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Dynamic pursuing ecological model concerning the nitrogen cycle in the environment of Chinese mainland

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Abstract — The paper gives a special dynamic pursuing ecological model on the bio-geochemical cycle of nitrogen in the whole range 9.6 million square kilometers of Chinese mainland, basing on the reservoir-content and flux-rate of nitrogen and among the four spheres: atmosphere, pedosphere, biosphere, and hydrosphere. and the law of bio-geochemical cycle of nitrogen, the model predicted the size of reservoir capacities and fluxes of nitrogen in each sphere. Through tested and verified, the model was proven reasonable and reliable.

Keywords: nitrogen cycle; fluxes; flux-rate; reservoir-content of nitrogen; dynamic pursuing model.

DYNAMIC ECOLOGICAL MODELING OF NITROGEN CYCLE

For quantitatively describing the process of nitrogen cycling, the authors put forward a dynamic ecological model with taking the amount of the fluxes-rate of nitrogen in atmosphere, biosphere, hydrosphere and pedosphere in Chinese mainland as basic variables, and basing on the variables are changeable over time, and related to each other. The model serves the following three principles.

1. Matter-equilibrium principle

The total nitrogen content in nature is constant, but it can change from one state to another without change in volume.

2. Dynamic pursuing model

The aforesaid principle expressed that the total amount of nitrogen is constant, however, the content of nitrogen in each sphere is changeable with time and related to other factors. We can use Ni $(t, N1, \cdots Ni)$ to represent the relation of the total amount of nitrogen in compartment i with time change, because many factors must be taken into account during calculating, therefore, we called the model dynamic and pursuing.

3. Ecological model

The model offers a scheme for controlling-plan on the impact of ecological

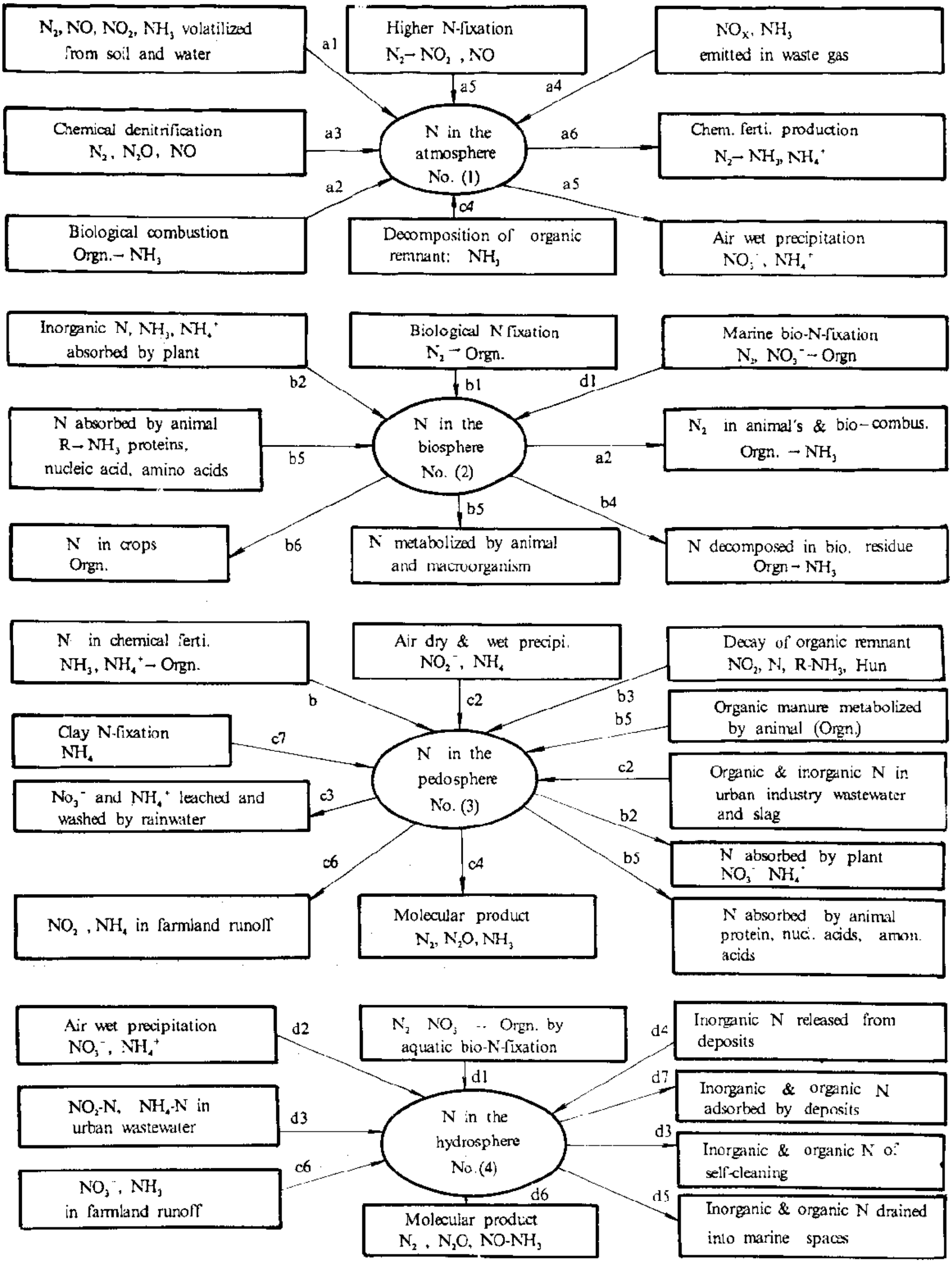


Fig.1 Dynamic model of N-cycle

balance arisen by population-growth, industrial and agricultural development, environment pollution, vegetation degeneration and soil erosion, based on the impact to ecological balance result from the change in amount of nitrogen.

On the basis of above three principles, we set up the dynamic pursuing ecological model of nitrogen cycle, which laid a foundation for further building mathematical model of nitrogen cycle (Fig.1).

MATHEMATICAL MODELING OF NITROGEN CYCLE

1. The function of the mathematical model of nitrogen cycle

The mathematical model is to show the change-law of nitrogen with time in nature, on the base that the dependent variable is the amount of nitrogen, the independent variable is time and the amount of nitrogen in each sphere was taken as the intermediate variable, it can be expressed as follows:

$$Ni\ (t) = Fi[t,\ N_1\ (t)\cdots\cdots,\ Nm(t)], \qquad (1)$$

the variable $i = 1$, 2, 3 and 4 represent atmosphere, biosphere, pedosphere and hydrosphere, respectively, $Ni\ (t)$ is the reservoir-content of nitrogen in each compartment, what the above equation suggested is as Fig.2 displayed.

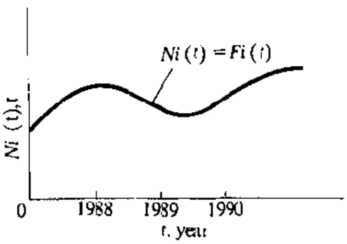


Fig.2 Change-drawing of total nitrogen

Upon the measured data, we can determine the value of each variable in mathematical model and get the mathematical model of nitrogen cycle in Chinese mainland.

2. Mathematical model on the change-law of nitrogen cycle

We can calculate the fluxes and flux-rate of nitrogen between two spheres with other associated practical data, because it is very difficult to get it directly, for example, Fij represents the amount of nitrogen from sphere i to sphere j and it is influenced by many factors (natural or with human activities), which can be computed with the following differential equations:

$$\frac{dN_1(t)}{dt} = F_{ha} + F_{La1} + F_{ba1} + F_{La2} + F_{aiu} + F_{La3} + F_{aa1} + F_{ba2} + F_{ba3} + F_{ba4} - F_{aLh} - F_{aL1} + F_{abh} - F_{aou} \qquad (2)$$

$$\frac{dN_2(t)}{dt} = F_{ab1} + F_{Lb1} + F_{biu} - F_{ba1} - F_{bL1} - F_{ba2} - F_{ba3} - F_{ba4} - F_{bL2} - F_{bht} - F_{bou} \qquad (3)$$

$$\frac{dN_3(t)}{dt} = K_{ab} \times F_{abh} + F_{aL10} + F_{LL1} + F_{bL1} + F_{bL2} + F_{LL2} + F_{aL20} + F_{Liu} - F_{Lb1} - F_{La1} - F_{Lh1} - F_{Lh2} - F_{La2} - F_{La3} - F_{Lou} \quad (4)$$

$$\frac{dN_4(t)}{dt} = F_{ah1} + F_{Lh2} + F_{Lh1} + F_{ah2} + F_{bh1} + F_{hh1} + F_{hiu} - F_{hout} - F_{ha} - F_{hh2} - F_{hou} \quad (5)$$

Where the right hand of the equation are the flux-rate of nitrogen (TgN/a).

(1) Fha: nitrogen released from hydrosphere to atmosphere; (2) F_{La1} : nitrogen volatilized into atmosphere using chemical fertilizer; (3) F_{La2}: nitrogen volatilized into atmosphere from farmland; (4) F_{ba1} : nitrogen emitted into atmosphere by biomass burning; (5)F_{La3}: nitrogen emitted into atmosphere from coal, oil and natural gas combustion; (6)F_{aa1} : nitrogen released into atmosphere during the processes of synthetic NH_3 and cement producing; (7) F_{b2}: nitrogen emitted to atmosphere, transpired by forest and released by animals excreta; (8) F_{b3}: nitrogen into atmosphere by mankind respiration; (9) F_{b4} : nitrogen into atmosphere by mankind respiration; (10) F_{aiu} : flux-rate of nitrogen emitted to atmosphere, released by industrial waste, refuse in generation, secondary pollution, terrestrial microbe decomposition and convection among different atmospheric layers; (11) F_{aLh} : nitrogen deposited to pedosphere and hydrosphere by precipitation and dust-deposit; (12) F_{aL1} : nitrogen leaved out in the process of chemical fertilizer and NH (artificial nitrogen fixation) production; (13) F_{abh} : total amount of bio-N-fixation; (14) F_{aou} : unavailable factors into pedosphere, hydrosphere, biosphere by air circulation and photochemical reactions; (15) F_{ab1} : nitrogen absorbed by terrestrial bio-N-fixation and photosynthesis; (16) F_{Lb1} : nitrogen absorbed by plant from soil; (17) F_{hiu} : unavailable factors with aquatic plant, animal and edible aquatic product; (18) F_{bL1} : nitrogen into soil, from human and animal's excreta; (19) F_{bL2} : nitrogen into soil, decomposed from biological residues; (20) F_{bh1} : nitrogen into hydrosphere from industrial and daily life waste; (21) F_{bou} : unknown factors of the change rate by the decomposition of biological body; (22) F_{aL10} : nitrogen into pedosphere of precipitation and dust-deposit; (23) F_{LL1} : annual nitrogen released by the remainder of manure or nitrogen fertilizer in soil; (24) F_{LL2} : N in soil accumulation with clay-nitrogen-fixation; (25) F_{aL20} : annual nitrogen released by applying of nitrogen fertilizer and manure; (26) F_{Liu} : nitrogen related to farmland-irrigation, fossil fuel to soil-sphere and so on; (27) F_{Lh1}: nitrogen leached into underground water; (28) F_{Lh2} : nitrogen wasted away by runoff; (29) F_{Lou} : flux-rate of unknown factors about the output of soil-sphere; (30) F_{ah1} : nitrogen fixed by aquatic living beings: (31) F_{ah2}: nitrogen into hydrosphere by precipitation and dust-deposit; (32) F_{hh1} : nitrogen released by sediment; (33) F_{hou} : unknown factors on nitrogen transform from nature into hydrosphere by other medium; (34) F_{hout} : nitrogen into foreign marine space with hydraulic movement; (35) F_{hh2} : the amount of nitrogen permeated; (36) F_{hou} : unknown factors of fluxes rate about the output of hydrosphere. $dN1(t)/dt$: the flux-rate of nitrogen reservoir content in atmosphere; $dN_2(t)/dt$: the flux-rate of nitrogen reservoir content in biosphere; $dN_3(t)/dt$: the flux-rate of nitrogen reservoir content in pedosphere; $dN_4(t)/dt$: the flux-rate of nitrogen reservoir content in hydrosphere.

3. Examples on calculation of variables in the mathematical model

Among the 36 specific items, we only give several items with their calculating-method in this article.

(1) Nitrogen released from farmland into atmosphere

The processes of nitrogen-releasing include: (a) volatilization of nitrogen; (b) chemical denitrification; (c) the formation of N_2 or NxOy when NO_2^- (or HNO_3) was reacted with some elements in the soil under acid condition or when raising the temperature. The amount of nitrogen released from farmland to atmosphere is related to soil types and the areas of crops, which can be got with the following equations

$$F_{La1} = A2 \times N(2) \times N(3), \quad (6)$$

$$A_2 = F_{La1} / [N(2) \times N(3)], \quad (7)$$

where, F_{La1} is the specific item about the nitrogen released from farmland to air, A_2 is the variable of the item, $N(2)$, $N(3)$ are the reservoir-content of nitrogen in biosphere and pedosphere, respectively.

(2) The amount of nitrogen absorbed by plant from soil

The amount of nitrogen absorbed by different plant is not equal, and the abilities of nitrogen-fixation of different crops are also different. So the nitrogen absorbed by plants can be gained in the Equations (12) and (13).

$$F_{Lb1} = B_1 \times N(2) \times N(3), \quad (8)$$

$$B_1 = F_{Lb1} / [N(2) \times N(3)], \quad (9)$$

where F_{Lb1} is the specific item of nitrogen absorbed from soil by plant, B_1 is the variable of the specific item, $N(2)$ and $N(3)$ are the same as that in the Equations (6) and (7).

(3) The amount of nitrogen wasted by soil-erosion

The amount of upper soil eroded in Chinese mainland is about 5 billion tons per year, and the amount of nitrogen eroded in the process is about 4.85 million tons, which result in nitrogen reducing in soil. The amount of nitrogen wasted by soil-erosion was calculated with the following equations:

$$F_{Lh2} = C5 \times N(3), \quad (10)$$

$$C_5 = F_{Lh2} / N(3), \quad (11)$$

In the equations, FLh_2 is the specific item about nitrogen wasted by soil-erosion, C_5 is the variable of the specific item, N(3) is the amount of nitrogen in pedosphere.

(4) The amount of nitrogen accumulated by aquatic living things

The amount of nitrogen accumulated by aquatic living things is related to its quantity and the concentration of nitrogen in water. The calculating-method is expressed as follows:

$$F_{ahl} = D_1 \times N(2) \times N(4) \ , \tag{12}$$

$$D_1 = F_{ahl} / [N(2) \times N(4)] \ , \tag{13}$$

Among them, F_{ahl} is the specific item about nitrogen absorbed by aquatic living things, D_1 is the variable of the specific item, $N(2)$ is the amount of nitrogen in biosphere and $N(4)$ is the amount of nitrogen in hydrosphere.

(5) The amount of nitrogen returned to soil from the remainder of living things.

The amount of nitrogen returned to soil from the residue of plant is:

$$F_{hl2} = B4 \times N(2), \tag{14}$$

$$B_4 = F_{h12} / N(2), \tag{15}$$

where, F_{h12} is the specific item of nitrogen returned to soil by residue of plant, B_4 is the parameter of the specific item, $N(2)$ is the amount of nitrogen in biosphere.

4. Checking of the mathematical model

(1) The stability of the model

The stability of the model is to see if its convergence is presented in the process of forecasting calculation, the content of nitrogen should be positive and finite in the process of cycling if the model is stable (Fig. 3).

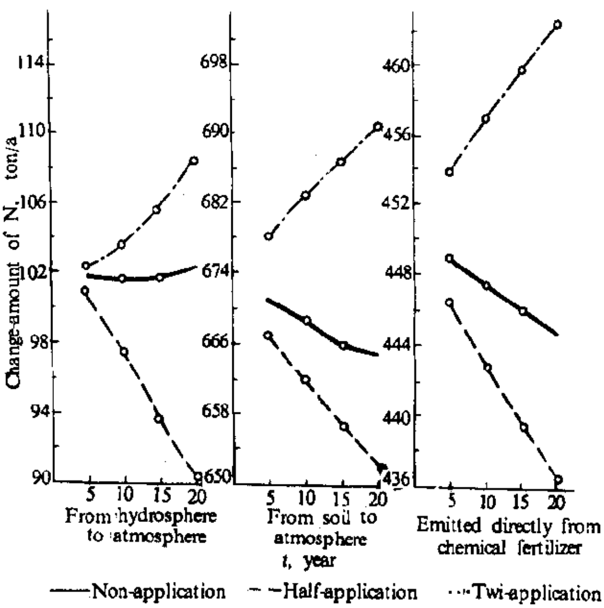


Fig.3 Forecast curve of the amount of N_2O, NH_3 in atmosphere as the change of applying amount of chemical fertilizer

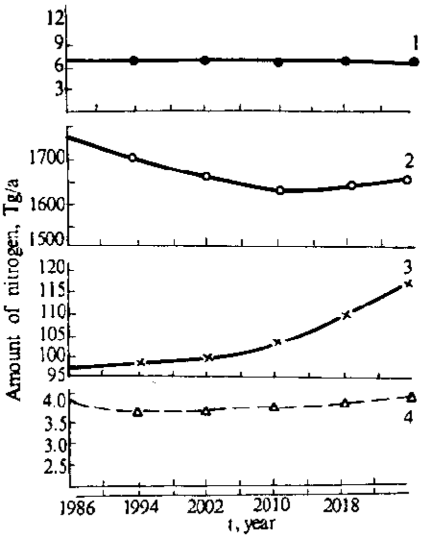


Fig.4 Forecast of the amount of nitrogen in each compartment in the future 40 years
1. atmosphere 2. pedosphere 3. biosphere
4. hydrosphere

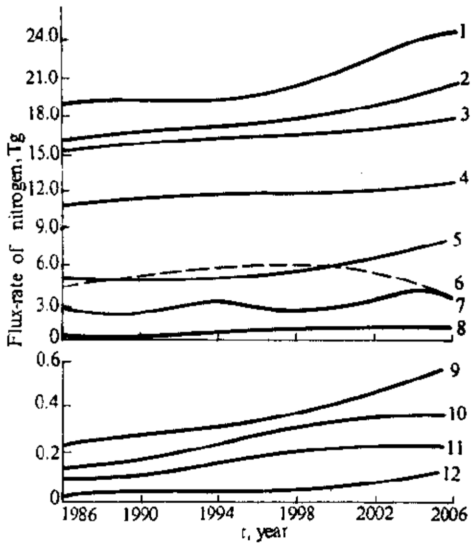


Fig.5 The change-trend of fluxes of nitrogen in each ecological sphere

Through checking, the model is stable, that can be understood from the next three reasons: firstly, the model was established based on the three principles mentioned previously that ensure the stability of the model in the basic theory; secondly, after comparing various mathematical calculation while opening the equations, we adopt the accurate method (Runge-kuta; Kinzelbach, 1989) which also ensure the stability of the mathematical model; thirdly, the calculative results of nitrogen cycle of 10th year, 40th year, testified the model are stable and convergent, too, that data are shown in Fig.4 and Fig.5.

In Fig.5, the numbers 1 – 12 are described as follows: 1. nitrogen absorbed by plant; 2. nitrogen by bio-N-fixation; 3. nitrogen in dry and wet deposition; 4. organic nitrogen seeped into soil; 5. NH_3 released by animal; 6. organic nitrogen wasted by runoff; 7. organic nitrogen into soil from the remnant of living things; 8. NH_3 released by human body; 9. N_2O emitted by fuelcombustion; 10. $NH_3 \cdot H_2O$ released by farmland; 11. NH_3 emitted in NH_3production; 12. NH_3 released by forest.

(2) The susceptibility of model

The susceptibility is that when the variables in the model change, the equations are stable, and through changing the size of each variable, we can determine which variable is the major factor affecting the calculating result and known the susceptibility of every variable, which can be seen in Fig.3.

(3) Comparison of the calculated data with the measured data

Through the relevant testing and verifying, and comparing the calculated data with the measured data (Table 1), we conclude that the model was reliable.

Table 1 Comparison between calculated and practical data (1988)

Checking items	Measured data, Tg/a	Calculated data, Tg/a	Relative difference, %
Amount of N by bio-N-fixation	18.64	16.89	−9.4
N emitted during producing NH_3	0.1574	0.1658	5.3
N contained in crops	12.1	10.6	−12.4
N in applied manure	5.38	5.12	−4.8
N emitted in the process of combusting fossil fuel (NH_3)	0.4003	0.430	−7.4
N emitted in the process of combusting fossil fuel (N_2O)	0.2912	0.199	31.7
N volatilized from chemical fertilizer	0.0403	0.0442	0.4
N released from forest	0.0726	0.0854	−18
N volatilized in the process of biomass burning (N_2O)	0.0479	0.044	8.1
N released from farmland (N_2O, NH_3)	0.139	0.15	7.9
N released by animal's bodies	5.4	5.2	−3.7
N released by human body	1.425	1.39	−2.5
N volatilized from chemical fertilizer (NH_3)	4.12	7.73	87.6
N into marine space by hydraulic movement (NH_3-N)	0.16	0.24	50.0

FORECAST OF RESERVOIR-CONTENT AND FLUXES OF NITROGEN

1. Forecasting equation

The size of $N(t)$ within time "t" can be got in the forecasting equations. If the forecasting-time is disperse, we adopt difference equations, and if the forecasting-time is consecutive, we adopt differential equations to calculate the value of each variable.

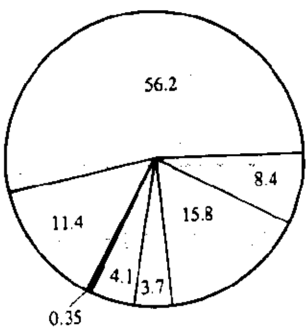
2. Forecasting result

The reservoir-content of nitrogen in each compartment is changeable with time, as the flux-rate between two spheres changed. We start the calculation after taking the data of 1986 as the initial point (Table 2 – Table 9).

(1) The forecasting result of the reservoir-content of nitrogen and the flux-rate in atmosphere

The nitrogen takes 79% of air in volume, its amount reaches 3.86×10^{19} g in the range of China, the amount of nitrogen is 72.5×10^{17}g , so the reservoir-content change in air is insignificant with the change of the fluxes of nitrogen. It can be understood through Fig.3. The annual decrease of nitrogen in air by dry and wet deposition (Li, 1981), NH_3-making, fertilizer producing and nitrogen-fixation by living things is about 34 – 36 g; on the other hand, the increase of nitrogen by fossil fuel combustion, biomass burning, manure-utilization and release from farmland, animal and human being, is about 10 – 12 Tg (Fig.6) , if the molecular nitrogen which emitted into atmosphere with rottenness of living things, water-evaporating, sediment-releasing, rock-weathering and waste-combusting are considered, the increase of nitrogen in air is nearly equal to the decrease.

The oxidation of N_2O in the upper layer of atmosphere, and the NH_3 near the surface of earth are the important factors in enhancing the greenhouse effect. According to the calculation of the model, the main resources of N_2O are fossil fuel combustion and biomass burning, and most NH_3 is released by animal' s and human bodies.



Sources	%
Coal combustion	56.2
Oil combustion	11.4
Natural gas combustion	0.35
Biomass burning	4.1
Chemical fertilizer decomposition	3.7
Agricultural soils	15.8
Forest soils	8.4

Fig.6 N_2O emission from different sources in China (1988)

a. Forecast of N_2O released from coal-combustion in China

Table 2 Comparison between calculated and measured quantities of N_2O from coal combustion (TgN/a)

Years	Measured data	Calculated data	M.D.-C.D.	(M.D.-C.D.)/M.D.
1978	0.139	0.131	0.008	0.055
1979	0.144	0.140	0.004	0.030
1980	0.150	0.148	0.002	0.012
1981	0.149	0.157	0.008	0.056
1982	0.157	0.167	0.010	0.062
1983	0.169	0.177	0.008	0.045
1984	0.184	0.187	0.003	0.017
1985	0.200	0.198	0.002	0.010
1986	0.211	0.209	0.002	0.008
1987	0.227	0.221	0.006	0.026
1988	0.241	0.233	0.008	0.031

The forecasting equation is

$$Yc = 1.259 \times 10^{-10} \times T^{4.766}, \quad (16)$$

$r=0.999$; $S=6.756\times 10^{-3}$; T represents the years.

Table 3 Predicted N_2O emission from coal combustion (Tg N/a)

Years	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010
Predicted data	0.260	0.289	0.320	0.354	0.390	0.429	0.472	0.518	0.567	0.620	0.676

b. Forecast of N_2O from oil combustion in China

Table 4 Comparison between calculated and measured quantities of N_2O from oil combustion (Tg N/a)

Years	Measured data	Calculated data	M.D.- C.D.	(M.D.- C.D.)/M.D.
1981	0.0369	0.0349	0.0020	0.0534
1982	0.0364	0.0365	0.0001	0.0033
1983	0.0371	0.0382	0.0011	0.0286
1984	0.0383	0.0399	0.0016	0.0406
1985	0.0407	0.0416	0.0009	0.0222
1986	0.0432	0.0434	0.0002	0.0048
1987	0.0457	0.0453	0.0004	0.0095
1988	0.0488	0.0472	0.0016	0.0331

Forecasting equation is:

$$Ya = 4.151 \times 10^{-10} \times T^{3.629}, \tag{17}$$

$$r = 0.999;\ S = 1.36 \times 10^{-3}.$$

Table 5 Predicted N_2O emission from oil combustion (10^{10} g N/a)

Years	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010
Predicted data	5.12	5.54	5.99	6.47	6.97	7.50	8.06	8.65	9.27	9.92	10.60

c. Forecast of N_2O from natural gas combustion in China

Table 6 Comparison between calculated and measured quantities of N_2O from natural gas combustion (Tg N/a)

Years	Measured data	Calculated data	M.D.- C.D.	(M.D.- C.D.)/M.D.
1981	0.00130	0.00122	0.00008	0.06176
1982	0.00121	0.00125	0.00004	0.03653
1983	0.00124	0.00129	0.00005	0.03971
1984	0.00133	0.00132	0.00001	0.00390
1985	0.00132	0.00136	0.00004	0.03100
1986	0.00143	0.00140	0.00003	0.02267
1987	0.00142	0.00143	0.00001	0.01042
1988	0.00151	0.00147	0.00004	0.02480

d. Forecasting equation is

$$Yg = 5.608 \times 10^{-10} \times T^{2.272}, \tag{18}$$

$$r = 0.999;\ S = 5.033.$$

Table 7 Predicted N_2O emission from natural gas combustion (10^9 g N/a)

Years	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010
Predicted *D.*	1.550	1.629	1.711	1.795	1.881	1.969	2.060	2.153	2.248	2.345	2.445

e. Forecast of N_2O from biomass combustion in China

Table 8 Comparison between calculated and measured quantities of N_2O from biomass combustion (Tg N/a)

Years	Measured data	Calculated data	M.D.-C.D.	(M.D.-C.D.)/M.D.
1978	0.0125	0.0134	0.0009	0.068
1979	0.0144	0.0139	0.0005	0.037
1980	0.0140	0.0144	0.0004	0.027
1981	0.0144	0.0149	0.0005	0.036
1982	0.0158	0.0155	0.0003	0.021
1983	0.0171	0.0160	0.0011	0.063
1984	0.0181	0.0166	0.0015	0.083
1985	0.0173	0.0172	0.0001	0.006
1986	0.0177	0.0178	0.0001	0.005
1987	0.0182	0.0184	0.0002	0.011
1988	0.0177	0.0190	0.0013	0.075

f. Forecasting equation is

$$Yb = 3.655 \times 10^{-8} \times T^{2.940}, \quad (19)$$

$$r = 0.999; \quad S = 8.681 \times 10^{6}$$

Table 9 Predicted N_2O emission from biomass burning (Tg N/a)

Years	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010
Predicted *D.*	0.020	0.022	0.023	0.025	0.026	0.028	0.029	0.031	0.033	0.035	0.037

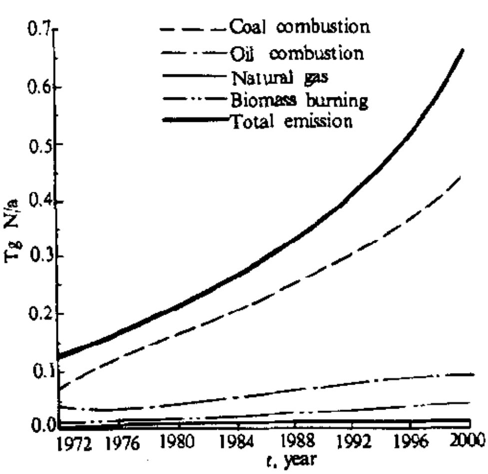


Fig. 7 Estimated N_2O emission (1972—2000)

The forecasting result demonstrate that the total amount of N_2O from fossil fuel combustion and biomass burning will reach to 0.534 Tg N/a to 2000 however, it is only 0.274 Tg N/a in 1987.

g. Estimating of NH_3 emission from different sources in China (Fig.7 and Table 10).

(2) Forecast to the reservoir-content and fluxes of nitrogen in biosphere

The pools of nitrogen in biosphere include human body, animal, plant, microorganism, algae and other living things. The consume of agricultural products increase rapidly with the population growth which engendered the amount of nitrogen in crops increases by the rate of 0.75 − 0.8 Tg each year (Table 11). The amount of nitrogen in biosphere shall reach low peak after 20 years, due to the degradation of grassland, and the decrease of vegetation area. The biggest resource of nitrogen, the forest taken to 11.55% in the area in 1987 in China, forecast to 1990 is 10.3% and up to 2000 is only 8.35%, after then it will become great as its own balance and natural turnover (China Statistics Press, 1984), which is shown in Table 11.

Table 10 Sources and amount of NH_x emission (Tg N/a)

Sources	Coal *C.*	Chemical fertilizer	Human bodies	Animal emission	Farmland emission	NH-producing emission	Forest emission	Total
NH	0.377	0.477	1.41	5.09	0.072	0.166	0.085	2.6

Table 11 Forecast and comparison of amount of nitrogen in crops (Tg N/a)

Types of crops	1986	1990	2000
Rice	3.787	4.39	5.18
Wheat	1.893	2.48	2.95
Potato	0.122	0.13	0.16
Maize	1.512	2.23	2.78
Sorghum	0.145	0.24	0.28
Cereal	0.177	0.21	0.23
Soybean	0.287	0.36	0.48
Cotton	0.415	0.69	0.82
Oil-bearing crops	0.759	0.68	0.92
Fibre crops	0.042	0.05	0.10
Sugarcane	0.071	0.08	0.11
Fruit	0.135	0.15	0.36
Vegetable	0.36	0.39	0.59
Total.	8.835	12.08	14.96

(3) Forecast on the reservoir-content and fluxes of nitrogen in pedosphere (Fu, 1989; Li, 1981; Zhang, 1989; Institute of Soil-Manure of Chinese Academy of Agricultural Sciences, 1986)

We classified the soil in Chinese mainland into nineteen types, and divided each type into four parts in depth from top to bottom, 0 − 20cm, 20 − 50cm, 50 − 100cm and 100 − 200cm, for calculating the amount of nitrogen easily upon the next three equations:

$$Wij = \sum_j Sij \times Hij \times Di \tag{20}$$

$$Wsni = \sum_j Wij \times Nij, \tag{21}$$

$$N_L = \sum_i^{18} Wsni, \tag{22}$$

where *Hij* is the depth of the "*j*" section in the "*i*" type soil; *Di* is the average density of "*i*" type soil; *Sij* is the area of the "*j*" section in the "*i*" type soil; *Wij* is the total mass of the "*j*" section in the "*i*" type soil; *Wsni* is the total amount of nitrogen in each type soil, *Nij* is the concentration of nitrogen of "*j*" section in "*i*" type soil, and N_L is the amount of nitrogen in all the type soil.

The amount of nitrogen in pedosphere is 53 Tg N and the carbon is 2422 Tg C, the rate of N/C is 1:16. The amount of nitrogen in soil is decreasing on the forecast-curve, which resulted from soil-erosion, desertification and decrease in farmland area. As soil erosion, the amount of total nitrogen wasted is about 4.85 million tons. Since most soil nutrient is concentrated in the ploughing layer, soil erosion'also result in land degradation (Institute of Soil-Manure of Chinese Academy of Agricultural Sciences, 1986). The decrease of amount of nitrogen in soil will become less severe around 2000, nevertheless, the differences of increase and decrease is nearly zero.

(4) The reservoir-content and fluxes of nitrogen in hydrosphere

The pools of nitrogen in hydrosphere include inland river, river, lake and reservoir. The area of the near sea, we think it as the last pool of the nutrient elements. We all know that the aquatic compartment shall be getting more polluted with the soil-erosion increasing, industry sewage and domestic sewage-draining. The NH_4^+ drained into water in 1990 from Chinese mainland is 0.12 Tg and in 2000 will be up to 0.16 Tg (Institute of Soil-Manure of Chinese Academy of Agriculture Sciences, 1983). The amount of NH_4^+ drained into water in 1990 is 0.14 Tg by the model. The total amount of nitrogen in hydrosphere is getting greater than before, which is in accord with the practical data.

RESULTS AND DISCUSSION

The dynamic ecological model of nitrogen cycle upon the quantitative study to the rule of nitrogen cycle in nature and through testification was set up, the model is stable and convergent.

The amount of nitrogen within 40 years in each compartment with the model was predicted.

The amount and the fluxes rate of nitrogen within each compartment have been forecasted and checked in the future twenty years with the practical data as the initial point.

The flux and species of nitrogen in the environment of China in nature are listed in Table 12.

Table 12 The flux and species of nitrogen (Tg N/a)

	Input items	Main types of nitrogen	Size
Atmosphere	Water evaporation	N_2O, NO, NH_3	0.102
	Soil volatilization	N_2, NO, N_2O, NH_3	0.138
	Biomass combustion	NO, N_2O, ORGN	0.043
	Fossil fuel combustion	N_2O, NO_x, NH_3	0.624
	Higher N-fixation	$N_2 \to NH_4^+$, NO_3^-	8.544
Biosphere	N absorbed by plants	NO_3^-, NH_4^+	19.03
	N in human and animal's bodies	ORGN, NH_3	0.870
	Organic N-fertilizer absorbed by plant	ORGN $\to NO_3^-$, N $\to NH_4^+$	1.499
	N in crops	ORGN	1.900
Pedosphere	N into soil by chemical fertilizer	NH_3^- $NH_4^+ -$ ORGN	1.420
	N by clay-N-fixation	NH_4^+	2.58
	N in annual applied chemical fertilizer	NH_3^- NH_4^+	3.331
Hydrosphere	N by aquatic bio-N-fixation	$N_2 \to$ ORGN	0.065
	N in urban and industrial waste water	ORGN, NO_3^-, NH_4^+	11.31
	N released from deposits	ORGN, N_2O, NO_3^-, NH_4^+	0.216
	Output items	Main types	Size
Atmosphere	Atmospheric dry and wet deposit	NO_3^-, NH_4^+	15.43
	Chemical nitrogen fertilizer production	$N_2 \to NH_3^-$ NH_4^+	0.165
	Bio-N-fixation	$N_2 \to$ ORGN	16.70
	Others	NH_4^+-N, NO_3^--N, ORGN-N	0.002
Biosphere	N in human and animal's excrete	ORGN	5.01
	Decomposition of biological residue	ORGN $\to N_2$, NH_3	2.70
	Decaying of solid waste	ORGN — NH_3	
Pedosphere	N from soil to underground water	NO_3^-, NH_4^+, ORGN	0.72
	Runoff of farmland	NO_3^-, NH_4^+, ORGN	4.85
	Others	NO_3^-, NH_4^+, ORGN	13.364
Hydrosph.	Self cleaning	NO_3^-, NH_4^+, ORGN	0.230
	N absorbed by deposits	NO_3^-, NH_4^+	0.216

The result of calculating shows that the good-circulation is bound to fall into bad circulation if the normal natural cycle of bio-geochemical element was destroyed by mankind, and that shall be very unhelpful to human. It is imperious for human to take attentions on protecting the natural ecological balance of human living environment, and which has been forecasted by forescholar that to get a new balance of nitrogen will take 100 years.

Because of the limited knowledge of mankind to the process of natural change, some unknown variables are to be modified and mended in the future.

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