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RESEARCH ARTICLE

Responses of nematode communities to different land uses in an aquic brown soil

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Abstract An analysis of the seasonal and vertical distribution of soil nematode communities under three contrasting land uses, i.e., cropland, abandoned cropland and woodland was conducted in an aquic brown soil. The results showed that different land-use types affected the spatiotemporal distribution of soil nematodes and their dominant genera, and different dominant genera showed different responses to land use. In the abandoned cropland and woodland, most dominant genera were present in the 0–20 cm layers and *Chiloplacus* was mainly distributed in the 5–30 cm layers, while in the cropland, *Pratylenchus* exhibited an even distribution from the 0–5 cm to the 40–50 cm depth. Soil environmental parameters under different land use could influence soil nematodes; soil porosity, total organic C, total N and the C/N ratio could positively influence the abundance of some dominant genera. Faunal profiles revealed that environmental stability and the homeostasis in the abandoned cropland and woodland lead to higher levels of community structure, and the soil food web tends to succeed to maturity. Nematode faunal analyses are a useful indicator for interpreting the stress and/or nutrient conditions under different land uses.

Keywords soil nematodes, dominant genera, faunal analysis, land use, aquic brown soil

1 Introduction

Since the 1990s, issues of sustainable land use have attracted increasing attention. As an important constituent of sustainable agroecosystems, soil is influenced by different land use regimes, which influence soil productivity and biota on different levels. In agroecosystems, different land use regimes could produce a series of disturbances to soil ecosystems, resulting in many environmental problems, such as nutrient loss, soil erosion and biodiversity loss; and the abundance, diversity and activity of soil biota change accordingly (Fu et al., 2000; Islam and Weil, 2000; Kladivko, 2001; Chemini and Rizolli, 2003; Liang et al., 2005a; Ou et al., 2005).

As one of the most abundant groups of soil invertebrates, soil nematodes relate closely to soil ecosystem processes and act as useful monitors of environmental conditions and ecosystem function (Bongers and Bongers, 1998). Soil nematodes could affect soil ecosystems indirectly through changing food web structures and decomposition pathways (Yeates, 1996; Yeates et al., 2000; Wu et al., 2002; Liang et al., 2005b; Ou et al., 2005).

Previous studies both at home and abroad mainly focused on soil nematode communities under different land use regimes (Wu et al., 2002; Ou et al., 2005; Wang et al., 2005), and much attention was paid to the surface or cultivation layer of soils; however, studies carried out in a small scale or in the same location are relatively rare. Therefore, the objectives of this study were to monitor the nematode faunal response to different land uses in an aquic brown soil using faunal profile analyses, and determine the relationships between nematode communities and soil physicochemical properties, so as to provide scientific basis for understanding the response of soil ecosystem processes to different land use types.

2 Materials and methods

2.1 Study site

The study was conducted at the Shenyang Experimental Station of Ecology (41°31′ N, 123°22′ E), Chinese Academy of Sciences, a Chinese Ecosystem Research

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Network (CERN) site at Shilihe Town of Sujiatun District, south suburb of Shenyang Municipality, representative of that area and also an important part in the network research. Climatically, the station is located in a continental temperate monsoon zone, with a dry-cold winter and a warm-wet summer. The annual mean temperature is between 7.0°C to 8.0°C, annual precipitation is 650 to 700 mm, and the annual non-frost period is 147 to 164 days. The soil at the study site is classified as an aquic brown soil (silty loam Hapli-Udic Cambosols in Chinese Soil Taxonomy) (Liang et al., 2005b), containing 20.20 g/kg organic matter, 1.40 g/kg total N, 0.75 g/kg total P, and 100.00 mg/kg available K, with pH 6.5. Before the establishment of the station in 1990, the whole area consisted of paddy fields with comparatively homogeneous and sufficient soil fertility; after 1990, parts of the land were converted to maize production, remained fallow, or converted to woodland (Zhang et al., 2004).

Soil samples were collected from three types of land use, i.e., cropland-maize (*Zea mays*), abandoned cropland (dominant weeds were *Ambrosia triifida*, *Conyza canadensis*, *Humulus scandens*, *Metaplexis japonica*), and woodland (*Populus canadensis*), respectively.

2.2 Sampling and analytical methods

Four replicate profiles (each 25 m^2) for each land use pattern were sampled at a depth of 0 to 50 cm, and subdivided into layers of 0–5, 5–10, 10–20, 20–30, 30–40, and 40–50 cm, respectively. Each soil sample comprised 5 subsamples. All samples were stored in plastic bags separately, and immediately transferred to a refrigerator at 4°C. Samples were collected in spring (April) and summer (August), 2004.

Before analyses, samples were air-dried at room temperature and then sieved through a 2 mm screen. Soil moisture was measured by oven-drying at 105°C for 24 h, and soil pH was determined with a glass electrode in 1:2.5 soil:water solution (w/v). Total nitrogen (TN) was measured with the Kjeldahl method; total C was analyzed by dry combustion, using a Shimadzu TOC 5000 Total C analyzer; soil bulk density was determined by using stainless steel ring and oven-drying at 105°C; for total P determination, soils were first digested with mixed acids of H_2SO_4 and $HClO_4$ and then analyzed with the molybdophosphate method, and finally available P was determined by the Olsen method. Soil available nitrogen was extracted with 2 mol/L KCl and determined with the magnesium oxide-devarda alloy method (Lu, 2000). Soil basic chemical properties in different land use types are shown in Table 1.

2.3 Soil nematode extraction and identification

Nematodes were extracted from 200 g of soil (fresh weight) from each sample using sugar flotation and centrifugation method (Liang et al., 2005a), then killed by heat (60°C) and fixed by TAF. The total number of soil nematodes was counted, and 100 individuals were randomly selected in each sample and their genera were identified based on stoma and esophageal morphology using an inverted compound microscope, according to Bongers (1988).

2.4 Soil nematode faunal analysis

Based on Ferris et al. (2001), the ecological indices were calculated as follows: enrichment index (EI) = 100 × (e/($e+b$)), which provides an indicator of resources available to the soil food web and the responses of primary decomposers to those resources; structure index (SI) = 100 × (s/($b+s$)), which indicates changes in soil food web induced by artificial disturbance or ecological restoration, where e is the abundance of individuals in guilds in the enrichment component (Ba1 and Fu2 guilds) weighted by their respective k_e values, b is the abundance of individuals in the basal component (Fu2 and Ba2) weighted by their k_b values, and s is the abundance of individuals in the structural component (Ba3-Ba5, Fu3-Fu5, Om3-Om5 and Ca2-Ca5 guilds) weighted by their k_s values (Ferris, et al., 2001; Liang et al., 2005b). The two indices allow graphic representation of the condition of the food web (Ferris, et al., 2001).

2.5 Statistical analyses

Nematode abundance was $\log_{10}(X+1)$ transformed before analysis. Three-way analysis of variance was then performed for the numbers of dominant genera, species richness and ecological indices, with land use, sampling date and soil depth as independent variables. Linear correlations between nematode data and selected soil physicochemical properties were determined using Pearson's correlation coefficients. All statistical analyses were performed with SPSS software package. Differences at $P < 0.05$ level were considered as statistically significant.

Table 1 Main chemical properties under different land use types

land use type	total N/g·kg^{-1}	total P/g·kg^{-1}	available N/mg·kg^{-1}	available P/mg·kg^{-1}	organic matter/g·kg^{-1}	pH
cropland	1.036	0.423	95.8	10.7	19.53	5.7
abandoned cropland	1.466	0.541	127.9	27.2	29.78	6.7
woodland	2.048	0.536	151.4	17.8	37.57	7.2

Table 2 Relative abundance (%) of nematode genera under different land use types

genus	guild	land use (April 2004)			land use (August 2004)		
		cropland	abandoned cropland	woodland	cropland	abandoned cropland	woodland
Bunonema	Ba1	0.0	0.1	0.0	0.0	0.2	0.0
Diploscapter	Ba1	0.5	0.1	1.0	0.3	0.1	1.3
Panagrolaimus	Ba1	0.2	0.1	0.0	0.7	1.0	1.3
Protorhabditis	Ba1	2.0	0.1	0.7	0.3	5.3	1.3
Acrobeles	Ba2	1.9	4.3	0.9	5.7	11.3	3.1
Acrobeloides	Ba2	11.7	18.2	4.6	1.2	3.7	0.8
Cephalobus	Ba2	1.0	1.4	0.0	0.0	0.1	0.0
Chiloplacus	Ba2	1.0	12.5	1.6	0.5	3.9	3.3
Eucephalobus	Ba2	1.7	1.9	1.8	2.0	0.5	0.6
Heterocephalobus	Ba2	0.1	0.0	0.0	1.6	1.6	1.6
Microlaimus	Ba2	0.0	0.0	0.0	0.0	0.1	0.0
Plectus	Ba2	0.1	0.1	0.0	0.0	0.1	0.0
Achromadora	Ba3	0.0	0.0	0.2	0.0	0.1	0.0
Bastiania	Ba3	0.0	0.0	0.2	0.0	0.0	0.0
Metateratocephalobus	Ba3	0.2	0.1	0.1	0.1	0.1	0.3
Prismatolaimus	Ba3	2.2	0.1	0.3	1.0	2.8	1.0
Aphelenchoides	Fu2	1.8	0.3	0.1	8.1	0.4	0.4
Aphelenchus	Fu2	5.4	4.8	2.8	1.0	1.7	0.8
Ditylenchus	Fu2	0.2	0.2	0.7	0.9	0.2	0.1
Deladenus	Fu2	0.0	0.8	0.8	0.0	0.0	0.0
Paraphelenchus	Fu2	0.0	0.0	0.0	0.2	0.2	0.0
Pseudhalenchus	Fu2	0.0	0.1	0.2	0.0	0.0	0.0
Tylencholaimellus	Fu4	0.0	0.0	0.0	0.0	0.6	0.0
Tylencholaimus	Fu4	0.2	0.0	0.0	0.9	0.0	0.0
Seinura	Ca2	0.0	0.1	0.0	0.3	0.0	0.0
Dorydorella	Om4	0.0	0.2	0.5	0.5	0.0	0.9
Epidorylaimus	Om4	0.1	0.3	0.1	0.7	0.6	0.0
Eudorylaimus	Om4	0.4	0.3	1.0	1.3	3.7	0.5
Longidorella	Om4	0.0	0.0	0.0	0.1	0.1	0.2
Microdorylaimus	Om4	0.0	1.5	0.3	0.5	1.1	0.6
Mononchus	Om4	0.0	0.0	0.1	0.0	0.0	0.1
Thonus	Om4	0.2	0.1	0.0	0.0	0.0	0.6
Thornia	Om4	0.0	0.0	0.0	0.0	0.1	0.0
Aporcelaimellus	Om5	0.1	0.6	2.8	1.3	0.9	3.5
Dorylaimellus	Om5	0.0	0.0	0.0	0.8	0.0	0.0
Laimydorus	Om5	0.2	1.5	0.2	0.0	0.0	0.0
Mesodorylaimus	Om5	0.0	0.0	0.0	0.0	1.2	0.1
Nygolaimus	Om5	0.0	0.0	0.0	0.0	0.1	0.0
Paraxonchium	Om5	0.0	0.0	0.0	0.0	0.0	0.1
Prodorylaimus	Om5	0.0	0.0	0.0	0.0	1.4	0.0
Aglenchus	H2	0.0	0.3	4.7	0.3	0.6	2.0
Basiria	H2	0.1	0.2	0.3	0.0	0.0	0.0
Beleodorus	H2	0.7	0.0	0.2	1.1	0.3	0.0
Cephalenchus	H2	0.1	0.6	0.1	0.2	0.0	0.5
Filenchus	H2	2.8	2.2	5.2	3.0	2.0	0.8
Malenchus	H2	0.0	0.0	0.4	0.0	0.0	0.3
Paratylenchus	H2	1.3	32.1	39.7	1.7	22.1	37.3
Psilenchus	H2	0.0	0.1	0.5	0.5	0.5	0.5
Tylenchus	H2	0.9	0.2	0.0	0.0	0.3	0.0
Macroposthonia	H3	0.0	0.7	0.0	0.0	0.0	0.0
Bitylenchus	H3	0.3	0.2	0.3	0.5	1.8	0.1
Criconemoides	H3	0.3	0.2	0.3	0.1	1.2	0.2
Helicotylenchus	H3	16.4	2.3	25.9	32.3	1.8	34.7
Hemicycliophora	H3	0.0	0.0	0.0	0.0	0.1	0.0
Heterodera	H3	0.4	0.3	0.1	0.0	0.3	0.2
Hoplotylus	H3	0.0	0.0	0.0	0.0	0.4	0.0
Merlinius	H3	0.0	0.0	0.0	0.0	0.0	0.3
Pratylenchoides	H3	0.0	0.1	0.0	0.0	0.0	0.0
Pratylenchus	H3	45.4	0.3	1.0	28.7	0.2	0.0
Rotylenchus	H3	0.0	0.0	0.1	0.2	0.2	0.2
Tylenchorhynchus	H3	0.0	0.0	0.0	0.0	0.0	0.1
Zygotylenchus	H3	0.0	10.5	0.2	1.3	25.2	0.4

(*Continued*)

genus	guild	land use (April 2004)			land use (August 2004)		
		cropland	abandoned cropland	woodland	cropland	abandoned cropland	woodland
Longidorus	H5	0.0	0.0	0.0	0.1	0.0	0.0
Xiphinema	H5	0.1	0.0	0.0	0.0	0.0	0.0
number of genera		33	40	37	36	44	36

Note: Ba: Bacterivores; Fu: Fungivores; Om: Omnivores; Ca: Canivores; H: Herbivores. Numbers following Ba, Fu, Om, Ca, H represent the cp values belonging to each genus.

3 Results

3.1 Nematode community composition under different land use types

During the study period, 64 genera were recorded throughout the three land use types (Table 2). The abandoned cropland had the highest generic richness of 40 in April and 44 in August, followed by the woodland and cropland. Significant effects of depth, date and land use on the abundance of dominant genera were observed ($P < 0.01$), but no significant interaction effects were observed (Table 3). In the cropland, *Acrobeloides*, *Helicotylenchus* and *Pratylenchus* were dominant genera, and about 60% of *Acrobeloides* and *Helicotylenchus* were present in the 0–20 cm layer. *Pratylenchus* showed an even distribution from 0–5 to 40–50 cm depth. *Acrobeles*, *Acrobeloides*, *Chiloplacus*, *Paratylenchus* and *Zygotylenchus* were prevalent in the abandoned cropland, among which *Acrobeles* and *Acrobeloides* were mainly present in the 0–20 cm layer and *Chiloplacus* was mainly distributed in 5–30 cm layer under each of the land use types. Only two genera, *Pratylenchus* and *Helicotylenchus*, prevailed in the woodland and most of them were present in the 0–20 cm layer (Table 4). Except for *Helicotylenchus* and *Zygotylenchus*, a significant difference was observed in the number of the dominant genera with respect to varied depth, sampling dates and land use types (Table 3), and significant interaction effects among depth, date and land use were observed on the numbers of dominant genera, except for those of *Helicotylenchus*, *Pratylenchus* and *Zygotylenchus*.

3.2 Nematode faunal analysis among different land use types

Among different land use types, significant differences were observed in the values of enrichment index (*EI*) and structure index (*SI*) ($P < 0.01$). The profiles revealed a degraded food web stressed by disturbance in the cropland, because most plots of the sampling sites were clustered in quadrat D (Fig. 1a). In the abandoned cropland, most plots appeared in quadrat C, indicating a structured food web with low disturbance (Fig. 1b). The faunal profiles revealed the food webs in woodland were mature or structured, and the environment was little disturbed since all plots appeared in quadrats B and C (Fig. 1 c).

3.3 Correlations between soil physicochemical parameters and nematodes

Soil porosity was correlated positively with generic richness (*S*) and the numbers of *Acrobeles*, *Paratylenchus*, *Helicotylenchus* and *Zygotylenchus*. Different nematode genera responded differently to soil pH, which was correlated positively with the numbers of *Acrobeloides*, *Chiloplacus* and *Paratylenchus*, and negatively with *S*, *EI*, and the numbers of *Helicotylenchus* and *Pratylenchus*. Soil total organic C and total N were correlated positively with the numbers of *Acrobeles*,

Table 3 Three-way ANOVA of *F*-values of the effect of land use, sampling date and soil depth on soil nematodes indices and dominant genera

	ecological indices			dominant genera						
	GR	*EI*	*SI*	ABL	ABD	CHI	PAR	HEL	PRA	ZYG
land use	13.18^{**}	21.54^{**}	24.50^{**}	38.42^{**}	51.84^{**}	105.42^{**}	82.13^{**}	24.69^{**}	94.34^{**}	34.66^{**}
sampling date	12.73^{**}	0.40^{ns}	33.75^{**}	7.80^{**}	91.81^{**}	38.69^{**}	28.02^{**}	1.04^{ns}	13.21^{**}	3.61^{ns}
soil depth	6.02^{**}	0.51^{ns}	0.87^{ns}	8.62^{**}	7.89^{**}	7.76^{**}	21.67^{**}	13.44^{**}	1.67^{ns}	4.89^{**}
sampling date × land use	1.92^{ns}	0.18^{ns}	3.22^{*}	3.27^{*}	31.32^{**}	35.06^{**}	11.58^{**}	0.74^{ns}	11.77^{**}	3.21^{*}
soil depth × land use	1.82^{ns}	0.57^{ns}	1.51^{ns}	5.01^{**}	3.98^{**}	5.83^{**}	14.05^{**}	5.12^{**}	1.42^{ns}	4.88^{**}
sampling date × soil depth	1.32^{ns}	0.29^{ns}	1.56^{ns}	3.85^{**}	5.34^{**}	2.38^{*}	4.46^{**}	0.86^{ns}	0.98^{ns}	1.11^{ns}
sampling date × soil depth × land use	1.53^{ns}	0.40^{ns}	1.73^{ns}	3.67^{**}	2.75^{*}	3.48^{**}	2.25^{*}	3.30^{**}	0.95^{ns}	1.14^{ns}

Note: *GR*: Number of genera; *EI*: Enrichment index; *SI*: Structure index; ABL: *Acrobeles*; ABD: *Acrobeloides*; CHI: *Chiloplacus*; PAR: *Paratylechus*; HEL: *Helicotylenchus*; PRA: *Pratylechus*; ZYG: *Zygotylenchus*. *: $P < 0.05$; **: $P < 0.01$, ns: non-significant.

Table 4 Abundance of dominant genera in different land use, sampling date and soil depth (individuals per 100 cm^3 dry soil) (mean ± SE)

dominant genera	land use (April 2004)			land use (August 2004)		
	cropland	abandoned cropland	woodland	cropland	abandoned cropland	woodland
Acrobeles						
0–5 cm	7 ± 6	111 ± 40	7 ± 6	9 ± 0	55 ± 9	8 ± 5
5–10 cm	14 ± 8	13 ± 5	7 ± 5	19 ± 5	91 ± 21	4 ± 2
10–20 cm	4 ± 1	8 ± 5	1 ± 1	12 ± 8	45 ± 14	3 ± 2
20–30 cm	2 ± 1	3 ± 2	–	9 ± 4	35 ± 13	6 ± 2
30–40 cm	2 ± 1	6 ± 2	–	4 ± 2	11 ± 4	3 ± 2
40–50 cm	2 ± 1	4 ± 1	1 ± 1	5 ± 2	30 ± 7	3 ± 1
Acrobeloides						
0–5 cm	13 ± 2	96 ± 21	15 ± 4	4 ± 4	4 ± 4	–
5–10 cm	29 ± 4	187 ± 45	31 ± 13	3 ± 1	16 ± 7	1 ± 1
10–20 cm	49 ± 16	156 ± 44	9 ± 6	4 ± 2	23 ± 15	1 ± 1
20–30 cm	34 ± 7	111 ± 26	8 ± 3	1 ± 0	19 ± 4	1 ± 1
30–40 cm	26 ± 12	49 ± 2	2 ± 1	1 ± 1	6 ± 4	2 ± 1
40–50 cm	17 ± 4	13 ± 2	–	–	4 ± 2	–
Chiloplacus						
0–5 cm	2 ± 2	19 ± 8	5 ± 5	–	6 ± 4	2 ± 1
5–10 cm	–	55 ± 8	6 ± 4	1 ± 1	18 ± 3	4 ± 1
10–20 cm	5 ± 3	63 ± 19	4 ± 2	1 ± 1	37 ± 4	2 ± 1
20–30 cm	4 ± 2	92 ± 21	3 ± 2	2 ± 2	16 ± 5	9 ± 6
30–40 cm	2 ± 1	56 ± 7	1 ± 1	–	7 ± 7	5 ± 3
40–50 cm	2 ± 1	16 ± 4	–	–	6 ± 4	2 ± 1
Paratylenchus						
0–5 cm	12 ± 5	175 ± 36	172 ± 28	9 ± 4	48 ± 33	43 ± 11
5–10 cm	7 ± 4	504 ± 80	165 ± 50	6 ± 3	280 ± 94	57 ± 19
10–20 cm	2 ± 1	470 ± 88	81 ± 7	2 ± 1	173 ± 65	40 ± 10
20–30 cm	1 ± 1	165 ± 28	84 ± 22	1 ± 1	86 ± 16	57 ± 15
30–40 cm	1 ± 1	42 ± 11	21 ± 7	–	31 ± 12	61 ± 10
40–50 cm	–	21 ± 10	15 ± 3	–	18 ± 12	17 ± 4
Helicotylenchus						
0–5 cm	154 ± 67	6 ± 3	153 ± 49	13 ± 6	34 ± 12	220 ± 42
5–10 cm	73 ± 25	6 ± 4	51 ± 18	117 ± 27	3 ± 3	101 ± 49
10–20 cm	35 ± 13	2 ± 2	12 ± 6	69 ± 13	2 ± 2	32 ± 15
20–30 cm	44 ± 28	6 ± 4	16 ± 9	46 ± 10	4 ± 2	29 ± 20
30–40 cm	9 ± 7	7 ± 4	38 ± 11	36 ± 13	3 ± 2	12 ± 3
40–50 cm	5 ± 3	3 ± 6	46 ± 5	42 ± 3	–	36 ± 10
Pratylenchus						
0–5 cm	99 ± 38	1 ± 1	–	8 ± 2	–	–
5–10 cm	140 ± 64	5 ± 5	3 ± 2	85 ± 21	3 ± 3	–
10–20 cm	84 ± 34	–	–	91 ± 16	–	–
20–30 cm	121 ± 26	2 ± 2	–	39 ± 7	2 ± 2	–
30–40 cm	119 ± 18	1 ± 1	2 ± 2	40 ± 9	–	–
40–50 cm	64 ± 10	–	3 ± 2	34 ± 7	–	–
Zygotylenchus						
0–5 cm	–	109 ± 59	–	4 ± 2	116 ± 44	4 ± 2
5–10 cm	–	149 ± 78	–	1 ± 1	373 ± 153	1 ± 1
10–20 cm	–	59 ± 38	–	1 ± 1	136 ± 30	–
20–30 cm	–	51 ± 28	1 ± 1	1 ± 1	62 ± 13	1 ± 1
30–40 cm	–	28 ± 11	–	2 ± 1	63 ± 15	–
40–50 cm	–	7 ± 5	–	1 ± 1	12 ± 2	–

Helicotylenchus and *S* and negatively with the numbers of *Chiloplacus*. Significant positive correlations were found between the C/N ratio and *SI* (Table 5).

4 Discussion

The results indicate that the vertical and seasonal distribution of nematode communities showed different responses to the different land use types. This discrepancy might relate to the different life history of the species, changes in food availability and quality, and in soil physiochemical properties (Norton and Niblack, 1991).

It is generally accepted that undisturbed systems have more diverse communities of soil organisms (Kandji et al., 2001). Fu et al. (2000) reported similar results that nematode abundance was higher in the no-tillage system than

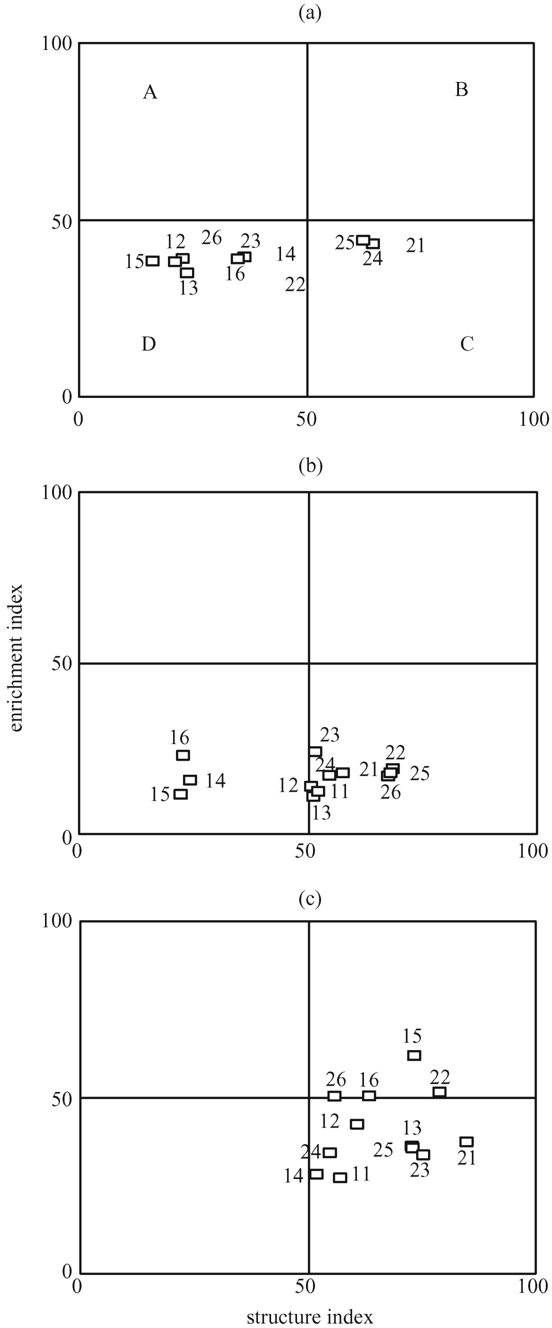

Fig. 1 Results of nematode faunal analysis in different land use types. (a) Cropland; (b) Abandoned cropland; (c) Woodland. Numbers of 11–16 represent sampling sites at different depths on April, and 21–26 represent sampling sites on August 2004

in the conventional tillage system. The present study revealed that generic richness was highest in the abandoned cropland compared to other land use types. Different genera of nematodes showed different vertical and seasonal distribution patterns. The most dominant genera were present in the 0–20 cm layer; their distribution may relate to soil nutrient conditions and physical properties. In addition, soil ventilation might be one of the important factors that influence nematode distribution patterns. Soil porosity affects nematode distribution *via* its influence on oxygen diffusion. In grass and barley fields, Sohlenius and Sandor (1987) observed that due to the influence of soil ventilation, omnivore-predators and plant parasites with bigger body size mainly distributed at the soil surface layer.

Due to the influence of tillage, soil structure was changed, which could have resulted in changes in the vertical distribution pattern of soil animals. This phenomenon might relate to the differences in the distribution of food resources (Ingham et al., 1985). The root system of plants is considered to be the most important biotic factor (Norton and Niblack 1991). The distribution of *Paratylenchus*, *Zygotylenchus*, and *Helicotylenchus* in the soil profile may reflect the distribution of the plant root.

Based on nematode functional guilds, Ferris et al. (2001) reported that nematode faunal analysis is a useful indicator to interpret the structure-enrichment conditions of the food web (Ferris et al., 2001, Wu et al., 2002; Ferris and Matute, 2003; Liang et al., 2005b). The faunal profiles under different land uses indicate that the values of *SI* were higher and *EI* lower in the abandoned cropland and woodland, and soil food webs were structured with little disturbance. Higher values of *SI* in the abandoned cropland and woodland might relate to the presence of omnivore-predators, and reflect a relatively stable soil environment with multi-trophic links in the food web. In the cropland, both *SI* and *EI* were lower due to the cultivation and other artificial disturbances, and soil food web was stressed. Because of the influence of different land use regimes, total N and organic matter were higher in the abandoned cropland and woodland than in the cropland, which could provide enough food resources for nematode communities in different trophic levels and result in higher values of *SI*. This study supports the observations of Ou et al. (2005) that environmental stability and homeostasis of the abandoned cropland and woodland lead to higher levels of community structure and the soil food web tends to succeed to maturity. Since soil nematode community structure relates closely with changes in food resource, nutrient cycling and decomposition pathways (Norton and Niblack, 1991), changes in the nematode community composition due to different land use regimes could ultimately influence ecosystem function *via* changing the structure of soil food webs and nutrient decomposition pathways.

In conclusion, our results indicate that different land use types differ tremendously in terms of their effects on the seasonal and spatial distribution of soil nematodes. Nematode faunal analyses are a useful indicator for interpreting the stress and/or nutrient conditions under different land use types.

Table 5 Correlation coefficients (r) between the numbers of nematode dominant genera, ecological indices and soil physicochemical properties ($n = 72$)

	soil porosity	pH	total organic C	total N	C/N
dominant genus					
Acrobeles	0.292**	−0.032	0.218**	0.230**	0.103
Acrobeloides	0.102	0.314**	−0.030	−0.031	−0.012
Chiloplacus	−0.048	0.481**	−0.176*	−0.169*	−0.189*
Paratylenchus	0.294**	0.317**	0.066	0.087	0.024
Helicotylenchus	0.330**	−0.236**	0.538**	0.528**	0.269**
Pratylenchus	−0.073	−0.472**	−0.048	−0.057	0.077
Zygotylenchus	0.245**	0.047	0.048	0.056	0.030
ecological index					
number of genera (S)	0.380**	−0.245**	0.267**	0.267**	0.142
enrichment index (EI)	−0.093	−0.265**	0.049	0.023	0.083
structure index (SI)	0.159	0.025	0.182*	0.160	0.198*

Note: $^{*}P < 0.05$, $^{**}P < 0.01$.

References

Bongers T (1988). De Nematoden van Nederland. Utrecht: Stichting Uitgeverij Koninklijke Nederlandse Natuurhistorische Vereniging (in Dutch)

Bongers T, Bongers M (1998). Functional diversity of nematodes. Appl Soil Ecol, 10: 239–251

Chemini C, Rizolli A (2003). Land use change and biodiversity conservation in the Alps. J Mount Ecol, 7 (Suppl.): 1–7

Ferris H, Bongers T, de Goede R G M (2001). A framework for soil food web diagnostics: extension of the nematode faunal analysis concept. Appl Soil Ecol, 18: 13–29

Ferris H, Matute M M (2003). Structural and functional succession in the nematode fauna of a soil food web. Appl Soil Ecol, 23: 93–110

Fu S L, Coleman D C, Hendrix P F, Crossley Jr D A (2000). Responses of trophic groups of soil nematodes to residue application under conventional tillage and no-till regimes. Soil Biol Biochem, 32: 1731–1741

Ingham R E, Anderson R V, Gould W D, Coleman D C (1985). Vertical distribution of nematodes in a short grass prairie. Pedobiologia, 28: 155–160

Islam K R, Weil R R (2000). Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric Ecosyst Environ, 79: 9–16

Kandji S T, Ogol C K P O, Albrecht A (2001). Diversity of plant-parasitic nematodes and their relationships with some soil physico-chemical characteristics in improved fallows in western Kenya. Appl Soil Ecol, 18: 143–157

Kladivko E J (2001). Tillage systems and soil ecology. Soil Till Res, 61: 61–76

Liang W J, Li Q, Jiang Y, Neher D A (2005a). Nematode faunal analysis in an aquic brown soil fertilised with slow-release urea, Northeast China. Appl Soil Ecol, 29, 185–192

Liang W J, Zhang X K, Jiang Y, Ou W, Neher D A (2005b). Vertical distribution of bacterivorous nematodes under different land uses. J Nematol, 37: 361–365

Lu R K (2000). Analytical Methods of Soil and Agro-chemistry. Beijing: China Agricultural Science and Technology Press (in Chinese)

Norton D C, Niblack T L (1991). Biology and ecology of nematodes. In: Nickle W R, ed. Manual of Agricultural Nematology. New York: Marcel Dekker Inc., 47–71

Ou W, Liang W J, Jiang Y, Li Q, Wen D Z (2005). Vertical distribution of soil nematodes under different land use types in an aquic brown soil. Pedobiologia, 49: 139–148

Sohlenius B, Sandor A (1987). Vertical distribution of nematodes in arable soil under grass (*Festuca pratensis*) and barley (*Hordeum distichum*). Biol Fertil Soils, 3: 19–25

Wang G L, Wang Y, Han L L, Zhang M W, Li B (2005). Soil animal communities of variously utilized in the Dongting Lake region. Acta Ecol Sin, 25: 2629–2636 (in Chinese)

Wu J H, Fu C Z, Chen S S, Chen J K (2002). Soil faunal response to land use: effect of estuarine tideland reclamation on nematode communities. Appl Soil Ecol, 21, 131–147

Yeates G W (1996). Impact of historical changes in land use on the soil fauna. New Zeal J Ecol, 15: 99–106

Yeates G W, Hawke M F, Rijkse W C (2000). Changes in soil fauna and soil conditions under *Pinus radiata* agroforestry regimes during a 25-year tree rotation. Biol Fertil Soils, 31: 391–406

Zhang Y G, Jiang Y, Liang W J, Wen D Z, Zhang Y L (2004). Vertical variation and storage of nitrogen in an aquic brown soil under different land uses. J For Res, 15: 192–196