American-Eurasian J. Agric. & Environ. Sci., 4 (1): 55-61, 2008
ISSN 1818-6769

Geostatistical Analysis of Soil Nematode Communities under Degraded and Meliorated Grasslands in the Horqin Sand Land

[1,3]*Chunjian Shi*, [1,3]*Xiaoke Zhang*, [1]*Yong Jiang*, [1]*Deming Jiang and* [2]*Yosef Steinberger*

[1]Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China
[2]The Mina and Everard Goodman Faculty of life Sciences, Bar-Ilan University, Bamat Gan 52900, Israel
[3]Graduate University of the Chinese Academy of Sciences, Beijing, 100049, China

Abstract: Geostatistics was applied to assess the spatial distribution of soil nematodes communities under Degraded Grassland (DG) and Meliorated Grassland (MG) in the Horqin Sand Land, Northeast China. Two 140 ×140 m plots, one in DG and the other in MG, were divided into grids with 20 m spacing that included totally 128 sampling points. Soil samples were collected from the depth of 0-20 cm in April 2006. The result showed that nematode richness (number of genera) and abundance were lower under DG than under MG. *Acrobeles* and *Bitylenchus* were dominant genera under both DG and MG. The numbers of total nematodes and trophic groups were spatial dependent. Gaussian and Exponential models were the best-fitted models for the studying variables. The spatial ranges for total nematodes, bacterivores and omnivores-predators were shorter under MG than under DG. Maps obtained by kriging showed that the numbers of total nematodes and trophic groups had different distribution patterns under DG and MG. Heterogeneity in the total nematodes and trophic groups was lower under DG than under MG.

Key words: Degraded grassland % meliorated grassland % soil nematode community % geostatistical analysis % Horqin sand land

INTRODUCTION

Grassland degradation is a serious problem in China, especially in semiarid region in Inner Mongolia, Northeast China [1]. In order to enhance the productivity of grasslands, several methods were chosen to meliorate the environmental condition of soil [2, 3]. In Horqin Sandy Land, desertification is controlled and grassland productivity is enhanced by planting indigenous grasses, returning degraded farmland to grassland and fencing degraded grassland in recent decades. Re-seeding fine quality leguminous herb species in combination with plowing-harrowing on degraded alkaline grassland proved to be good alternatives to increase biomass and quality of the vegetation and improve soil physiochemical and biological properties in this region [4, 5].

Understanding the soil biotic environment change after melioration will be fruitful in choosing better melioration methods and further managements in grasslands improvement. Soil free living nematodes were ubiquitous [6] and occupying a central position in the soil food web [7]. Spatial variability in soil communities reflect heterogeneity in soil resources, patterns of soil process rates and facilitate coexistence biota [8]. The distribution of soil free living nematode in the field has been descried as aggregated, which implies underling spatial dependence in nematode data. Geostatistics has become a powerful tool for analyzing the spatial distribution of soil nematodes [6, 9, 10-12].

Recent studies concerning the spatial variability of soil properties, vegetations and the relationships between them have been carried out in different grasslands all over the world [13-17], but little information is available on the spatial distribution of soil nematode communities in grasslands, especially in the Horqin Sand Land in inner Mongolia, Northeast China. Our objectives were to describe the spatial distribution of soil nematodes communities under degraded and meliorated grasslands and to develop maps illustrating the horizontal distribution patterns of nematodes communities using geostatistical method.

Corresponding Author: Dr. Xiaoke Zhang, Institute of Applied Ecology, Chinese Academy od Sciences, Shenyang 110016, China

MATERIALS AND METHODS

Study site: This study was conducted at the western Horqin Sandy Land (43°02' N, 119°39' E) in Inner Mongolia, Northeast China, which was an experimental demonstration site of the Wulan’aodu Station of Desertification Research, Chinese Academy of Sciences. The study site has a temperate semiarid climate, with multiannual mean temperature of 6.2°C, multiannual mean precipitation 340 mm, which falls mainly during June to August, frost-free period is 140 days and the multiannual mean evaporation is 2300 mm [18]. The soil in the study site is an Aquic-Sandic Primosol (Chinese Soil Taxonomy), with 11.15 g kgG^1 total organic carbon, 1.0 g kgG^1 total nitrogen, 9.7 pH, 236.4 ìS cmG^1 electric conductivity in DG and 10.79 g kgG^1 total organic carbon, 1.0 g kgG^1 total nitrogen, 9.3 pH, 164.7ìS cmG^1 electric conductivity in MG.

Two grasslands each of 5 hectares were selected for study: The first site was Degraded Grassland (DG) without any improvements and the second site Meliorated Grassland (MG) by fencing and seeding once after plowing [4] in April, 2001. Both plots received no fertilizer and each of them was harvested every autumn. *Hemarthia japonica*, *Phragmites communis*, *Anewrolepidium Chinense* and *Calamagrostis epigeios* are the dominant species in MG, while *Astragalus adsurgens* and *Phragmites communis* are predominant in DG.

Soil sampling: Two 140 m ×140 m plots, one in DG and the other in MG, were marked on regular square grids with 20-m spacing. Each plot contained 64 sampling points. Soil samples from topsoil (0 to 20 cm) were collected from each sampling point on 24 April 2006. Soil samples were placed in an individual plastic bag, which were then sealed and placed in an insulated box to prevent overheating during transportation to the laboratory. All samples were kept at 4°C until biological and chemical analyses were undertaken.

Laboratory analysis: Soil nematodes were extracted from 100 g soil samples using sugar flotation and centrifugation [12, 19], counted and preserved in formalin and identified using an inverted compound microscope. Soil nematodes were expressed as the number of individuals per 100 g dry weight soil. The classification of nematode trophic groups was assigned to: (1) bacterivores, (2) fungivores, (3) plant parasites and (4) omnivores-predators based on known feeding habitats or esophageal morphology [20, 21].

Statistical analysis: Classical statistical parameters were calculated using Statistics Package for Social Science 10.0 software. Anisotropic semivariances of data were calculates using GS+ geostatistical software [22]. Geostatistics or regionalized variable theory is a useful tool to describe any spatially structured variable in the soil. Central to geostatistics is the semi-variogram, the function which describes the evolution of the semi-variance with the inter-sample distance. Semivariance ((h) is defined in the following equation:

$$\gamma(h)=\frac{1}{2N(h)}\sum_{i=1}^{N(h)}[z(x)-z(x_i+h)]^2$$

Where *N(h)* is the number of sample pairs with distance *h* as an interval and z (x_i) and z ($x_i + h$) are the values of variable at any two places separated by distance *h*. The semivariogram is the plots of the semivariogram against the distance, its shape indicates whether the variables are spatial dependent or not, e.g. there is spatial autocorrelation. Experimental semivariograms well-known parameters are nugget $C_{0,}$ sill (C_0+C) and range of spatial dependence *A* [12, 23]. The nugget variance (C_0) expresses the variability due to unseen patterns (sampling errors and scales shorter than minimum inter-sample distance). The sill variance minus the nugget variance is the structural variance (*C*). This term accounts for the part of the total variance that can be modeled by the spatial structure.

A block kriging was used for constructing of contour maps to provide enough estimate data. The contour maps of variables were then constructed using GS+software.

RESULTS AND DISCUSSION

Thirty three and thirty six nematode genera were identified under DG and MG, respectively. *Acrobeles* and *Bitylenchus* were dominant genera (relative abundance>10%) in both DG and MG, while *Dolichorhynchus* was only dominant in DG and *Helicotylenchus* and *Paratylenchus* in MG (Table 1). Nematode richness (number of genera) was lower in DG than in MG. Among the trophic groups, plant parasites were the most numerous, representing 57.7% to 61.3% of the soil nematode communities, followed by bacterivores, accounting for 26.8 to 36.1% of total nematodes, fungivores and omnivore-predators were the least abundant trophic groups (Table 2). These results were in agreement with those reported by Bardgett and Cook [24],

Table 1: Relative abundance (RA%, as percentage of total nematodes) of nematode genera under degraded and meliorated grasslands in the Horqin sand land

Genus	RA (%) DG	MG
Bacterivores	36.1	26.8
Acrobeles	12.7	10.6
Acrobeloides	4.7	2.8
Cervidellus	2.2	2.2
Chiloplacus	5.1	2.2
Diploscapter	0.0	0.6
Eucephalobus	6.8	7.4
Eumonhystera	0.0	0.2
Hetercephalobus	0.0	0.1
Mesorhabditis	3.6	0.2
Plectus	1.0	0.5
Fungivores	5.1	5.3
Aphelenchoides	1.7	0.9
Aphelenchus	1.7	0.8
Aprutides	1.0	0.0
Tylencholaimus	0.7	3.6
Plant parasites	57.7	61.3
Aglenchus	0.2	0.6
Bitylenchus	19.0	10.0
Boleodorus	0.6	0.2
Coslenchus	0.3	0.2
Criconemoides	1.8	6.4
Dolichorhynchus	10.5	5.1
Filenchus	3.6	2.1
Heterodera	0.2	2.5
Helicotylenchus	7.6	16.0
Lelenchus	0.4	0.2
Macroposthonia	0.7	0.4
Paratylenchus	8.0	13.0
Paratrichodorus	0.1	0.3
Pratylenchus	0.1	1.5
Psilenchus	0.6	0.0
Scutylenchus	1.1	1.6
Tylenchorhynchus	2.7	1.1
Tylenchus	0.2	0.1
Omnivores-predators	1.1	6.6
Aporcelaimellus	0.4	1.5
Discolaimus	0.0	0.2
Dorylaimllus	0.2	0.8
Mesodorylaimus	0.0	0.1
Microdorylaimus	0.1	0.7
Thonu	0.4	3.3

who found that omnivores and fungivores usually made up smaller proportions of the nematode community and predators were the least abundant in agricultural grassland.

The absolute abundances of total nematode and trophic groups were lower under DG than under MG (Table 2). The number of total nematodes detected in our study was similar with that observed by Jiang *et al*. [18] in soil nematode communities under *Caragana microphylla* shrubs in Horqin Sandy Land, Northeast China. The variation of nematodes ranged from 47.14% to 120.35% and 70.12% to 243.76% in DG and MG, respectively. For all the nematodes, the frequency distributions of population sizes were positively skewed (Table 2).

Semivariogram were estimated for total nematodes and the four trophic groups under DG and MG. Figure 1 showed the scaled experimental semivariance and the adjusted Semivariogram models for all the variables at two grasslands and the corresponding model-fitted parameters were listed in Table 3. Gaussian model was the best-fitted model for total nematodes and four trophic groups in DG, while Exponential model was the best fitted model for nematode communities in MG except fungivores with a best fitted model of Gaussian model.

Geostatistical analysis showed that all this variability was spatial dependent; variograms suggest that 50.00-60.84% of sample population variances were related to spatial autocorrelation over ranges of 304.8-410.9 m under DG, while 50.00-66.39% of sample population variance was related to spatial autocorrelation over ranges of 293.2-410.9 m under MG. The ranges for total nematodes, bacterivores and omnivores-predators were shorter under MG than under DG, which showed that DG was seldom affected by random factors. These results agreed with the findings reported by Roberston and Freckman [6] in an agricultural soil in America and Liang *et al*. [11, 12] in two agricultural soils in China. The ranges of spatial dependent in our study were considerably larger than 13.3 m, which was the largest spatial dependent range for nematode communities reported by Liang *et al*. [11] in Hailun Agroecological Experimental Station, Northeast China.

Figure 2 showed the maps obtained by kriging for nematodes communities under DG and MG. Different distribution patterns of total nematodes and the four trophic groups were found between DG and MG. Figure 2 also showed that MG has a higher degree of

Table 2: Descriptive statistics for soil nematodes (individuals per 100 g dry soil) under DG and MG in the Horqin sand land

Genus	Mean	S.D.	CV (%)	Minimum	Maximum	Skewness	Kurtosis
Degraded Grassland (DG)							
Total nematodes	91	43	47.14	26	241	0.90	0.94
Bacterivores	32	21	63.54	3	117	1.72	3.92
Fungivores	4	4	109.52	0	29	3.31	17.11
Plant parasites	53	28	53.91	8	145	0.85	0.50
Omnivores-predators	2	2	120.35	0	8	1.58	2.18
Meliorated Grassland (MG)							
Total nematodes	354	286	80.47	128	2391	5.93	42.06
Bacterivores	90	63	70.12	21	435	2.90	13.24
Fungivores	6	16	243.76	0	121	6.32	45.16
Plant parasites	226	222	98.25	63	1787	5.70	39.50
Omnivores-predators	32	25	77.32	4	145	1.76	5.50

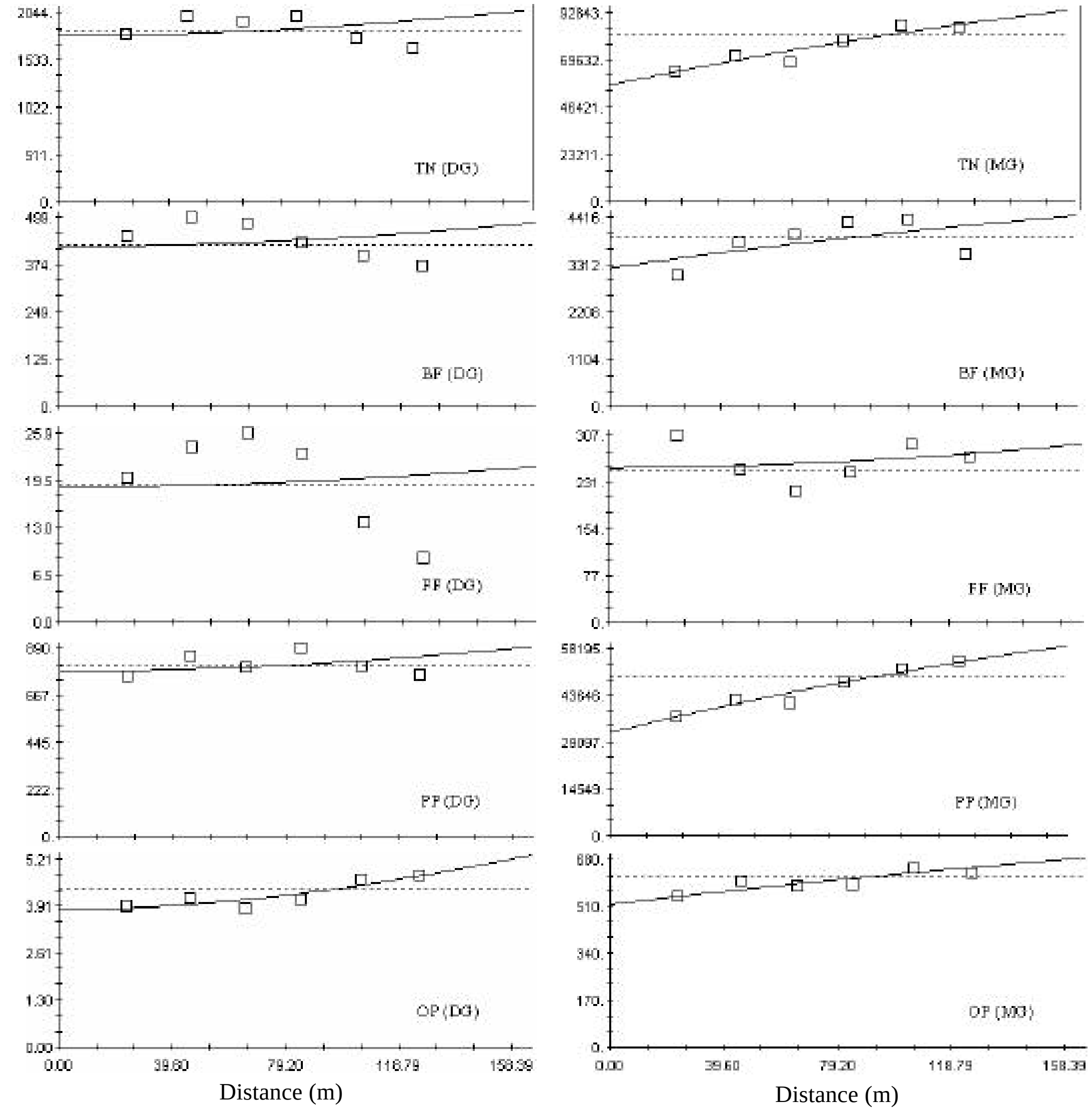

Fig. 1: Semivariograms for total nematodes and trophic groups under DG and MG
TN = Total nematodes, BF = Bacterivores, FF = Fungivores, PP = Plant parasites and OP = Omnivores-predators

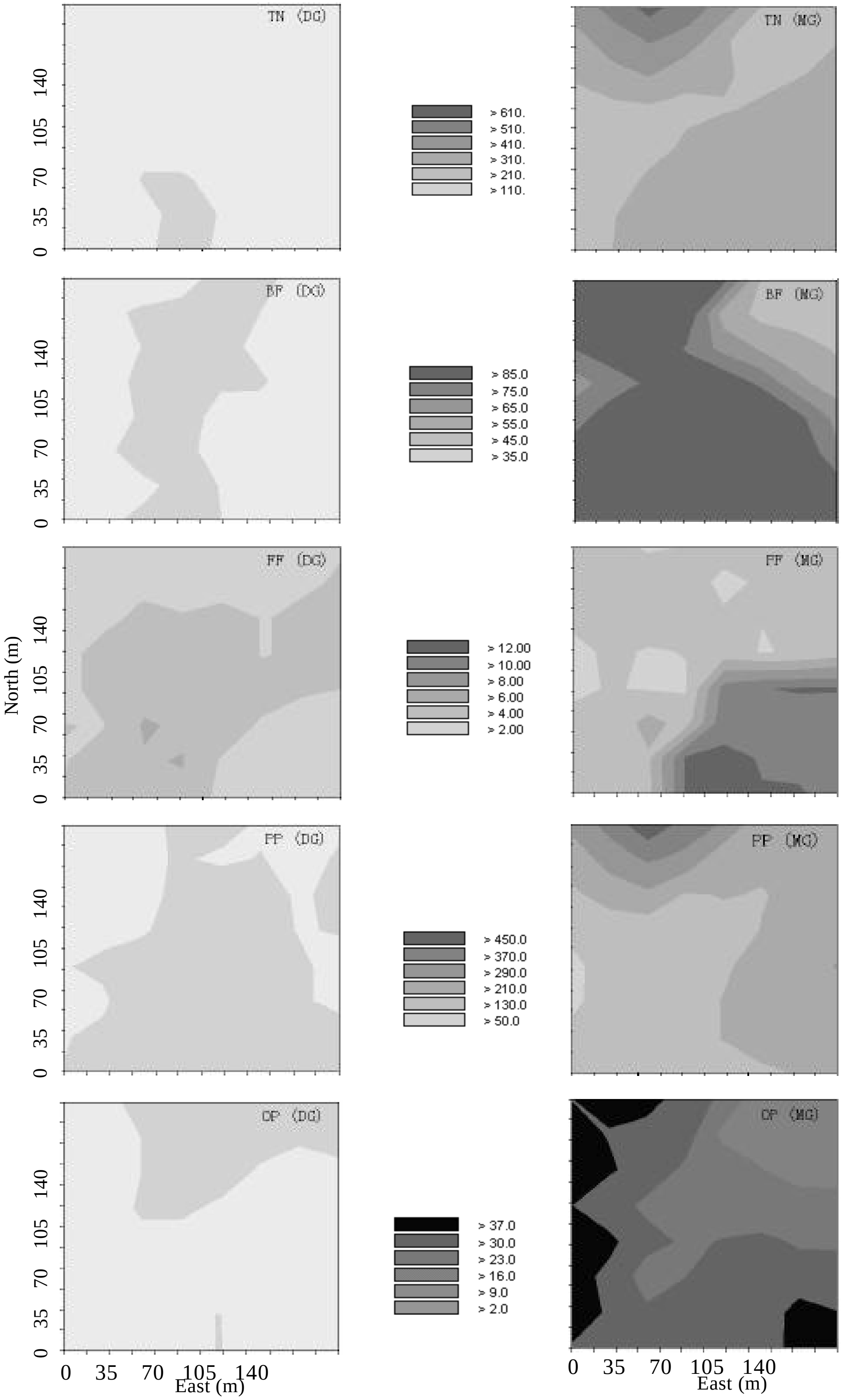

Fig. 2: Kriging maps for total nematodes and trophic groups under DG and MG

Table 3: Parameters of the best-fitted semivariogram model for soil nematodes

Variable	Treatment	Model	C_o(Nugget)	C_o+C(Sill)	$C/(C_o+C)$ (%)	A (range)	r^2
Total nematode	DG	Gaussian	1796.0	3593.00	50.01	410.900	0.460
MG	Exponential	56900.0	144900.0	60.73	301.70	0.882	
Bacterivores	DG	Gaussian	421.0	842.10	50.01	410.900	0.767
MG	Exponential	3230.0	6461.0	50.01	346.40	0.265	
Fungivores	DG	Gaussian	18.5	37.10	50.01	410.900	0.674
MG	Gaussian	254.6	509.3	50.01	410.90	0.120	
Plant parasites	DG	Gaussian	3.8	9.70	60.84	304.800	0.794
MG	Exponential	515.0	1030.0	50.00	410.90	0.711	
Omnivores-predators	DG	Gaussian	781.0	1562.10	50.00	410.900	0.033
	MG	Exponential	31900.0	94900.00	66.39	293.200	0.934

heterogeneity in total nematodes and four trophic groups, which may contribute to the greater plant species diversity under MG than under DG. In the semi-arid Horqin Sandy Land, desertification can be improved through the establishment of artificial vegetation which provides important protection against soil erosion by wind [25] and the melioration could play a positive role in improving soil environmental conditions [4] which might have a great effect on the soil nematode communities [26]. According to Wang *et al*. [27], the scale and degree of spatial heterogeneity in soil properties contribute greatly to the spatially heterogeneous distribution of flora and fauna which might have important consequences for both plant community structure and ecosystem-level processes [17].

CONCLUSION

The absolute abundances of total nematodes and trophic groups were spatial dependent. Gaussian model was the best-fitted model for total nematodes and trophic groups under DG, while Exponential model was the best fitted model under MG except fungivores with a best fitted model of Gaussian model. The spatial ranges for total nematodes, bacterivores and omnivores-predators were shorter under MG than under DG.

Maps of kriging showed that the total nematodes and four trophic groups have different distribution patterns. A higher degree of heterogeneity in total nematodes and four trophic groups was found under MG than under DG.

The use of geostatistics and the elaboration of maps proved to be crucial to monitor the melioration effects on soil nematode communities in a more detailed and comprehensive way. The kriging maps were a very valuable tool in monitoring the effect of grassland melioration on soil nematodes.

ACKNOWLEDGMENTS

This study was financially supported by found from the National Key Technologies R and D Program of China (No. 2005BA517A-8) and the Natural Science Foundation of China (No. 30700109).

REFERENCES

1. Wu, R.G. and H. Tiessen, 2002. Effect of land use on soil degradation in alpine grassland soil, China. Soil Sci. Soc. Am. J., 66: 1648-1655.
2. Zhang, W.D., S.Y. Guan, Y.J. Li and Y.Z. Wu, 2000. Effect of different restoration measure on the moisture and nutrient of soil of degraded grassland. J. Inner Mongolia Agric. Univ., 21: 31-35.
3. Wen, H.Y., H.L. Zhao and H. Fu, 2005. Effects of years for reclamation and enclosure years on soil properties of degraded sandy grassland. Acta Pratacul. Sin., 14: 31-37.
4. Jiang, D.M., Z.M. Liu, C.Y. Cao, Z.W. Kou and R.Y. Wang, 2003. Desertification and ecological restoration of Horqin Sandy Land. Beijing: China Environmental Science Press.
5. Liu, F.M., F.X. Meng, W.J. Liang, Y. Jiang and D.Z. Wen, 2005. Engineering measures and their effects on melioration of degraded grasslands in Horqin region. J. Liaoning Tech. Univ., 24 (Suppl.II): 257-259.
6. Robertson, G.P. and D.W. Freckman, 1995. The spatial distribution of nematode of trophic groups across a cultivated ecosystem. Ecology, 76: 1425-1432.
7. Neher, D.A., 2001. Role of nematodes in soil health and their use as indicators. J. Nematol., 33: 161-168.

8. Ettema, C.H., D.C. Coleman, G. Vellidis, R. Lowrance and S.L. Rathbun, 1998. Spatiotemporal distribution of bacterivorous nematodes and soil resources in a restored riparian wetland. Ecology, 79: 2721-2734.
9. Rossi, J.P., L. Delaville and P. Quénéhervé, 1996. Microspatial structure of a plant-parasitic nematode community in a sugarcane field in Martinique. Applied Soil Ecol., 3: 17-26.
10. Wheeler, T.G., B. Baugh, H. Kaufman, G. Schuster and K. Siders, 2000. Variability in time and space of *Meloidogyne incoginta* fall population density in cotton fields. J. Nematol., 32: 258-264.
11. Liang, W.J., Q. Li, Y. Jiang, W.B. Chen and D.Z. Wen, 2003. Effect of cultivation on spatial distribution of nematode trophic groups in black soil. Pedosphere, 13: 208-213.
12. Liang, W.J., Y. Jiang, Q. Li, Y.J. Liu and D.Z. Wen, 2005. Spatial distribution of bacterivorous nematodes in a Chinese Ecosystem Research Network (CERN) site. Ecol. Res., 20: 481-486.
13. Marriott, C.A., G. Hudson, D. Hamilton, R. Neilson, B. Boag, L.L. Handley, J. Wishart, C.M. Scrimgeour and D. Robinson, 1997. Spatial variability of soil total C and N and their stable isotopes in an upland Scottish grassland. Plant Soil, 196: 151-162.
14. Hirobe, M., N. Onte, N. Karasawa, G.S. Zhang, L.H. Wang and K. Yoshikawa, 2001. Plant species effect on the spatial patterns of soil properties in Mu-us desert ecosystem, Inner Mongolia, China. Plant Soil, 234: 195-205.
15. Corazza, E.J., M. Brossard, T. Muraoka and M.A.C. Filho, 2003. Spatial variability of soil phosphorus of a low productivity *Brachiaria brizantha* pasture. Scienta Agricola, 60: 559-564.
16. Sauer, T.J., C.A. Cambardella and S.W. Meek, 2006. Spatial variation of soil properties relating to vegetation changes. Plant Soil, 280: 1-5.
17. Su, Y.Z., Y.L. Li and H.L. Zhao, 2006. Soil properties and their spatial pattern in a degraded sandy grassland under post-grazing restoration, Inner Mongolia, northern China. Biogeochemistry, 79: 297-314.
18. Jiang, D.M., Q. Li, F.M. Liu, Y. Jiang and W.J. Liang, 2007. Vertical distribution of soil nematodes in an age sequence of *Caragana micophylla* plantations in the Horqin Sandy Land, Northeast China. Ecol. Res., 22: 49-56.
19. Li, Q., W.J. Liang, Y. Jiang, Y. Shi, J.G. Zhu and D.A. Neher, 2007. Effect of elevated CO_2 and N fertilisation on soil nematode abundance and diversity in a wheat field. Appl. Soil Ecol., 36: 63-69.
20. Yeates, G.W., T. Bongers, R.G.M. De Goede, D.W. Freckman and S.S. Georgieva, 1993. Feeding habits in soil nematode families and genera an outline for soil ecologists. J. Nematol., 25: 315-331.
21. Liang, W.J., Y. Phinhasi-Adiv, H. Shtultz and Y. Steinberger, 2000. Nematode population dynamics under the canopy of desert halophytes. Arid Soil Res. Rehabil., 14: 183-192.
22. Gamma Design Software. 2000. GS^+: geostatistics for the environmental sciences 5.1 User's Guide. Gamma Design Software, Plainwell.
23. Cambardella, C.A., T.B. Moorman, J.M. Novak, T.B. Parkin, D.L. Karlen, R.F. Turco and A.E. Konopka, 1994. Field-scale variability of soil properties in Central Iowa soils. Soil Sci. Soc. Am. J., 58: 1501-1511.
24. Bardgett, R.D. and R. Cook, 1998. Functional aspects of soil animal diversity in agricultural grasslands. Applied Soil Ecol., 10: 263-276.
25. Su, Y.Z. and H.L. Zhao, 2003. Soil properties and plant species in an age sequence of *Caragana microphylla* plantations in the Horqin Sandy Land, North China. Ecol. Eng., 20: 223-235.
26. Liang, W.J., S. Zhong, J.F. Hua, C.Y. Cao and Y. Jiang, 2007. Nematode Faunal Response to grassland degradation in Horqin sandy land. Pedosphere, 17: 611-618.
27. Wang, Y.F., Z.Z. Chen and L.T. Tieszen, 2002. Distribution of soil organic carbon on the major grasslands of Xilinguole, Inner Mongolia, China. Acta Phytoecol. Sin., 22: 545-551.