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Vegetation and Community Changes of Elm (*Ulmus pumila*) Woodlands in Northeastern China in 1983–2011

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Abstract: Elm (*Ulmus pumila*), widely distributed in the north temperate zone, contributes to a special savanna-like woodland in typical grassland region in the northeastern China. This woodland performs a variety of ecological functions and environmental significance, such as decreasing soil erosion, stabilizing sand dunes, preserving species diversity. However, in the last approximate 30 years, the species composition, productivity and distribution area of elm woodland has decreased severely. A series of studies have been carried out to find out whether the climate changes or human disturbances caused the degradation of elm woodland and how these factors affected elm woodland. In this study, undisturbed, plowing and grazing elm woodland were investigated in 1983 and 2011 by using Point-Centered Quarter method. The relationship between vegetation changes and environmental factors was analyzed by Bray-Curtis ordination. The results show that in 2011, species diversity and understory productivity of undisturbed elm woodland decrease slightly compared to those of undisturbed elm woodland in 1983. However, nearly 60% of the species is lost in the plowing and grazing elm woodland relative to the species undisturbed elm woodland in 1983. Interestingly, plowing stimulates the growth of elm and certain understory species through furrowing soil and accelerating soil nutrient turnover rate. Grazing disturbance not only leads to species loss and productivity decrease, but also induces changes in elm growth (small, short and twisted). The mean age of the elm was 29 ± 2 yr in undisturbed and plowing elm woodland, while only 15 yr in the grazing elm woodland. The results of Bray-Curtis ordination analysis show that all sample stands clustered to three groups: Group I including the undisturbed sample stands of 83UE (undisturbed elm woodland in 1983) and 11UE (undisturbed elm woodland in 2011); Group II including sample stands of PE (elm woodland disturbed by plowing); Group III including samples stands of GE (elm woodland disturbed by grazing). The results indicate that the long time disturbance of the plowing and grazing have converted elm woodland to different community types. Climate change is not the primary reason causing the degradation of elm woodland, but plowing and grazing disturbance. Both plowing and grazing decrease the vegetation composition and species diversity. Grazing further decreases vegetation productivity and inhibits the growth of elm tree. Therefore, we suggest that reasonable plowing and exclusive grazing would be favorable for future regeneration of degraded elm woodland.

Keywords: Elm (*Ulmus pumila*) woodland; species diversity; plant distribution; Bray-Curtis ordination

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1 Introduction

Elm (*Ulmus pumila*), depending on its strong drought and cold tolerance and salinity resistance, is widely distributed in the north temperate zone (Zhu, 1992; Rackham, 1998; Jackson *et al.*, 2000). *U. pumila* is a constructive species of savanna-like woodland stands, which is found in typical meadow steppe regions in the

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northeastern China and in forest-steppe transects in Taiga Mountain in Mongolia (Li *et al.*, 2001; Liu *et al.*, 2003; Dulamsuren *et al.*, 2005). Comparing with forest, the *U. pumila* woodlands generally have lower tree canopy covers and shorter tree height. *U. pumila* coverage was less than 25% with an average tree height lower than 5 m, and *U. pumila* scattered as single trees or small groups on the sand dunes (Li *et al.*, 2004; Dulamsuren *et al.*, 2009a). In the northeastern China, the elm woodland is mainly distributed in the east of the Horqin Sandland and the west of the Songnen Plain, especially in the drainage area of the Liaohe River.

Although *U. pumila* is widely found across the north temperate zone, the existence of elm woodland is specially found in China and Mongolia (Zhu, 1992; Dulamsuren *et al.*, 2005). Various studies about elm woodland had been carried out since the 1980s. The biological and ecological traits of the elm woodland, such as structure, species composition, have been reported in previous studies (Zhu, 1992; Yang *et al.*, 1996; Li and Yang, 2003). It is unclear that whether the unusual savanna-like appearance of the elm woodland is resulted from the natural resources limitation or the disturbance from human activities (Hilbig, 1995; Yang *et al.*, 2003). Dulamasuren (2009a) confirmed that the irregular distribution of *U. pumila* depended on the loose, stony soil distribution in Taiga Mountain in Mongolia. *U. pumila* trees, through decreasing transpiration rate, increasing water use efficiency and non-photochemical quenching, physiologically adapted to drought and high irradiance environment (Shi *et al.*, 2004; Dulamsuren *et al.*, 2009b). But at the seedling stage, *U. pumila* was susceptible to environmental stress. Previous studies suggested that low soil humidity and sand burial could influence the regeneration and distribution of *U. pumila* (Shi *et al.*, 2004; Dulamsuren *et al.*, 2009a).

In China, intensified land utilizations lead to the degradation of the elm woodland. For example, the elm woodland area shrank nearly 67% from 1988 to 1996 in the Horqin sandy land of Inner Mongolia (Li *et al.*, 2004). The extinction of species, the decrease of diversity and productivity and the loss of ecosystem function were also reported in previous researches (Yang *et al.*, 1996; Li *et al.*, 2001). Some studies pointed out that the degradation of elm woodland was primarily attributed to heavy grazing and cultivating, and the on-going global climate change might interact with these human activities to accelerating degradation of elm woodland (Li *et al.*, 2003; Yang *et al.*, 2003; Li *et al.*, 2004). However, it is less understood to the extent that the human disturbance and global climate change affect the degradation of elm woodland as well as the underlying mechanisms of these effects (Cantarel *et al.*, 2013).

It was demonstrated that the Bray-Curtis Ordination was an efficient method to interpret the effects of environmental factors on vegetation composition (McCune *et al.*, 2002). Ruiz-Jaén and Aide (2005), using the Bray-Curtis Ordination, interpreted not only the vegetation changes of the forest in Puerto Rico, but also the percentage of the forest restoration.

In this study, the Bray-Curtis Ordination method was used to analyze the relationship between the species changes and environmental factors. We analyzed the data of undisturbed, plowing and grazing elm woodland collected in 1983 and 2011 to interpret: 1) whether the community changes of the elm woodland were caused by climate change or human disturbance; 2) responses of elm woodland to different disturbances; 3) the relationships between environment factors and disturbances. Overall, we hope this study will give instructions to further study on the degradation of the elm woodland and future restoration of elm woodland.

2 Materials and Methods

2.1 Study area

The study area (44°36′–44°38′N, 123°40′–123°43′E) was located near the Grassland Ecological Research Station of Northeast Normal University, Jilin Province, China. This area has low (120 m to 300 m above sea level) and flat topography with scattered sand dunes and meadows. The climate is semi-hygrophilous or semi-arid, which is characterized by a continental monsoon with Asiantic anticyclone from Siberia in winter and cyclone from the Pacific Ocean in summer. Mean annual temperature ranges from 4.6℃ to 6.4℃, varying from –16℃ in January to 25℃ in July. Annual precipitation ranges from 280 mm to 400 mm, mostly falling in the summer months, and annual potential evaporation varies from 1200 mm to 2000 mm, approximately four times as much as the average precipitation (Gao *et al.*, 2008).

Sandy loam is favorable for the elm woodland, and it is the reason why the elm woodland is often found on the sand dunes in the steppe region but on the flat meadows with castanozem and saline-alkalised soil. In the studied elm woodland, there is no shrub layer. The understory vegetation was similar to vegetation composition of the grassland in the same region. Perennial grasses (*Leymus chinensis* and *Agropyron cristatum*), perennial legumes (*Vicia amoena* and *Lespedeza daurica*), and forbs (*Setaria viridis*, *etc*.) are the primary species of the understory vegetation. In the plowing elm woodland, the locals mainly plowed soybean and mungbean in the inter space, buck wheat and castor bean were also planted occasionally, and no fertilizer was used. In the grazing elm woodland, the understory vegetation was heavily grazed by sheep and goats from early Spring to late Autumn.

2.2 Sampling and data analysis

In this study, four kinds of elm woodlands were selected: undisturbed elm woodland investigated in 1983 (83UE), undisturbed elm woodland investigated in 2011 (11UE), elm woodland continually disturbed by plowing (PE) and grazing (GE) investigated in 2011. The undisturbed elm woodlands were fenced from the disturbances by human activities. PE and GE elm woodlands were continually utilized more than 10 years.

Elm dataset collected in 2004 was used for the development of equations for the estimation of the aboveground biomass (AB) and age (A). The aboveground biomass is calculated as:

$$AB = -80.487 + 9.744 \times Dc + 5.358 \times Db - 6.498 \times H \ (R^2 = 0.836,\ P < 0.01) \quad (1)$$

The age is calculated as:

$$A = 3.542 - 0.152 \times Dc + 1.209 \times Db - 0.256 \times H \ (R^2 = 0.981,\ P < 0.01) \quad (2)$$

where *D*c is chest diameter, *D*b is bottom diameter, and *H* is the height.

Three 200 m transects were laid out in each of the four elm woodlands. Vegetation survey were conducted every 20 m along each transect. The Point-Centered Quarter method was used to obtain data of elm trees and shrubs. The aboveground biomass and age of the elm trees were calculated from tree height, bottom and chest diameters. The understory vegetation in 4 m^2 plots was harvested. The plants were sorted and counted by species. The plants were over-dried to constant weight and the aboveground biomass was measured for each species. Species diversity (Shannon-Wiener index (H')) and evenness index (Pielou Evenness (J)) were calculated by the following equations:

$$H' = -\sum_{i=1}^{s} P_i \ln P_i \quad (3)$$

$$J = H'/\ln(s) \quad (4)$$

where P_i is the percentage of the *i*th species, and *s* is the total number of species.

2.3 Bray-Curtis Ordination

The relationship of the community composition of the elm woodland and the environmental variables was analyzed by using Bray-Curtis Ordination (PC-ORD software, MjM, USA) (MuCune *et al.*, 2002). Bray-Curtis ordination, usually known as polar ordination, was used as a fast, effective, multipurpose ordination technique for the evaluation of relationships between vegetation and environmental parameters. For this study, environmental variables are landform (landform was defined to 83UE = 1, 11UE = 2, PE = 3, GE = 4), soil organic carbon (Soil C), available phosphorus (Soil P), nitrogen (Soil N) and humidity (Soil H). The landform of 83UE and 11UE were defined to different levels of the consideration of long-term climate change effects (temperature and precipitation changes from 1983 to 2010 are shown in Fig. 1), which may play an important role for the degradation of the elm woodland (Yang *et al.*, 2003). We also examed the relationship between the density of *U. pumila* (UlmPD) and the sample stands. The sample stands and species frequency were recorded in main matrix in PC-ORD software package accordingly. Environmental variables were recorded in the second matrix. The bulk and noise of raw data were decreased by deleting species occurrence lower than 3

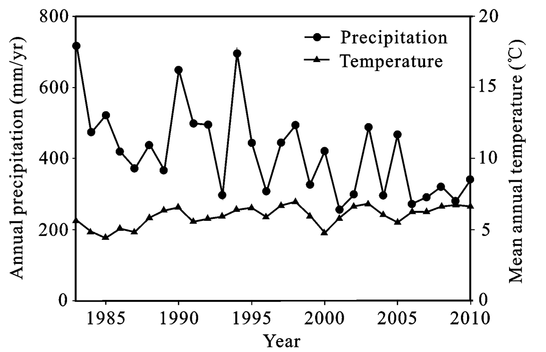

Fig. 1 Annual precipitation and mean annual temperature from 1983 to 2010

(McCune *et al.*, 2002). Before the Bray- Curtis ordination was carried out, the relativization by maximum was conducted for the main matrix, Sorensen distance measure was selected for the calculation and variance-regression was used as endpoint selection method.

2.4 Statistics analysis

PCORD 5.0 (PC-ORD for windows, MjM, USA) software package was used to conduct the Bray-Curtis ordination. Data are presented as arithmetic means ± standard error. ANOVA was carried out by using SPSS 13.0 (SPSS Inc.) statistical software. All the figures in this paper were done through SigmaPlot 10.0 (SigmaPlot for Windows, Systat Software Inc.).

3 Results

3.1 Species change

For the 1983 and 2011 vegetation survey, 68 species were found in total. There were 11 Gramineae plants, 10 Compositae plants, 7 Leguminosae plants, *etc*. (Table 1). In 1983, 55 species were found when the elm woodland was not disturbed, while in 2011, 11 species had been lost, but 10 new species were observed. In the plowing and grazing elm woodlands, there were only 24 and 21 species, respectively. Compared to the undisturbed elm woodland in 1983, the understory species was lost by 55.56% and 61.11%, respectively, in the plowing and grazing elm woodlands. In the plowing elm woodland, Compositae *Artemisia scoparia* and Chenopodiaceae *Chenopodium acuminatum* were abundant; whereas the understory was dominated by *Chloris virgata* in the grazing elm woodland.

3.2 Species diversity, evenness and understory productivity

There were no differences in species diversity between the 83UE and 11UE despite the 11UE had relatively less species compared to the 83UE (Fig. 2) ($P > 0.05$). In the plowing and grazing elm woodlands, species diversity

Table 1 Species composition of elm woodlands under different conditions

Species	Family	83UE	11UE	PE	GE
Ulmus pumila	Ulmaceae	▲	▲	▲	▲
U. macrocarpa	Ulmaceae	▲	▲		
Achnatherum avinoides	Gramineae	▲	▲		
Agropyron cristatum	Gramineae	▲	▲	▲	▲
Cleistogenes squarrosa	Gramineae	▲	▲	▲	▲
Hierochlor glabra	Gramineae	▲	▲		
Leymus chinensis	Gramineae	▲	▲	▲	▲
Poa sphondylodes	Gramineae			▲	
Setaria viridis	Gramineae	▲	▲	▲	▲
Stipa baicalensis	Gramineae	▲	▲		
Chloris virgata	Gramineae		▲	▲	▲
Digitaria chrysoblephara	Gramineae		▲	▲	▲
Eragrostis pilosa	Gramineae			▲	▲
Serratura yamatsutana	Compositae	▲	▲		
Scorzonera grabra	Compositae	▲			
Ixeris sonchifolia	Compositae	▲	▲		
I. chinensis	Compositae	▲	▲		
Senecio ambraceus	Compositae	▲			
Artemisia mongolica	Compositae	▲			
A. scoparia	Compositae		▲	▲	▲
A. sieversiana	Compositae	▲	▲		
A. lavanclulaefolia	Compositae	▲			
A. oxycephala	Compositae	▲			
Astragalus scaberrimus	Leguminosae	▲	▲		

Continued Table 1

Species	Family	83UE	11UE	PE	GE
Glycyrrhiza uralensis	Leguminosae	▲	▲		
Gueldenstaedtia verna	Leguminosae	▲	▲	▲	
Lespedeza hedysaroides	Leguminosae	▲	▲	▲	
L. davurica	Leguminosae	▲	▲	▲	▲
Vicia amoena	Leguminosae	▲	▲		
V. cracca	Leguminosae	▲			
Eurotia ceratoides	Chenopodiaceae	▲	▲	▲	▲
Corispermum elongatum	Chenopodiaceae	▲	▲	▲	
Chenopodium acuminatum	Chenopodiaceae	▲	▲	▲	
C. aristatum	Chenopodiaceae	▲	▲	▲	▲
Salsola collina	Chenopodiaceae	▲	▲	▲	▲
Euphorbia esula	Euphorbiaceae	▲			
E. humifusa	Euphorbiaceae	▲	▲	▲	▲
Securinega suffruticosa	Euphorbiaceae	▲	▲		
Speranskia tuberoulata	Euphorbiaceae	▲	▲		
Allium anisopodium	Liliaceae	▲			
A. ramosum	Liliaceae		▲	▲	
Asparagus cochinchinensis	Liliaceae		▲	▲	▲
Armeniaca sibirica	Rosaceae	▲	▲		
Potentilla filipendula	Rosaceae	▲	▲		
Sanguisorba officinalis	Rosaceae		▲	▲	▲
Leonurus manshuricus	Labiatae	▲			
Schizonepeta multifida	Labiatae	▲			
Viola prionatha	Violaceae	▲			
V. dissecta	Violaceae	▲			
Calystegia pellita	Convolvulaceae	▲			
Convolvulus chinensis	Convolvulaceae				
Cynanchum thesioides	Asclepiadaceae	▲			
Periploca sepium	Asclepiadaceae	▲	▲	▲	▲
Dracocephalum moldavica	Lamiaceae		▲		
Scutellaria regeliana	Lamiaceae	▲	▲		
Incarvillea sinensis	Bignoniaceae	▲			
Lappula squarrosa	Boraginaceae	▲			
Dontostemon micranthus	Cruciferae	▲			
Ephedra sinica	Ephedraceae		▲		▲
Erodium stephaninum	Geraniaceae	▲	▲	▲	
Canabis sativa	Moraceae	▲			▲
Polygala tenuifolia	Polygalaceae		▲		
Thalictrum squarrosum	Ranunculaceae	▲	▲		▲
Rhamnus davurica	Rhamnaceae	▲	▲		
Rubia cordifolia	Rubiaceae	▲			▲
Diarthron linifolium	Thymelaeaceae	▲			
Ampelopsis aconitifolia	Vitaceae	▲			
Carex duriuscula	Cyperaceae		▲		

Notes: ▲ means the existence of species in elm woodland. 83UE and 11UE represent the undisturbed elm woodlands investigated in 1983 and 2011; and PE and GE represent elm woodlands under plowing and grazing disturbances, respectively was remarkable lower than that of the undisturbed elm woodland ($P < 0.01$). Between the 83UE and 11UE, the Pielou Evenness was not shown statistical significance ($P > 0.05$). But plowing and grazing disturbances significantly decreased Pielou Evenness compared to that of the undisturbed elm woodlands ($P < 0.01$).

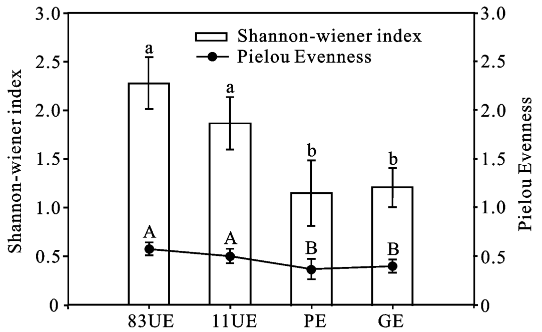

Fig. 2 Species diversity and Pielou Evenness of elm woodlands studied. 83UE and 11UE represent undisturbed elm woodlands investigated in 1983 and 2011; PE represents elm woodlands under plowing disturbance, and GE represents elm woodlands under grazing disturbance. Different letters (a, b or A, B) mean significance difference at $P < 0.01$ level among sites. Data are presented as Mean ± SE

The highest understory productivity was found in the plowing elm woodland; whereas the lowest was observed in the grazing elm woodland (Fig. 3). There were no differences between the 83UE and 11UE in the understory productivity. Compared to the undisturbed elm woodlands, the plowing elm woodland had significantly higher understory productivity; whereas the grazing elm woodland had apparently lower understory productivity ($P < 0.01$).

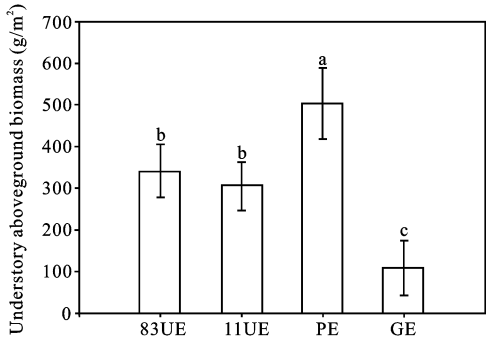

Fig. 3 Understory aboveground biomass of studied elm woodlands. 83UE and 11UE represent undisturbed elm woodlands investigated in 1983 and 2011; PE represents elm woodlands under plowing disturbance, and GE represents elm woodlands under grazing disturbances. Different letters (a, b and c) mean significance difference at $P < 0.01$ level among sites. Data are presented as Mean ± SE

3.3 Reponses of elm tree to different disturbances

The distribution pattern of elm was either scattered or clustered (Fig. 4). The elm was often stout and tall in scattered pattern under plowing disturbance, but thin, short and twisted in clustered pattern under grazing disturbance. In addition, the tree canopy in elm woodland were normally less than 25%, average height of mature trees was lower than 5 m. Elm woodlands are typically featured a complex mosaic landscape both within the elm woodland and on regional landscape scale.

In the undisturbed elm woodlands, there were no differences in average tree aboveground biomass, average height and average chest diameter among 83UE, 11UE and PE (Fig. 5). However, average tree aboveground biomass, average height and average chest diameter were significantly lower in the grazing elm woodland

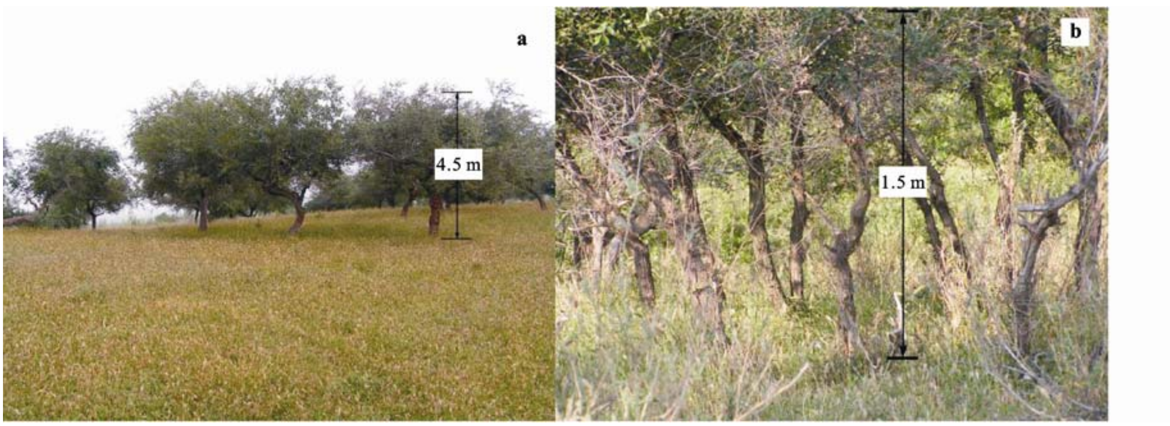

Fig. 4 Different appearance patterns of elm (*U. pumila*) in elm woodland. a) scattered elms which were stout and tall; and b) clustered elms which were thin, short and twisted

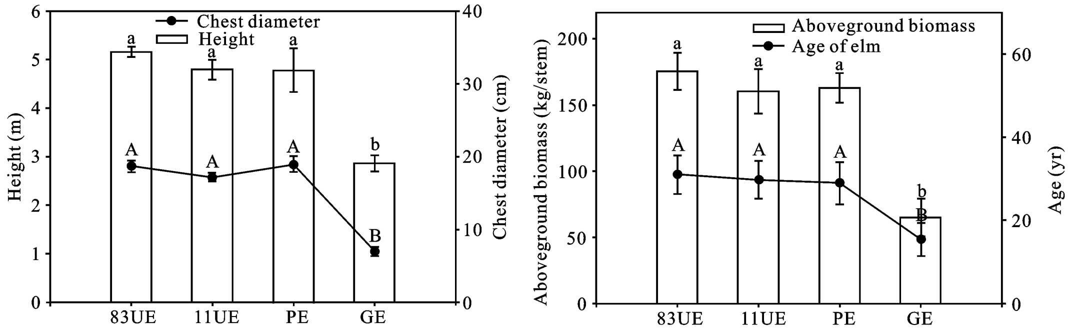

Fig. 5 Height, chest diameter, aboveground biomass and age of elm in the studied elm woodlands. 83UE and 11UE represent undisturbed elm woodlands investigated in 1983 and 2011; PE represents elm woodlands under plowing disturbance, and GE represents elm woodlands under grazing disturbance. Different letters (a, b, or A, B) mean significance difference at $P < 0.01$ level among sites. Data are presented as Mean ± SE

compared to that of the undisturbed elm woodlands and the plowing elm woodland ($P < 0.01$). Elm age was about 30 yr in the undisturbed and plowing elm woodlands, while it was only 15 yr in the grazing elm woodland.

3.4 Bray-Curtis Ordination analysis

The results of the Bray-Curtis Ordination analysis indicated that all the sample stands were classified to three groups (Fig. 6). Sample stand 1–20 (except sample 10), collected in 83UE and 11UE, were mainly distributed in Group I; sample stand 21–30 (except sample 28), collected in PE, were mainly clustered in Group II; and sample stand 31–40, collected in GE, were clustered in Group III.

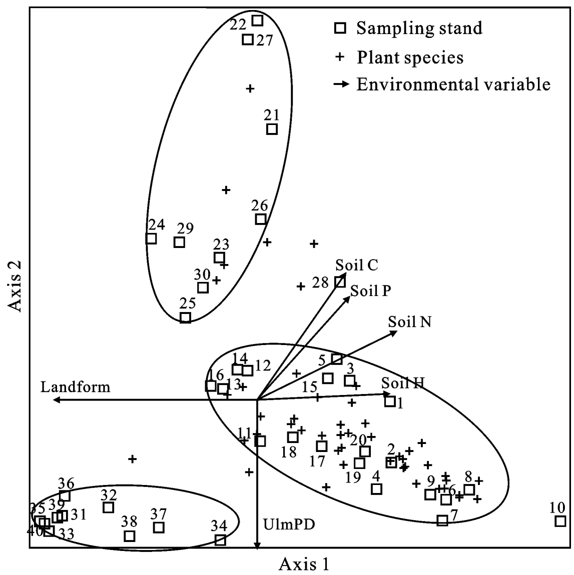

Fig. 6 Bray-Curtis Ordination diagram of elm woodland under different types of utilizations. The angles and lengths of radiating lines indicate the direction and strength of relationships of the variables with the ordination scores. Landform is classified by different utilizations (83UE = 1, 11UE = 2, PE = 3, GE = 4). Soil C, soil P, soil N and soil H represent organic carbon, phosphorus, nitrogen and humidity of soil, respectively. UlmPD represents the density of *U. pumila* in each type of elm woodland

Correlation between the environmental variables and the ordination scores were apparently different (Table 2 and Table 3). Landform was negatively correlated with axis 1 ($R = -0.889$). Soil humidity and nitrogen were positively correlated with axis 1 ($R = 0.717$, $R = 0.736$). Soil organic carbon ($R = 0.703$) and soil phosphorus ($R = 0.635$) were positively correlated with axis 2. The density of *U. pumila* (UlmPD) was negatively correlated with axis 2 ($R = -0.791$) and soil C ($R = -0.543$) (Table 3).

Table 2 Bray-Curtis Ordination analysis of correlation between environmental variables and ordinations axes

	Axis 1	Axis 2	Axis 3
Landform	–0.889**	0.026	–0.144
Soil H	0.717**	0.158	0.162
Soil N	0.736**	0.516*	0.250
Soil C	0.587*	0.703**	0.131
Soil P	0.599*	0.635**	0.150
UlmPD	–0.007	–0.791**	–0.045

Notes: ** means $P < 0.01$, and * means $P < 0.05$. Landform is classified by different land utilizations (83UE = 1, 11UE = 2, PE = 3, GE = 4). Soil C, soil P, soil N and soil H represent organic carbon, phosphorus, nitrogen and humidity of soil, respectively. UlmPD represents the density of *U. pumila* in the studied elm woodlands

4 Discussion

From 1983 to 2011, 10 new species were collected in elm woodlands, which were mostly synanthropic plants, such as *C. virgata*, *A. scoparia*. The appearance of these

Table 3 Bray-Curtis Ordination analysis of correlation among environmental variable

	Landform	Soil H	Soil N	Soil C	Soil P	UlmPD
Landform	1.000	–0.758**	–0.786**	–0.594*	–0.634**	–0.108
Soil H		1.000	0.736**	0.593*	0.632**	–0.071
Soil N			1.000	0.928**	0.951**	–0.400
Soil C				1.000	0.943**	–0.543*
Soil P					1.000	–0.502
UlmPD						1.000

Notes: ** means $P < 0.01$, and * means $P < 0.05$. Landform is classified by different land utilizations (83UE = 1, 11UE = 2, PE = 3, GE = 4). Soil C, soil P, soil N and soil H represent organic carbon, phosphorus, nitrogen and humidity of soil, respectively. UlmPD represents the density of *U. pumila* in the studied elm woodlands

new species might be caused not only by climate change, but also by the unconspicuous and discontinuous disturbances of human activities (Li *et al.*, 2003; Yang *et al.*, 2003; Kolström *et al.*, 2011). The great loss of species in plowing and grazing elm woodlands were the direct effect of great intense of land plowing and herbivore browsing (Belsky and Blumental, 1997; Wang *et al.*, 2010a). Those activities also stimulated the growing of synanthropic plants, e.g., *A. scoparia* and *C. acuminatum*, in the understory of elm woodlands. However, such synanthropic species was not found in the elm woodland in the Taiga Mountain in Mongolia (Dulamsuren *et al.*, 2005; 2009a; 2009b). The low species diversity and evenness in the plowing and grazing elm woodlands suggested that high intense plowing and over-grazing could directly remove species and reduce species diversity and evenness (Yang *et al.*, 2003; Dulamsuren *et al.*, 2005; Zuo *et al.*, 2005). However, plowing did not decrease the understory aboveground productivity. It could be explained by the high amount and frequency of annual plants, such as *C. acuminatum*, which could grow up to the height of more than 2 m with high density. The results of some studies also indicated that frequent land plowing could stimulate the growth of annual plants through furrowing soil and accelerating litter turnover rate (Borendse, 1999). In the grazing elm woodland, the lowest species diversity and productivity demonstrated that this region was experiencing high intense of grazing, although some researchers pointed out that moderate grazing could increase productivity and species diversity (Wang *et al.*, 2010b). The understory was covered mostly by short and sparse *C. virgata*, which was an indicating plant for overgrazing in the nearby grassland region.

In the study area, *U. pumil* distribution patterns were either scattered or clustered, which were similar as *U. pumila* in the Taiga Mountain Mongolia (Dulamasuren, 2005). There were no differences in the aboveground biomass, height and chest diameter of the elm among 83UE, 11UE and PE. Despite potential plowing disturbance impacted the growth of elm, we observed relatively high aboveground biomass, height and chest diameter in the plowing elm woodland, which might be attributed to fertilization effects of fast growing annual plants. Furthermore, *Leguminosae* crops (soybean and mungbean) planting could partially stimulate understory vegetation growth through increasing the soil nitrogen concentration. On the other hand, grazing significantly suppressed the growth of the elm, which might be caused by directly herbivore browsing and/or the reduction in nutrient import due to the massive removal of understory plants (Hou and Yang, 2006; Conti and Díaz, 2013). It also suggested that the study area has been over grazed. In 2011, elm age was less than 30 yr, and it was interesting that elm did not grow older comparing to 83UE. But the same result was found that elms in the Taiga Mountain in Mongolia had an age about 17 years (Dulamsuren *et al.*, 2009b). Therefore, we hypothesized that either the elm, when grow to certain age, might not grow much bigger in shape, or it might be problematic to estimate elm age using height and chest diameter. And these need further studies in the future.

The results of many studies implied that climate change might cause the degradation of the elm woodland (Yang *et al.*, 2003; Li *et al.*, 2004; Drobyshev *et al.*, 2013). The results of Bray-Curtis Ordination analysis in this study showed that the undisturbed elm woodland sample stands (1–20) was clustered to Group I, even we defined different values to the elm woodland in 83UE and 11UE. The Group II, the sample stands from PE, and Group III, the sample stands from GE, were distinctively different with Group I (83UE and 11UE). It pointed out that, although long time climate changes affected species composition of elm woodlands, but not drive elm woodlands succeed to different direction. In addition, long time plowing and grazing disturbances already converted elm woodlands to different types of community. The negative correlation between landform and soil variables showed that grazing utilization associated great removal of ground cover could significantly cause the losses of C, N and P (Bormann and Likens, 1979; Johnson, 1995). Moreover, we also treated the density of *U. pumila* (UlmPD) as an environment variable to examine the relationship between UlmPD and the sample stands. UlmPD was lower in Group II (PE), but higher in Group III (GE), and it was strongly negatively correlated with axis 2. This means that the plowing and grazing disturbances have different effects on the growth of elm. Therefore, to some extent, it indicated that low soil nutrient status would slow down elm growth and also could explain why the elms are short and twist in GE.

5 Conclusions

Based the results of this study on long time community changes of the elm woodland, it is suggested that the climate changes do not deteriorate the elm woodland consistence in general. The main reason caused the degradation of the elm woodland is plowing and grazing disturbances. Such disturbances directly destroy species composition and decreases biodiversity. The plowing and grazing disturbances act in different ways to alter the performance of the elm woodland. In the plowing elm woodland, frequent soil furrowing destroys the soil structure and promotes the growth of annual plants, such as *C. acuminatum* and *S. viridis*, and indirectly accelerate litter turnover rate. In the grazing elm woodland, the intense livestock browsing removes the understory vegetation, and induces reductions in species and diversity. The constructive species, elm, are also favorable for livestock; therefore livestock browsing can also directly affect the establishment of elm seedling and further growth of elm.

In this study, we demonstrated that the Bray-Curtis Ordination analysis was successfully implied to reflect the different responses of the elm woodland to different land utilizations. This study also clarified the relationships among the species composition, environmental factors and ordination axes, such as the soil organic carbon, phosphorus, nitrogen and humidity were significant correlated with axis I, but negatively correlated with increasing landform (83UE = 1, 11UE = 2, PE = 3, GE = 4). It means that soil became deteriorated from 83UE to GE. And the observed distinctively grouping of sampled stands further explained that climate changes were not the primary reason for the degradation of elm woodland community. Rather, long-term plowing and grazing disturbances altered the succession of elm woodland. Therefore, reasonably plowing and exclusive grazing will be favorable for future regeneration of degraded elm woodlands.

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