, J. (2018): Atmospheric nitrogen deposition in terrestrial ecosystems: its impact on plant communities and consequences across trophic levels. – Functional Ecology 32: 1757-1769.
[32] Ti, C. P., Gao, B., Luo, Y. X., Wang, S. W., Chang, S. X., Yan, X. Y. (2018): Dry deposition of N has a major impact on surface water quality in the Taihu Lake region in southeast China. – Atmospheric Environment 190: 1-9.
[33] Ti, C. P., Xia, L. L., Chang, S. X., Yan, X. Y. (2019): Potential for mitigating global agricultural ammonia emission: a meta-analysis. – Environmental Pollution 245: 141-148.
[34] Vries, W. D., Posch, M., Sverdrup, H. U., Larssen, T., Hettelingh, J. P. (2015): Geochemical indicators for use in the computation of critical loads and dynamic risk assessments. – Critical Loads and Dynamic Risk Assessments 25: 15-58.
[35] Wang, X. Y., Yin, W. Q., Shan, Y. H., Feng, K., Zhu, J. G. (2009): Nitrogen and phosphorus input from wet deposition in Taihu Lake region: A case study in Changshu agro-ecological experimental station. – Chinese Journal of Applied Ecology 20: 2487-2492.
[36] Wang, J. F., Zhou, K. J., Wang, X. Q., Deng, J., Wu, L. F., Ma, X. Y., Zhong, X., Pu, F. L., Shi, L. L., Chen, J., Jiang, C. P. (2015): Atmospheric nitrogen and phosphorous deposition in Hangjiahu area. – China Environmental Science 35: 2754-2763.
[37] Wang, J. J., Zhao, Q. H., Pang, Y., Hu, K. M. (2017): Research on nutrient pollution load in Lake Taihu, in China. – Environmental Science and Pollution Research 24: 17829-17838.
[38] Wang, J. Q., Song, Y. Z., Huang, J. (2019): Change and control measures of nitrogen sources in Taihu lake basin in recent decades. – China Rural Water and Hydropower 12: 94-98.
[39] Wei, Y., Gu, J., Wang, H., Yao, T., Wu, Z. (2018): Uncovering the culprits of air pollution: evidence from China's economic sectors and regional heterogeneities. – Journal of Cleaner Production 171: 1481-1493.
[40] Xian, C., Zhang, X., Zhang, J., Fan, Y., Zheng, H., Salzman, J., Ouyang, Z. (2018): Recent patterns of anthropogenic reactive nitrogen emissions with urbanization in China: dynamics, major problems, and potential solutions. – Science of the Total Environment 656: 1071-1081.
[41] Xie, Y. X., Xiong, Z. Q., Xing, G. X., Sun, G. Q., Zhu, Z. L. (2007): Assessment of nitrogen pollutant sources in surface waters of Taihu Lake region. – Pedosphere 17: 200-208.
[42] Xu, P. Z., Qin, B. Q., Xiang, B., Behrendt, H., Huang, W. Y. (2006): Long-term Changes of the Nutrient Surpluses in Regional Agricultural Land. – Scientia Geographica Sinica 26: 668-673.
[43] Xu, W., Zhao, Y., Liu, X., Dore, A. J., Zhang, L., Liu, L., Cheng, M. (2018): Atmospheric nitrogen deposition in the Yangtze River basin: spatial pattern and source attribution. – Environmental Pollution 232: 546-555.


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DOI: http://dx.doi.org/10.15666/aeer/2002_10851101

[44] Xu, Z. B., Yang, Y., Bian, L., Cai, K., Zhang, Y., Ding, M. (2019): Dry and wet atmospheric deposition of nitrogen and phosphorus in Taihu Lake. – Environmental Monitoring and Forewarning. 19: 37-42.
[45] Yan, W. J., Mayorga, E., Li, X. Y., Seitzinger, S. P., Bouwman, A. F. (2010): Increasing anthropogenic nitrogen inputs and riverine DIN exports from the Changjiang River basin under changing human pressures. – Global Biogeochemical Cycles 24: GB0A06.
[46] Yang, Y. L., Qin, B. Q., Hu, W. P., Luo, L. C., Song, Y. Z. (2007): Atmospheric deposition of nitrogen and phosphorus nutrients in Taihu Lake. – Oceanologia et Limnologia Sinica 38: 104-110.
[47] Yu, Y., Liu, H. (2020): Economic growth, industrial structure and nitrogen oxide emissions reduction and prediction in China. – Atmospheric Pollution Research 11 1042-1050.
[48] Yu, H., Zhang, L. L., Yan, S. W., Li, H. L., Yu, J. (2011): Atmospheric wet deposition characteristics of nitrogen and phosphorus nutrients in Taihu lake and contributions to the lake. – Research of Environmental Science 24: 1210-1219.
[49] Yu, G., Jia, Y., He, N., Zhu, J., Chen, Z., Wang, Q., Piao, S., Liu, X., He, H., Guo, X. (2019): Stabilization of atmospheric nitrogen deposition in China over the past decade. – Nature Geoscience 12: 424-429.
[50] Zhang, H., Li, H. P., Li, X. Y., Li, Z. F. (2014): Temporal changes of nitrogen balance and their driving factors in typical agricultural area of Tai Lake basin. – Chinese Journal of Soil Science 45: 1119-1129.
[51] Zhang, C., Wu, Q., Peng, J. C., Wang, F., Liu, B. L., Zhou, W. J. (2019): Calculation of the value and evaluation of the function for ecosystem services of urban green space: a case study in Nanjing. – Ecological Science 38: 142-149.
[52] Zheng, S., Bian, H., Quan, Q., Xu, L., He, N. (2018): Effect of nitrogen and acid deposition on soil respiration in a temperate forest in China. – Geoderma 329: 82-90.
[53] Zhu, J. X., He, N. P., Wang, Q. F., Yuan, G. F., Wen, D., Yu, G. R., Jia, Y. L. (2015): The composition, spatial patterns, and influencing factors of atmospheric wet nitrogen deposition in Chinese terrestrial ecosystems. – Science of the Total Environment 511: 777-785.


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