划分土壤类型的一种新方法 ——以功能生态学理论为基础 *

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摘 要 借助功能生态学的理论 ,提出了运用土壤的特征物质(CM)和特征时间(CT)区分土壤类型的新方法。通过数学模拟 ,分别计算了灰色森林土和黑钙土的特征物质和特征时间:当灰色森林土和黑钙土的年凋落物量分别为 5.5 t·hm^{-2}和 11.2 t·hm^{-2}时 ,它们的 CM 和 CT 分别为 133 t·hm^{-2}、80 年和 820 t·hm^{-2}、650 年。CM 和 CT 的值随着输入土壤的物质量和土壤中分解速度的变化而变化 ,而且受外界环境因素(包括自然因素和人为因素)的影响。CT 随土壤深度的增加而增大。

关键词 土壤类型 ,特征物质 ,特征时间 ,功能生态学

中图分类号 S155 **文献标识码** A **文章编号** 1000 - 4890(2003)04 - 0097 - 05

A new method to distinguish soil types based on functional ecology. YIN Guangcai[1] , A S Kerzhentcef[2] , V V Bugrovskiy[3] , ZHOU Guoyi[1] , WEN Dazhi[1] ([1] *South China Institute of Botany , Chinese Academy of Sciences , Guangzhou* , 510650 , *China ;* [2] *The Institute of Basic Biology for Fundamental Problems , Pushchino , Russian Cademy of Sciences , Moscow Region* 142290 , *Russia ;* [3] *Uvs-Noor International Biological Center for Biosphere Research , Russian Academy of Sciences , Kyzyl , Tuva* 667000 , *Russia*) . *Chinese Journal of Ecology* ,2003 ,**22**(4) :97～101.

Based on the theory of functional ecology , a new method for distinguishing soil types according to its characteristic mass (CM) and characteristic time (CT) was presented. By mathematical modeling , the CM and CT of Soddy-podzodsand Cherro-zem was calculated as the orders of 133 t·hm^{-2} and 80 years with an annual litter-fall mass about 5.5 t·hm^{-2} for Soddy-podzods , and 820 t·hm^{-2} , 650 years with an annual litter-fall mass 11.2 t·hm^{-2} for the Cherro-zem. Further more , the CM and CT varied with the change of mass input and decomposed velocity in the soil , which are influenced by the external factors (light , temperature , moisture etc.) and anthropologic factors. We also found that the lower the horizon was , the longer the CT would be.

Key words soil types , characteristic mass (CM) , characteristic time (CT) , functional ecology.

1 Introduction

Nowadays there is a tendency to study the vegetation and climate change based on isotopic composition of organic carbon[3～5 ,7 ,8 ,11 ,15] , but little work has been done with the CM and CT estimation by using mass balance of soils[9] . The genetic horizons are considered as a "capacity", in which the storage of matter is determined by the difference between matters' input and output. In this paper , the input matter is mainly considered as litter-fall , which includes above-ground litter , root detritus and the dead parts of the organisms. These components distribute among the soil profile horizons: A0 , A1 , AB , B , BC , C. The difference between the input and out matter shows the dynamics of the CM , which changed with the decomposition rate. If the decomposed rate is faster than the accumulated rate , then the accumulated matter in the soil will become less and less. In the end , the matter presented at the beginning will be completely replaced , this time interval is called the CT of the soil horizons. The maximum time of all horizons is the CT of the whole profile. The mass ex-

*中国科学院院创新项目(KZCX2-407)、国家基金委海外杰出青年合作基金(39928007) | 中国科学院海外杰出学者基金(2000 年度)和中国科学院 CERN 监测项目的联合资助。
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收稿日期:2002 - 04 - 28 改回日期:2002 - 11 - 02

isted in the soil profile is called the CM. Different kinds of soils have different CM and CT, which provided a new method to distinguish the soil types.

The employed supporting theory in this paper is functional ecology, which is based on the metabolism of an ecosystem or ecosystem cycle[1,12,14]. The ecosystem cycle unites the autotrophic and heterotrophic, living and dead organisms as a whole. This concept can be expressed by Figure 1[1]. Here FAR is the photosynthesis active radiation. T is temperature. The synthesis of plants mainly depends on three factors: light, temperature and moisture. Most photosynthesis production enters the soil directly and only a small part of masses flows through the trophic chain (primary producers-herbivores-carnivores-…… omnivores-detritivores-green plants). There are three channels for decomposed matters' output from soil: one is the mineral mass which is absorbed by the plants, another is CO_2 volatilizing from the soil to the atmosphere, and then the other is the return of the useful matter to organisms, nourishing their descendants or organs and fabric.

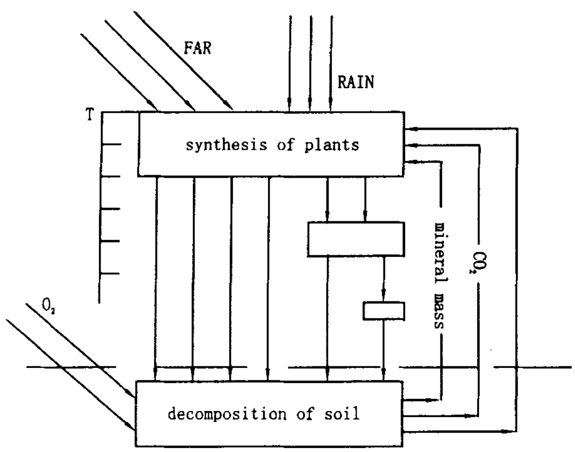


Fig. 1 Ecosystem cycle

2 A survey of research district

The Uvs-Noor basin is situated at the border of Tuva and Mongolia, with a latitude of 48～50 °N and a longitude of 91～99 °E. It expands from north to south 160 km, and 600 km from west to east. On the north, the basin is surrounded by the eastwestern Tannuh-Olah ridges and the Sanghilen plateau; On the south, by Bunai-Nuru and Han-Huhei ridges; On the west, by Tsagan-Shibetu ridge and by the Turgen-Ulah and Kharkhira massifs adjoining the Mongolian Altai; On the east, it is limited by the watershed with Selger-Muren river basin. The basin has no drainage. The salty lake Uvs-Nuur with an area of 80 km ×70 km and a depth of 15 m, is situated in the western part. It plays the role of a small internal sea where water from the whole basin flows down[6].

The annual mean precipitation is about 150 mm (250 mm in recent 5 years). The temperature in average of a year is below 0 ℃, but in summer is often as high as 30 ℃. With the increase of altitude, it becomes colder and colder. Above 3500 m, in Turhen-Ulah and Kharkhira massifs lays eternal snow.

The peculiarity of Uvs-Noor basin is that it can provide almost all the natural types in the world-deserts, dry and general steppes, forests on mountain slope and tundra at their peaks. It can be regarded as a "small biosphere", extending the farmost northern desert and the farmost southern tundra.

3 Methodology

3.1 Model structure

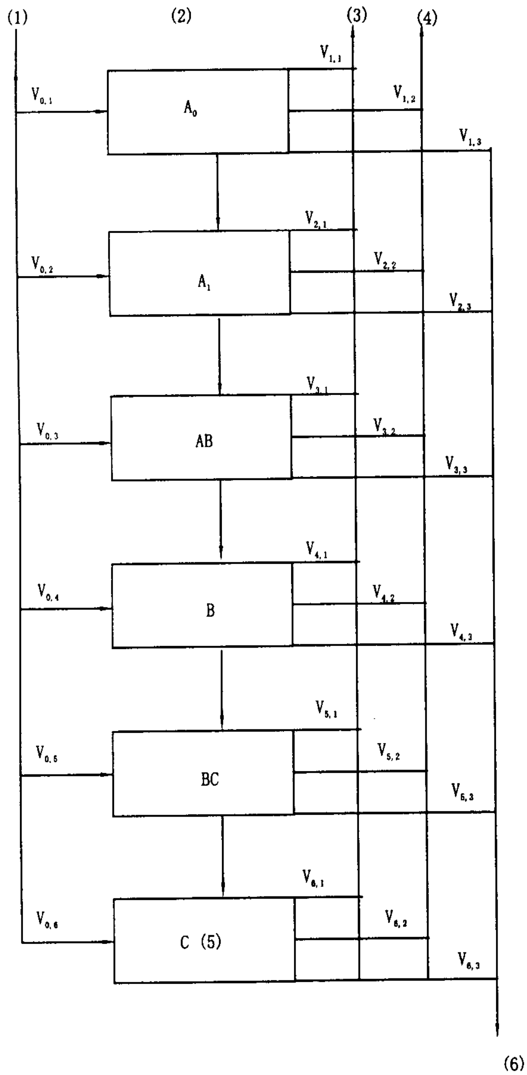
The input matter is the litter-fall which is distributed among soil profile horizons: A0, A1, AB, B, BC and C, and is proportional to the density of roots. There are four channels for matter output, which can be expressed by velocities correspondently, V_{i1} —the velocity of matter output from horizons to atmosphere; V_{i2} —the velocity of matter output into the phytomass (the increased ash quality); V_{i3} —the velocity of matter output from horizons to hydrosphere (the soluble mineral matter flows away with water); V_{i4} —the velocity of matter transition from a higher situated horizon to a lower one. The horizon number i may be changed according to specific profile without fundamental model changing. The concept scheme, given on figure 2, is described by the following equations[2,12]:

$$d_{mi}/ d_t = V_{i0} + (M_{i-1,4}) * (V_{i-1,4}) - \text{Sum}(M_i \cdot V_{ij}) \quad (j = 1 \cdots 4) \qquad (1)$$

or by finite different equations for computer:

$$M_{i,t=1} = M_{i,t+d_t}(V_{i0} + (M_{i-1} \cdot V_{i-1}) - \mathrm{Sum}(M_i \cdot V_{ij}) \quad (j = 1 \cdots 4) \qquad (2)$$

Where i means A0 , A1 , AB , B , BC , C; $j = 0$, 1 ,2 ,3 ,4 ; V_{i0} is the input matter to profile horizons. M_i is the organic matter in soil profile. It should be mentioned that measurement methods to these parameters require supplementary experiment.



(1) Litter-fall ; (2) Soil ; (3) Atmosphere ; (4) Phytomass ; (5) Bedding ; (6) Lithosphere ; (7) Hydrosphere

Fig. 2 Scheme of soil blocks

3.2 Model concept

Based on this structure scheme, a computer model was set up to imitate the mechanisms of the soil functions. The starting conditions are: supposing that the organic matter in each horizon equals zero , and inputting the value of annual litter-fall mass as original data. Based on the data of the field investiation twice (In Spring and Autumn) every year ,the amount of litter-fall was determined at different time in a year. The difference rate of the litter-fall ,influenced mainly by climate conditions ,is 1 divided by the relatively renewal time ,which is the value of the amount of annual litter-fall divided by the existing amount of litter-fall when supposing that the ecosystem is always in steady state. It is much slower in the cold and dry places than those with hot and humid climate for the decomposition rate ,accounting for about 1/ 10 to 1/ 60 per year in the forest area at frigid and temperate zone[13 ,16] 。For each horizon ,there is a velocity of input matter (litter-fall) and a decomposing velocity every year. The difference between them is the storage matter in the soil. When the value of original input matter reaches the minimun ($<= 0.1$) , the organic matter in the soil has been completely renewed. Till then , the CM and CT can be determined by its total mass and total time. The theoretical scheme for the formation and matter cycling of the organic profile during decomposition processes of litter-fall mass is shown in table 1. we take three treatments of the same type of soil to understand the dynamic process of the renewal organic masses in the soil profiles.

Treatment 1 :we take 4 units as the annual litter-fall , entering the soil , and the decomposition velocity is 50 %. Every year the original organic matter (4 units) is decomposed by halves (here we take the round values) and 4 units of new mass enter into the soil. In this way , we get a total value of accumulated organic matter in the soil. When the original organic matter is only 0. 1 or less than 0. 1 , we suppose that the original matter has been completely decomposed and there will be a new similar cycle. At this moment , the total mass is the CM and the time which it takes is the CT for this type of soil. Here for treatment 1 , the CM is 8. 1 , and the CT is 7 years. It means that for this type of soil , it will take 7 years to renew its organic mass when the annual litter-fall are 4 units and its decomposition velocity is 50 %.

Treatment 2 : the amount of input mass (litter-fall) is changed to half of the first treatment but with the same decomposition velocity. Another CM and

CT for the same type of soil can be obtained:4.1 and 6 years respectively. Treatment 3: the speed of velocity is changed to two times of the first variation but the amount of the input mass (litter-fall) remains stable for the same type of soil. Its CM and CT are 5.4 and 4 years, respectively.

Tab.1 Theoretical scheme for the formation and matter renewal of the organic profile during decomposition processes of litter-fall mass

Fraction number	Year of deposit and exposure of the litter-fall mass													
	1st	2nd	3rd	4th	5th	6th	7th	n+1	n+2	n+3	n+4	n+5	n+6	n+7
Treatment 1														
1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0						
2		2.0	2.0	2.0	2.0	2.0	2.0	2.0						
3			1.0	1.0	1.0	1.0	1.0	1.0	1.0					
4				0.5	0.5	0.5	0.5	0.5	0.5	0.5				
5					0.3	0.3	0.3	0.3	0.3	0.3	0.3			
6						0.2	0.2	0.2	0.2	0.2	0.2	0.2		
7							0.1	0.1	0.1	0.1	0.1	0.1	0.1	
Toal	4.0	6.0	7.0	7.5	7.8	8.0	8.1	8.1	2.1	1.1	0.6	0.3	0.1	
Treatment 2														
1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0						
2		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0					
3			0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5				
4														
5				0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3			
6					0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
							0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	2.0	3.0	3.5	3.8	4.0	4.1	4.1	4.1	2.1	1.1	0.6	0.3	0.1	
Treatment 3														
1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0						
2		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0					
3			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3				
4				0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1			
Total	4.0	5.0	5.3	5.4	5.4	5.4	5.4	5.4	1.4	0.4	0.1			

4 Results

Based on this concept, the CM and CT of Soddy-podzods and Cherro-zem were calculated with mathematical modeling. The data was from the field investigations (in Spring and in Autumn) to the grass land, where 1m *1m plots (10 plots) were randomly selected to estimate the biomass (including the living parts and litter-fall) of the grasses by harvest in Uvs-Noor basin in 1992[15]. By mathematic modeling which was mentioned above, a computer program was designed to simulate the accumulation of CM and CT according to formula (1) and (2). The starting conditions are: supposing that the organic substance in each horizons equals zero, and then inputting the value of annual litter-fall as original data. With the help of computer, the velocities were selected. By this way, the accumulated organic matter in soil horizons (CM) and accumulated time (CT) (years) were calculated. The calculation ends only when the CM accounts for the present quantity of organic matter in corresponding soil horizons, then the next horizon. By simulation, the CM of Soddy-podzods soil, being equal to 133 t ·hm^{-2} with an annual litter-fall mass about 5.5 t ·hm^{-2}, is completely renewed during the time interval of 80 years, which is the CT. The CM of Cherro-zem, being equal to 820 t ·hm^{-2} with an annual litter-fall mass 11.2 t ·hm^{-2}, is renewed during 650 years. The CM and corresponding CT internals of genetic horizons are given in Table 2.

Tab.2 CM and CT internals of genetic horizons

Soil	A0		A1		AB		B		BC		Sum
	M	T	M	T	M	T	M	T	M	T	
Soddy-Podzods	30	20	52	60	23	80	16	80	12	80	133
Cherro-Zem	10	4	160	80	200	120	300	620	150	650	820

This table has given a list of CM and CT of each genetic horizons for given profiles. For example, as for Soddy-podzod soil, the CM and CT of A0 are 30 t

·hm^{-2} and 20 years, AB, 23 t ·hm^{-2} and 60 years separately. As for Cherro-zem, it takes only 4 years for horizon A0 with CM 10 t ·hm^{-2} to renew its matter completely, while for its lower horizons, it will take 80, 120, 220, 650 years individually. Among these values, only the maximum time interval and the maximum CM of the whole profile are the CT and CM for the given profile.

5 Conclusion

The new method provides an attractive approach for estimating soil types by their CM and CT. Different types of soil have different CM and CT, and the CT changes with the soil depth. The lower horizon is, the longer CT it will be. It is also suggested that the soil ecosystem is an open system with an equilibrium dynamics, affected by soil-formation conditions and factors, which may cause the changes of transition velocities and annual organic matter in soil profiles.

However, the model concept was based on an ideal condition, and took the soil as a stationary regime, resulting from the inner succession of soils, which has not considered the influence of the outer factors on the soil. It should be further developed. But it can throw some light on the classification of soil types from a new aspect. The model can be adopted widely if the parameters representing the outer environmental factors were put into the model.

References

[1] Bugrovskiy VV, 1997. Functional Mathematical Modeling on Ecology [M]. Kizil, (in Russian).

[2] Bugrovskiy VV. *et al*. 1992. The Living Strategy of Ecosystem [M]. Pushchino, Izd. Nzbi AN, SSSR, (in Russian).

[3] Deines P. 1980. The Isotopic Composition of Reduced Organic Carbon[M]. In: Fritz P, Fontes J C, eds. Handbook of Environmental Isotope Geochemistry. Amesterdan: Elsevier Scientific Publishing Company, 329～406.

[4] Fredlund GG, Tieszen LL. 1997. Phytolith and carbon isotope evidence for late Quaternary vegetation and climate change in the Southern Black Hills, South Dakota[J]. *Quater. Res*., **47**: 206～217.

[5] Han JM, *et al*. 1996. The isotopic records of ancient climate changes in loess carbonate[J]. *Sci. China, Series D*, **26**(5): 399～404.

[6] Haslavskaya VE, Bugrovskiy VV. 1994. World of Uvs-Noor basin [M]. Novacibirisk.

[7] Humphrey JD, Ferring CR. 1994. Stable isotopic evidence for latest Pleistocene and Holocene climate change in north-central Texas[J]. *Quater. Res*., **41**: 200～213.

[8] Kelly EF, *et al*. 1991. Stable isotope ratios of carbon in phytoliths as a quantitative method of monitoring vegetation and climate change[J]. *Quater. Res*., **35**: 222～233.

[9] Kerzhentcef AS, *et al*. 1998. Methods of Regulation of Ecosystem Functions[C]. Dobrovoliskiy GV, *et al*. edited. Ecology and Soil [C], *Series* **1**: 219-236. (in Russian)

[10] Kovda VA, *et al*. 1993. The soil organic matter transformation model for the soil functions' numerical investigation in ecological system[C]. In: Information Problem of Biosphere Investigation, Experiment "Uvsu-Nuur", Phshchino, 355～359 (in Russian).

[11] Nord LC, *et al*. 1994. Late Quaternary vegetation and climate change in central Texas based on the isotopic composition of organic carbon[J]. *Quater. Res*., **41**: 109～120.

[12] Odum EP. 1981. Fundamentals of Ecology[M]. Beijing: People's Education Publishing House.

[13] Seastedt TR. 1988. Mass, nitorgen, and phosphorus dynamics in foligage and root detritus of tall grass paririe[J]. *Ecology*, **69**: 59～65.

[14] Shvartz SS. 1976. The theoretical basis for prognosticating the global ecosystem[R]. The United Symposium between Soviet Union and American, L "hydrometeoridata", (in Russian).

[15] Vossbrinck Coleman, CR, Wooley, FA. 1979. Abiotic and biotic factors in litter decomposition in a semiarid grass land[J]. *Ecology*, 60: 265～271.

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