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COUPLING ANALYSES OF FRAGILE ECO-ENVIRONMENT IN THE WEST OF THE SONGNEN PLAIN

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ABSTRACT: The fragile eco-environment is a special type of ecosystem, its response to the change of environmental conditions is very susceptive. So it is rather prone to be disturbed under unfavorable conditions. Human activity has greatly changed the geo-chemical process in the ecosystem, thus caused a series of positive and negative effects. In the ecosystem, especially in the fragile eco-environment, different systems and regimes are interconnected and interdetermined. For the suntainable development of ecosystem and the protection and rational utilization of resources, it is of great importance to study these internal relationships and seek rational regulation and control measure. This paper takes the fragile eco-environment in the west of the Songnen Plain as an example. Based on the study of the topograph, physiognomy, soil, vegetation and their geographic distribution in the landscape, the paper explains the structure of the ecologic landscape and quantifies the ecologic geo-chemical processes under different landscape conditions. In addition, the paper also tries making coupling analyses of the ecologic succession and the landscape geochemical environment. And in the paper, some research results are given.

KEY WORDS: west of the Songnen Plain; fragile eco-environment; ecologic structure; coupling of ecologic factors

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1 INTRODUCTION

In ecosystem, fragile eco-environment is defined as the "interface" between two or more systems of matter, energy, structure or function, and the transition region extending from this interface(NIU, 1989). The fragile eco-environment of the Songnen Plain, is situated on such a interface between various systems. Evolvement of landscape geochemical environment of this fragile eco-environment is determined by the combined action of many matter, energy and function systems. On one hand, it is controlled by natural factors such as geologic, geomorphic and geohydrologic conditions and so on, therefore the environment has one kind of transitional characteristic, on the other, located on the interface between agriculture, forestry and animal husbandry, affected by human activities and other factors, the landscape geo-chemical process process has created a vulnerable ecologic landscape primarily characteristic of salinization and desertification of soil. As the relationship between human and environment is opposite while unitive, through their planned and goaldirected production activities, human can drive the landscape geo-chemical environment to evolve rather rapidly by affecting and changing the geo-chemical flow mode in the landscape. There are many instances such as by

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building water conservancy system, human has changed the landscape geo-chemical flow in the water system, and the discharge of contamination to the environment and mowing and stock raising has caused plus or minus extra landscape geochemical flow. And the change of geochemical flow mode in the landscape has resulted in the change of environment and prompted the evolution of regional landscape geochemical environment. The Songnen Plain lies in the northeast of China, and its climate belongs to semiarid monsoon type. There are close relationships between the succession of different biotic communities and soil environment. Coupling analyses of these relationships is of great signification to the study of landscape geochemical property of the natural factors in this ecosystem and the rational protection and utilization of plants and soil resources.

2 ECOLOGIC AND LANDSCAPE CHARACTERISTICS OF THE STUDIED AERA

In the west of the Songnen Plain, under the mutual affect of semiarid climate and geomorphic, ecologic and geologic conditions, a special landscape structure has been formed up. The rough topograph of this zone appears as relatively higher in the west and lower in the east. Hills, mesas, fluvial alluvial bench land, fluvial flood plain, eolian dune, sand ribbons and salinized depression among the sand ribbons make the typical geomorphy in this zone. Composite and gramineous plants are predominant in the vegetation in the landscape, which change gradually from Chinese wildrye, ruderal meadow steppe in the east to the arid grassland in the west. The main soil is typical of chernozem and military. And there are weisenboden, wind-blown soil, asline-alkaline soil as well. The topographic change on the zonal scale and the microtopographic change control jointly the special variation and reciprocal combination of the landscape geochemical processes, thereafter created the complex and regular landscape geochemical environment in the fragile eco-environment of the Songnen Plain, and under this condition, the corresponding complex ecologic structure is formed up.

As far as the geographical distribution of plants as concerned, though the distribution area for different plants is different, there are some common characteristics (LI, 1997; LU *et al.*, 1996) . The *Puccinellia tenuiflora, Suaeda glauca, Hordeum brevisublatum* and *Saussurea runcinata* and so on are predominant plants on the salinized land in the forest-grassland zone and the salinized meadow in the grassland zone, lakeside, or near the riverside; while the *Kochia sieversiana* and *Polygonum sibiricum* spread widely on the salinized land in the grassland zone and desert belt and the salinized meadow; on the dry saline land and tibba in the grassland-desert zone, only a few plants such as *limonium suffruticosum*, the *Suaeda glauca* and *S. corniculata* appear in the high salinized land; the *Phragmites* communis are the common plants on the salinized meadow, lowlands in the salt marsh and lands of saline silver sand clay soil; in addition, in the zones such as field, roadside, wilderness and so on, which subject to the impact of human activity, the main plants are *Chloris virgata* and *Messerschmidia sibirica*. In the general, the rough trend for the distribution of plants can be summarized as— from the west to the east, the approximate ecological community transitional series is *Ruderal* community→Elm light forest brushwood community→ *Aneurolepidium chinense* + *Ruderal* community→ *Aneurole chinense pidium community*→ *Halomorphic* community→ *Phragmites* communies community.

3 MATERIAL AND METHODS

We chose 6 sites in the west of the Songnen Plain, the degree of soil salinization of these 6 sites is different. Then, at each site, we select three quadrats of 1.5m × 1.5m at random, and this process was triple. In the middle of July and August of 1999, two sampling and investigation was carried out. The type and distribution of vegetation, the biomass and so on was investigated and measured. Cover degree of plants was measured with the plant cover degree analyzer. Meanwhile, soil samples (0 – 80cm) were collected and soil water content (0 – 30cm) was measured on the spot. And the soil profile was observed and recorded. In the laboratory, soil pH, salt content, electrical conductivity of soil solution, exchangeable sodium percentage and the total salt content were measured after the pretreatment of the soil samples. After that, we picked out pH, soil water content, total soil salt content and cover degree of plants as primary indicators and used the software MATLAB to make statistic analyses and simulation. Then the coupling curvilinear equation for the relationship between the cover degree of plants and other three dependent variables was got and indices of ecological adjustability for different type of vegetation were calculated. Finally, the coupling analyses was carried out.

4 RESULTS AND DISSCUSSION

4.1 Analyses of the Landscape Geochemical Process in Different Landscapes

There is close relationship between the formation and combination of vegetation community and the corresponding landscape environment(Fig. 1). Under different condition of landscape geochemical grads, the growth of plants is different. In the environment with high or low value of landscape geochemical grads, plants will show some degree of maladjustment in their growth(the cover degree will decrease), only environment with moderate landscape geochemical grads is optimum to the growth of plants. These can be illustrated by the growth curve of plants, growths of most plants along the landscape geochemical grads appear as bell-like curve. And this is just the coupling effect of the landscape geochemical grads and growth conditions of plants.

In the normal curve equation $\Phi(x) = \frac{1}{\sqrt{2\pi}\delta e^{-\frac{(x-a)^2}{2\delta^2}}}$, where the parameter $\delta\ (\delta = \frac{1}{n-1}\sum (X_i - \overline{X})^2)$ reflects the steep degree of the curve, and the parameter a $(a = \frac{1}{n}\sum x_i,\ n = 7$ 或 $8)$ indicates the distance the focus of the curve deviate from the origin. The smaller the value of δ is, the more narrow and steeper the curve will be, vice versa, the higher the value of δ is, the smoother and wider the corresponding curve will be. While parameter a indicates the value of X when the value of $\Phi(r)$ is maximum. So we decided on pH, soil salt content and soil water content as the factors of geochemical grads, and plant cover degree as the factors of ecologic grads. Then the factors pH and soil salt content are classified into 7 ranks according to their value from low to high, whereas the soil water content is classified into 8 ranks(Table 1).

On this basis, we can use equation to fit the coupling curve of the geochemical grads and ecologic grads (Fig. 2) and get the values of δ and for all kinds of plants(Table 2). Where the value of δ shows implies the ecologic tolerant capacity of plants under certain soil grads, higher value of δ shows that the plants have higher capacity of ecologic tolerance, and its ecologic range is wider. While value of reflects the landscape geochemical grads of soil corresponding to the optimum ecologic grads, higher value of corresponds to the part of higher value of landscape geochemical grads of soil, while lower value of corresponds to the part of lower value of landscape geochemical grads of soil. Here, we can refer to δ as the landscape ecologic grads, and as the optimum ecologic geochemical grads.

Table 1 Standard for the classification of soil grads factors

Soil factors	Ranks of grads							
	1	2	3	4	5	6	7	8
pH	<6.5	6.5 – 7.0	7.0 – 7.5	7.5 – 8.5	8.5 – 9.0	9.0 – 9.5	> 9.5	
Salt content(%)	<0.03	0.03 – 0.1	0.1 – 0.25	0.25 – 0.4	0.4 – 0.55	0.55 – 0.70	> 0.70	
Water content(%)	<10	10 – 12	12 – 14	14 – 18	18 – 22	22 – 26	26 – 30	> 30

It can be found from the table above that the ecologic tolerant capacity for different plant to the same geochemical grads is quite different, that is to say, the value of δ is different. But in the general, landscape ecologic range of the *Aneurolepidium chinense* and *Phragmites* communis are relatively wider than ones of other plants.

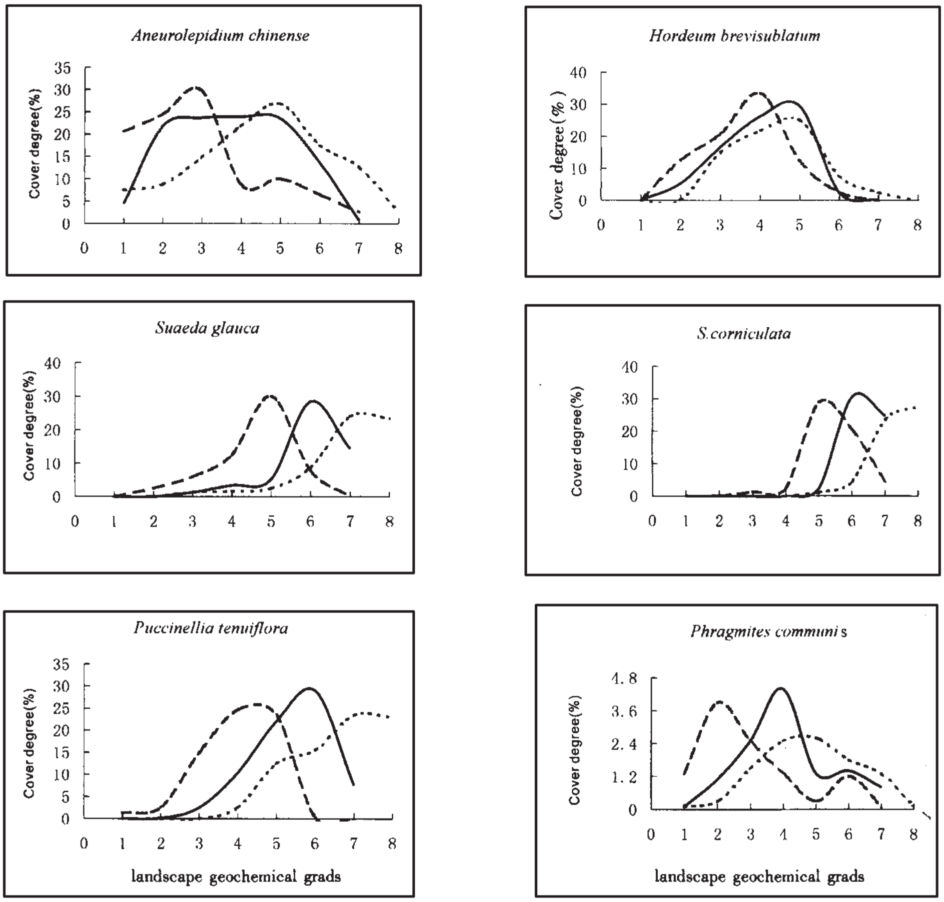

Fig. 1 The coupling curves for plant cover degree and different landscape geochemical grads
—— along the pH grads; - - - - along the salinity grads; ——along the moisture grads

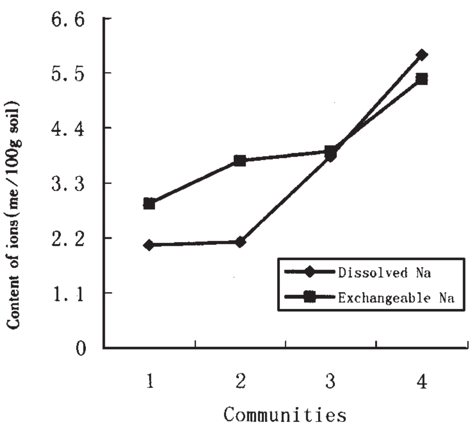

Fig. 2 Comparison of Na^+ content in soil for different communities
1 – *Aneurolepidium chinense* community 2 – *Chloris virgata* community 3 – *Puccinellia tenuiflora* community 4 – *S. corniculata* community

4.2 Coupling Analyses of Ecologic Succession and Landscape Geochemical Environment

Plants community is in mutual adaptation with certain landscape geochemical conditions. Change of physical and chemical property of soil in the landscape can cause the succession of community to take place along different direction. While the succession of ecosystem, in turn, can also influence the change of geochemical conditions in soil (HARRINGTON, 1991; TOSI *et al.*, 1964). And the coupling analyses of their internal relationship has become more and more arrestive (LI *et al.*, 1996; JUNK *et al.*, 1989).

In the fragile eco-environment of the Songnen Plain, under contemporary conditions, succession of plants community and chage of soil geochemical condi-

Table 2 Value of δ and a of plants in the Songnen Plain corresponding to pH, salt and soil moisture

	pH		Salt		Moisture	
	a	δ	*a*	δ	*a*	δ
Suaeda glauca	6	0.739	5	0.782	7.5	1.031
S. corniculata	6	0.755	5	0.801	8	0.821
Puccinellia tenuiflora	5.5	0.987	4.5	1.143	7	1.309
Artemisia anethifolia	5.5	1.409	5	1.090	7	0.955
Aeluropus littoralis var. sinensis	6	0.850	5	1.031	7.5	0.988
Obione sibirica	6	0.673	5	0.638	7	0.706
Hordeum brevisublatum	5	1.089	4	0.973	5	1.148
Kochia sieversiana	4	1.007	4.5	0.936	4.5	1.033
Glaux maritime	4.5	1.381	4	1.091	4.5	0.998
Tararacum sinicum	4.5	1.688	4	0.831	4.5	1.788
Saussurea runcinata	4	0.642	4	0.623	4.5	1.543
Allium polyrrhizum	4	0.718	4	1.226	4.5	1.019
Zris pallasii	4.5	1.026	4	0.849	4.5	1.022
Polygonum sibiricum	4.5	1.053	3	0.989	5	1.006
Chloris virgata	4	1.389	3	1.159	5	1.421
Messerschmidia sibirica	4	1.064	3	1.149	4.5	1.072
Aneurolepidium Chinense	4	1.865	3	1.509	4.5	1.593
Phragmites communis	4	1.143	2.5	1.692	5	1.565
Asparagus brachyphllus	2	1.026	7	0.712	2	1.034
Apocynum venatum	2	0.614	7	0.832	2	0.761
Limonium bicolor	2	0.931	6	0.798	3	1.117

tions are almost simultaneous, and under certain condition these two processes are interdetermined. But our research has shown that in this region, as far as the accumulation and distribution of salt in the soil profile as concerned, the influence of vegetation is more important. In a sense, it is the succession of vegetation that determine the regime of salt in the soil profile. This is because that in the west of the Songnen Plain, which is an inland arid region, the supergene water-soluble geochemical elements in the original soil transfer to the wettish lowands along with water, and may be raised by evaporation or eluviated by precipitation. Their distribution in soil is influenced by the movement of water in the up or down direction. As vegetation is an important environmental factors affecting the movement of water in soil, and the species, cover degree, growth status and other factors of plants can greatly affect the movement of water in soil. And the root system, water-absorbing capacity and distribution depth are different for different plants, so are their influence to the soil environment (MACARTHUR *et al.*, 1963; MCAULIFFE, 1994).

During the process of retrogressive succession of vegetation community, decrease in the cover degree and substitution of the species of plants will lead to the change of the amount of soil water absorbed and utilized by plants, and the transpiration from the leaves and evaporation from the soil surface will be changed too. These factors, then, will influence the accumulation rate of salt in soil, sequentially change their distribution in soil. On the other hand, decrease in the cover degree of plants enhance not only the evaporation from soil surface, but also the decomposition of organic matter. The latter can emit much Na_2CO_3 and $NaHCO_3$, thus increase the content of exchangeable sodium and at the same time, reduce the content of exchangeable calcium and exchangeable magnesium, and as a result, the value of ESP will increase eventually.

The Aneurolepidium chinense is the predominant plants species in the grassland of the Songnen Plain. Decrease in this species of plants may imply the beginning of retrogressive succession of the community. Just as Table 3 shows, retrogression of *Aneurolepidium chinense* has caused the increase of value of EC and ESP, and meanwhile we can find that, as to the influence to the soil EC and ESP, the index of weightiness of the *Aneurolepidium chinense* is higher than the index of the relative cover degree of the *Aneurolepidium chinense* (in the equations, 6.25> 3.97 and 75.6> 44.89).

Additionally, it can be found form the comparison of the curves of these equations that there are considerable similarity among them, and this shows that it is synchronous for the processes of sallification and basification of soil during the retrogression of vegetation.

Table 3 Coupling curve equations for retrogression of the *Aneurolepidium chinense* community and change of soil factors

Equations	Correlation coefficient	Sample number
EC = 11.12 − 6.25lgIV	r = −0.8499	n = 18
EC = 7.88 − 3.97lgC	r = −0.8755	n = 18
ESP = 136.58 − 75.6lgIV	r = −0.7510	n = 18
ESP = 88.88 − 44.89lgC	r = −0.7246	n = 18

EC: electric conductivity; ESP: exchangeable sodium percentage;
IV: important value of *Aneurolepidium chinense*;
C: relative cover degree of *Aneurolepidium chinense*

During the retrogression of community, accumulation of Na^+ in the root part of soil is increased, and sodium content in plants of different community is obviously different. This shows that the high sodium content in plants is due to their longterm adaption to the habitat.

It can be observed from Table 4 that amount of Ca^+, Mg^{2+} and K^+ in the root part of soil tend to decrease during the retrogression, while the relative decrease of exchangeable Ca^+, Mg^{2+} and K^+ is market (value of ESP increase). Meanwhile, amount of soluble Na^+ and exchangeable Na + both increase. According to the suggestion of Boleinofu, Ca^{2+}, K^+, Mg^{2+} and Na^+ all belong to elements of bioaccumulation, but the sequence for biologic absorption rate of them is Ca> K> Mg> Na. Therefore, it is obvious that the landscape geochemical environment resulted from the aforementioned retrogressive succession is adverse to the well growth of plants.

In addition, based on the understanding to the succession of typical ecologic community in the Songnen Plain, tried to take some control measures so as to make it develop towards the progressive succession. As a result, total salt content and value of pH decrease in the whole soil profile during the process of ecologic progressive succession, especially in the surface layer of soil. Other salt ions such as Na^+, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-} have similar change. While changes of Ca^{2+} and Mg^{2+} are inverse to a turn (Table 5). And the soil landscape geochemical environment of this type is more favorable to the growth of plants.

5 CONCLUSIONS

The Songnen Plain lies in she monsoon climate zone of semiarid. Its environment is very vulnerable. Affected by the irrational production activities of human, retrogression of the system tends to aggravate day by day. The succession and balance of ecosystem in this region are influenced by both natural and anthropic factors. Coupling analyses of ecologic has shown that there is close correlativity between the soil geochemical environment and ecologic grads of vegetation. Most plants' growth curves along the landscape geochemical grads appear as bell-like and this is just the result of coupling effect of geochemical grads and growth conditions of plants. Under nowadays conditions, it is almost coinstantaneous for the succession of plants community and change of soil geochemical conditions, and these two processes can be interdetermined under certain condition. Therefore we can try to switch the retrogressed plants community in the west of the Songnen Plain to the progressive succession by the adoption of a

Table 4 Change of environmental factors in soil during ecologic succession

Community	Soluble salts (me/100g soil)							
	Ca^{2+}	Mg^{2+}	K^+	Na^+	CO_3^{2-}	HCO_3^-	SO_4^{2-}	Cl^-
1	0.089	0.109	0.355	2.053	0.304	0.477	0.161	0.432
2	0.200	0.077	0.151	2.123	0.726	0.551	0.353	0.274
3	0.043	0.109	0.057	3.841	1.929	0.869	0.281	0.233
4	0.138	0.052	0.259	5.822	2.631	1.308	0.461	0.718

Community	pH	Total content of salt (%)	Degree of alkaline (%)
1	8.65	0.12	24.62
2	8.75	0.16	34.69
3	9.60	0.23	41.12
4	9.74	0.36	54.74

1 − *Aneurolepidium chinense* community, 2 − *Chloris virgata* community 3 − *Puccinellia tenuiflora* community, 4 − *S. corniculata* community

Table 5 Progressive succession of vegetation community and changes of soil geochemical conditions

Community	Soil horizon (cm)	pH	Content of salt (mmol/100g soil)	Content of ions (me/100g soil)							
				K^+	Na^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
Alkali	0 – 20	9.72	8.37	0.011	8.318	0.110	0.150	6.780	3.098	0.844	1.886
spot	20 – 50	9.55	6.718	0.007	6.919	0.200	0.298	4.610	2.681	0.756	0.898
	50 – 80	9.49	3.48	0.009	3.430	0.292	0.396	2.824	0.886	0.412	0.936
Chloris	0 – 20	9.50	6.64	0.017	6.464	0.084	0.124	5.818	2.865	0.476	1.674
virgata	20 – 50	9.35	6.66	0.017	6.552	0.106	0.136	4.480	2.770	0.636	1.944
	50 – 80	8.70	4.21	0.015	2.724	0.248	0.224	0.614	2.187	0.197	0.568
Aneurolepidium	0 – 20	7.75	3.56	0.021	3.551	0.478	0.358	–	1.951	0.449	1.470
chinense	20 – 50	8.70	5.04	0.029	4.914	0.332	0.080	1.580	1.810	2.600	2.320
	50 – 80	9.36	6.11	0.016	6.155	0.256	0.040	2.668	2.605	1.051	1.828

series of comprehensive improvement measures such as increasing application amount of organic manure so as to increase the soil organic content, applying soil amendment to decrease the content of soil salinity and pH, using water resource facilities to reduce groundwater level and so on. Our experiment has shown that during the ecologic progressive succession , not only the total salt content and value of pH in the whole soil profile decreased greatly, but also the physical property of soil was improved markedly.

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