DESERTIFICATION OF THE TYPICAL STEPPE LANDSCAPE UNDER FIELD/STOCK-FARMING MANAGEMENT: AN ASSESSMENT IN WUFUHAO SETTLEMENT, CENTRAL INNER MONGOLIA

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Received: 5th May 2010, **Accepted:** 13th April 2011

ABSTRACT

Desertification of the Eurasian steppe biome brings serious problems to the natural environment, socio-economy and people’s lives on both local and global scales. In the present study, we focused on the field/pasture-boundary in geographical land-use patterns, distributed in the Typical steppe zone (*Stipa krylovii*/*Cleistogenes squarrosa*/*Leymus chinensis*-dominant steppe) of Inner Mongolia, China, and assessed landscape structure and fragility through the interdisciplinary research. A study site was established in Wufuhao Settlement (41°11'42''N, 111°34'24''E; 1.2km×2.0km; ca. 1615m a.s.l.), and field surveys consisting of vegetation mapping and sociological censuses were carried out during the 2002-2007 period. The results are summarized as follows: (1) a gently undulating hilly-landform stretched out, (2) since a mass immigration in the 1910’s, natural vegetation has been changed into fields (63.9% of the study site) and *Populus*/*Ulmus*-plantations (8.6%), (3) 139 vascular plant species were detected, including crops, weeds and halophilous plants, and (4) five types of herbaceous plant communities were distinguished by TWINSPAN, coupled with the difference in micro-scale landforms, cultivation and grazing by livestock. Consequently, in spite of approaches for the environmental restoration, soil erosion by water-flows and winds, salinization, and the degradation of the remaining grassland vegetation, most of which having been caused by unsustainable field/stock-farming management, resulted in an irreversible destruction of the indigenous steppe landscape.

Key words: desertification, field/pasture-boundary, Inner Mongolia, land-use management, micro-scale landform

Nomenclature: “Key to the Higher Plants of Daqing Mountain in Inner Mongolia” (Zhao, 2005)

INTRODUCTION

Desertification of the Eurasian steppe biome (Archibold, 1995) brings serious problems to the natural environment, socio-economy and people's lives on both local and global scales; i.e., loss of unique wildlife, reduction of ecosystem services, frequent occurrence of sand storms and soil erosion, and acceleration of climate change (e.g., United Nations Environment Programme, 1992, 1997; Koizumi *et al.*, 2000; Yoshikawa *et al.*, 2004). In the semi-arid region of China, human activities of field farming and pasturage have damaged indigenous grasslands, and, since 1980's, scientific researches and national projects toward environment restoration and sustainable land-use have proceeded intensively (e.g., Yoshino, 1997; Wang and Wu, 1999; Wuyunna and Okamoto, 2004; Konagaya *et al.*, 2005).

In the present study, we focused on the field/pasture-boundary in geographical land-use patterns, distributed in the Typical steppe zone (*Stipa krylovii*/*Cleistogenes squarrosa*/ *Leymus chinensis*-dominant steppe) of Inner Mongolia (Xu, 2004), and assessed landscape structure and fragility through the interdisciplinary research.

Earlier literatures summarizing the historical process of steppe degradation in China (e.g., Kobayashi, 1990; Ba, 2006, 2007) indicated that agricultural reclamation was a major factor of desertification, as the cases of Mu Us, Hunshandake and Keerqin Sandlands. Therefore, intensive landscape ecological investigation on field/pasture-boundary, a transitional zone in where attempts of agricultural developments have taken places in the semi-arid area, is thought to be essential to build up the on-the-site scenarios about desertification, restoration or sustainable land-use. Our interest is (1) to grasp the variety in and the distributional patterns of both vascular plants and plant assemblages, as the ecological indicators or the functional types, and (2) to examine the effects of micro-scale landforms and field/stock-farming management on the vegetation structure in a settlement-scale landscape.

STUDY AREA

We chose Wufuhao Settlement (41°11'42"N, 111°34'24"E; ca. 1615m a.s.l.) for the present study after a physiognomic inspection of landscapes around Wuchuan Town, being located at ca. 45km north of Hohhot, the capital of Inner Mongolia. Steep Daqing Chan Mountain Range lies between Wuchuan and Hohhot, and its northern foot connects to plateau (ca. 1500-2000m a.s.l.) which is characterized by gently undulating hilly-landform (ca. 100-200m in relative height), consisting of dome-shaped hillocks, inter-hillock lowlands and meandering wadis, intermittent streams (Fig. 1).

Wuchuan area is situated on the semi-arid/arid boundary in the steppe climate zone (United Nations Environment Programme, 1992; Tokuoka and The Institute of Desert Research, Chinese Academy of Sciences, 2002; Xu, 2004). Annual mean temperature at the nearest meteorological station at Wuchuan Town (ca. 17km southwest of Wufuhao Settlement) is 2.5°C, and annual precipitation is 360.4mm, 68% falling during June-August (Editorial Committee for Topography of Wuchuan County, 1988). Coldest and hottest monthly mean temperature is –15.8°C (January) and 18.5°C (July), respectively. The bedrock is mainly reddish-brown/purplish-grey soft sandstone, frequently containing rounded gravels, and soil consisting of medium-sized sand with silt and small-sized gravels is very loose and poor in organic matter.

As a whole, the original vegetation is estimated to *Stipa krylovii*/*Cleistogenes squarrosa*/*Leymus chinensis*-dominant steppe (Institute of Plants, Chinese Academy of Science, 1982; Xu, 2004), although most of all had been changed into fields or degraded grasslands by severe cultivation and/or grazing after the middle of the 18th century (Editorial Committee for Topography of Wuchuan County, 1988; Fig. 1).

Fig. 1: View of Wufuhao Settlement and its neighbourhood, Wuchuan District, Inner Mongolia. Photograph was taken at the upper-position of gentle hillock slopes on 26th August, 2004.

METHODS

Field surveys

After general observations of the landform, vegetation and habitat for characteristic plants in the study area, a study site for vegetation surveys was established covering the center of Wufuhao Settlement (1.2km×2.0km; Fig. 2a). Then, field investigations were carried out in the summer seasons during the 2002-2007 period.

A total of 92 quadrats (1m×1m) were arranged in order to include various herbaceous vegetation types which were estimated to be distributed from the riverbeds to the top of the hillocks (ca. 1600-1655m a.s.l.), and phytosociological descriptions at each quadrat were carried out by Braun-Blanquet (1964) in the latter half of August of 2006 and 2007. Floristic inventories of vascular plants and landform classification according to the micro-scale criterion have been performed in the study site for six years.

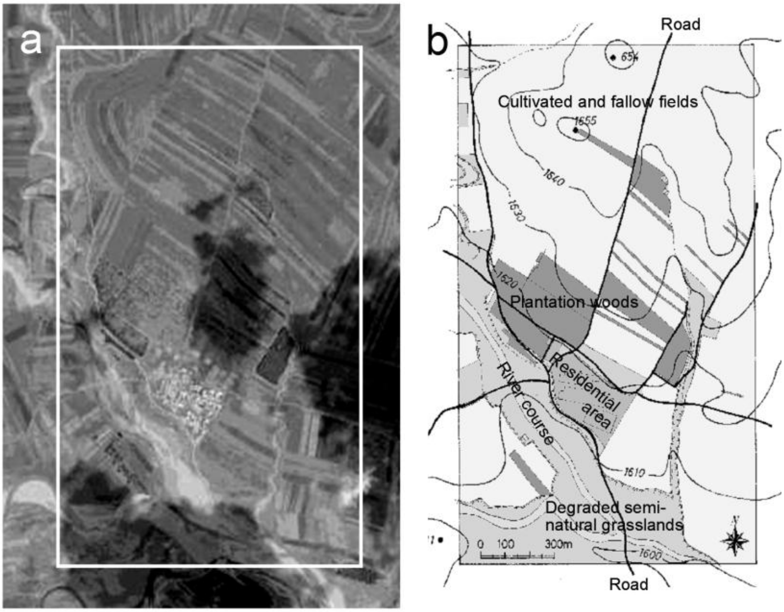
In order to reconstruct historical changes in the demographic structure and land-use management of Wufuhao Settlement, including countermeasures against desertification, interviews with residents and the local government officials were carried out intermittently.

Data analysis

Two Way Indicator Species Analysis (TWINSPAN; Hill, 1979) and Detrended Correspondence Analysis (DCA; Hill and Gauch, 1980) were used to analyze vegetation data. A data matrix consisting of 92 sampling quadrats vs. 94 emergent species was prepared, and the calculation was performed by PC-ORD for Windows (McCune and Mefford, 1999). In TWINSPAN, pseudo-species cut levels were set at 0, 1, 5, 25, 50 and 75, according to the dominance scale of Braun-Blanquet (1964).

For evaluating both herbaceous vegetation and site condition, ecological characteristics of plant species (e.g., Nakamura *et al*., 1998, 2000; Kawanabe *et al.*, 1998; Wuyunna *et al.*, 1999; Zhao, 2005; Han *et al.*, 2004) were considered for detected species in the field surveys; namely (1) life-forms (annual forbs, perennial forbs, annual graminaceous (i.e., grasses and sedge) plants, perennial graminaceous plants and dwarf-shrubs/shrubs), (2) origins (crops, weeds and wild plants), (3) response to grazing pressure (decreasing, stable and increasing in respect of relative dominance) and (4) habitat preferences (hydrophytes, hygrophytes, mesophyte, xerophytes, halophytes and psammophytes).

Fig. 2: Satellite image (a) and actual land-use map in 2007 (b) of the study site.
The study site (a rectangle in white; 1.2km×2.0km) is overlaid on the satellite image (Google Earth, downloaded on 22nd February, 2008).



RESULTS AND DISCUSSION

History of human impacts and land-protection

The original Wufuhao Settlement was established around 1915 by farmers who migrated from Shanxi and Shandong regions, China. In 2003, Wufuhao Settlement consisted of 33 households and 112 residents, in which workforce population was 68. Total area of their fields was 72.7ha, and mainly potatoes, oats and rapeseeds have been cultivated rotationally. Residents also bred nearly 70 sheep, 20 goats and 45 cattle as a cash livestock, and, once a day, they took these domestic animals to the patches of remaining grasslands and plantation woods from homesteads in order to take exercises and feed fresh plants.

After the adoption of the household contract responsibility system in 1981, activities in field/stock-farming sharply increased coupling with the expansion of trading area, the economic globalization, and thus brought degradation of vegetation and the land. For instance, farmers (1) have reclaimed the remaining grasslands and spread chemical fertilizers and pesticides in order to harvest larger amount of cash crops (e.g., potatoes for starch powder and rapeseeds for vegetable oil), and (2) have converted livestock (e.g., goat for cashmere and cattle for milk) and frequently put them in the common land to grazing. Various kinds of approaches against wind-/water-erosion of soils, such as (1) improvement of shapes and arrangement of field ridges, (2) fallowness of degraded fields, (3) sowing of leguminous pioneer species and (4) afforestation of *Populus* species, have been conducted, especially under the national policy of “Returning Cultivated Land to Forest/Grass Land” in 1994.

Present land-use pattern

Through the analyses of satellite images (Google Earth, 2004-2010; Fig. 2a) and ground-truth, we physiognomically distinguished five types of land-use units in the study site (1.2km×2.0km); (1) cultivated and fallow fields, (2) plantation woods, (3) degraded semi-natural grasslands, (4) river course (occasionally inundated, wet and bare lowland) and (5) residential area and roads (Fig. 2b).

Original vegetation had mainly changed into (1) cultivated and fallow fields covering the gentle hillock slopes (63.9% of the study site) and (2) *Populus*/*Ulmus*-plantation woods on severely disturbed places (8.6%; mostly planted around 1980). Degraded semi-natural grasslands (19.7%) consisted of “lowland meadow”-type covering the riverbeds and “upland grassland”-type scattering on the hillock slopes.

Flora

A total of 139 vascular plant species were detected in the study site (Table 1), including five species of crops (e.g., *Solanum tuberosum*, *Avena sativa* and *Zea mays*) and six species of planted shrubs and trees (e.g., *Populus simonii*, *Ulmus pumila* and *Salix cheilophila*).

Perennial herbaceous species occupied 62.6% of the total species detected, and members of genera Artemisia, Potentilla and Carex diversified into various habitats. Annuals, especially species of Chenopodiaceae and Polygonaceae, were also obvious under the severe human impacts, and they shared 28.8% of the total.

Table 1: Summary of the life-form composition for vascular plants collected in the Wufuhao study site (1.2km×2.0km).

Life-forms		No. of species		(%)
Summer and winter annuals		40		28.8
	Forbs		30	
	Graminaceous plants *		10	
Perennials		87		62.6
	Ferns		1	
	Forbs		59	
	Graminaceous plants		27	
Dwarf-shrubs		6		4.3
Shrubs †		3		2.1
Trees †		3		2.1
Total		139		100.0

* Graminaceous plants consist of grasses and sedge.

† Almost all of individuals were estimated to be planted.

Classification of degraded herbaceous vegetation

Using TWINSPAN, 92 phytosociological samples were classified into two categories in the first division and eventually into five types in the third division (Fig. 3). The former was characterized by the opportunistic streams of meandering wadis in the riverbeds, and the latter varying in respect to physiognomy, species composition and habitat selection coupling with micro-scale landforms and human impacts (Fig. 3, Table 2). Vegetational features of each herbaceous community are summarized below.

Eleocharis sp.-*Halerpestes ruthenica* community (mentioned "B" both in Fig. 3 and Table 2; *n* = 12) was firstly separated from other vegetation types by reference to *Eleocharis* sp. (*Eleocharis intersita?*), *Halerpestes ruthenica* and *Blysmus sinocompressus*, perennial hygrophytes in salinized unstable habitats, and was accompanied by halophytes such as *Potamogeton intramongolicus*, *Scirpus pumilus* and *Triglochin palustre* (Table 2). This community was distributed in the wet/flooded habitats in the river courses (Table 2), and was used for grazing.

Fig. 3: Dendrogram of Two-Way Indicator Species Analysis (TWINSPAN) identifying five vegetation types with indicator species listed at divisions.

Herbaceous vegetation in the Wufuhao study site (1.2km×2.0km) was surveyed at 92 quadrats (1m×1m) in August 2006 and 2007. A1a＝*Chenopodium album-Setaria viridis-Convolvulus arvensis* community, A1b ＝ *Chenopodium album-Polygonum aviculare-Poa annua* community, A2a ＝ *Cleistogenes polyphylla-Medicago lupulina-Heteropappus altaicus* community, A2b ＝ *Potentilla chinensis-Elymus dahuricus* community, B＝*Eleocharis* sp.-*Halerpestes ruthenica* community.

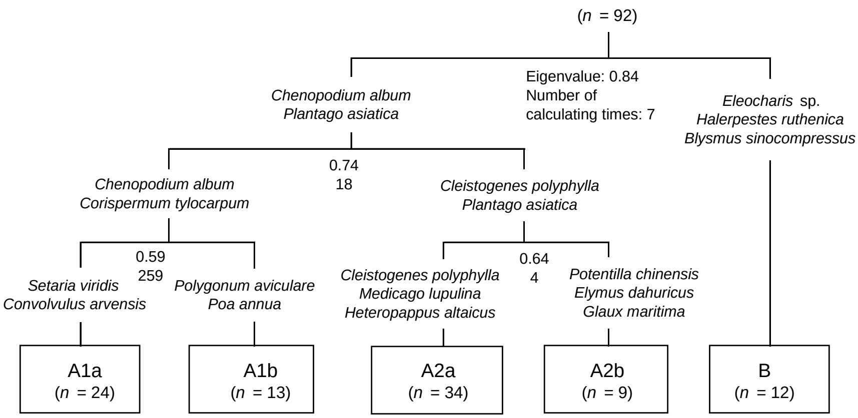


Table 2: Synoptic table of indicator and preferential species in the five vegetation types identifying by TWINSPAN. See Fig. 3 for vegetation types and the details.

Vegetation types		A1a	A1b	A2a	A2b	B	Total number of quadrat appeared
Number of quadrats		24	13	34	9	12	
Mean coverage of the herb layer (%)		67	41	52	59	60	
Density of species (/ 1m²) mean		6.6	7.4	12.0	8.1	4.5	
range		3−11	3−12	1−21	5−11	1−7	
Micro-scale landform types							
River courses of the present and the		·	·	·	1	11	
River bars		·	5	·	3	1	
River terraces of emergence		·	·	3	5	·	
Hill-foot gentle slopes		10	8	13	·	·	
Hill-side and -crest gentle slopes		14	·	17	·	·	
Gully bottoms		·	·	1	·	·	
Land-use types							
Cultivated and fallow fields		23	·	·	·	·	
Degraded semi-natural grasslands		·	6	11	9	12	
Plantation woods		·	·	22	·	·	
Residential area and bare roads		1	7	1	·	·	
Crepis crocea (Lam.) Babc.	pf	I +−1	·	I +	I +	·	7
Chenopodium aristatum L.	af	II +−1	I +	I +	I +	·	10
Convolvulus arvensis L.	pf	III +−2	·	·	·	·	13
Solanum tuberosum L.	pf	II 2−5	·	·	·	·	8
Carum buriaticum Turcz.	pf	I +	I +	·	·	·	4
Fagopyrum tataricum (L.) Gaertn.	af	II +−2	·	·	·	·	6
Setaria viridis (L.) Beauv.	ag	IV +−3	II +	I +	·	·	28
Artemisia lavandulaefolia DC.	pf	I 2−4	·	I +−2	I +	·	8
Zea mays L.	ag	I 2−4	·	·	·	·	4
Avena sativa L.	ag	II +−4	·	·	·	·	9
Saussurea salsa Spreng.	pf	II +−3	II 1−3	I +−1	·	·	14
Chenopodium album L.	af	V +−4	IV +−3	I +	II +	·	39
Corispermum tylocarpum Hanace	af	III +−2	IV +−1	I +	II +	·	27
Polygonum aviculare L.	af	I 1−2	V +−5	I +	I +	·	15
Camphorosma monspeliaca [1]	dss	·	II 1−2	·	·	·	5
Potentilla bifurca L.	pf	I 2	I +−4	I 1−2	·	·	6
Lepidium apetalum Willd.	af	·	III +−2	I +	·	·	10
Poa annua L.	ag	I +	IV +−2	I +−2	II 1	·	16
Leymus chinensis (Trin.) Tzvel.	pg	II +−4	II +−2	II +−4	·	·	25
Geranium sibiricum L.	af	I +	·	I +	·	·	7
Artemisia argyi Levl. et Vant.	pf	·	II +−1	II +−1	I +	·	14
Artemisia commutata Bess.	pf	I 2	I +	I +−2	I +	·	9
Plantago asiatica L.	pf	I +	III +	III +−2	III +−1	·	30
Artemisia ordosica Krasch.	dss	I 1−2	I +−2	III +−2	I 1	·	23
Artemisia sacrorum Ledeb.	pf	I +	I +−3	II +−3	I +	·	15
Potentilla multicaulis Bunge	pf	I +	I +	II +	·	·	12
Potentilla ambigua Gaudin	pf	I 1	·	I +−1	·	·	7
Carex arnellii Christ ex Scheutz	pg	·	·	I +−3	·	·	4
Iris lactea var. *chinensis* (Fisch.) Koidz.	pf	·	I 1	II +−3	·	·	9
Thalictrum petaloideum L.	pf	·	·	I +	·	·	4
Lappula myosotis V.Wolf.	af	·	·	I +	·	·	6
Astragalus tataricus Franch.	pf	·	·	IV +−2	·	·	23
Astragalus membranaceus (Fisch.) Bunge	pf	·	·	I +	·	·	4
Ixeris chinensis subsp. *graminifolia* Kitag.	pf	I +	·	III +−2	I +	·	20
Artemisia dracunculus L.	pf	·	·	II +	·	·	11
Cleistogenes squarrosa (Trin.) Keng.	pg	·	·	II +	I +	·	11
Agropyron cristatum (L.) Gaertn.	pg	·	·	II +−1	·	·	8
Lespedeza bicolor Turcz.	dss	I +	·	I +−2	·	·	6
Artemisia frigida Willd.	pf	·	·	II +−3	·	·	8
Leymus secalinus (Georgi) Tzvelve	pg	·	·	II +−3	·	·	8
Medicago lupulina L.	af	·	·	IV +−2	·	·	25
Stipa krylovii Roshev.	pg	I +	·	III +−4	·	·	19
Heteropappus altaicus (Willd.) Novopokr.	pf	·	·	IV +−3	·	·	22
Cleistogenes polyphylla Keng.	pg	·	·	IV +−4	·	·	27
Thymus serpyllum L.	dss	·	·	III +−3	·	·	16
Carex reptabunda (Trautv.) V. Kreez.	pg	·	I +	I 1−2	IV +−3	·	10
Elymus dahuricus Turcz.	pg	·	·	·	IV 2−4	·	6
Glaux maritima L.	pf	·	·	·	IV +−1	I +	7
Taraxacum mongolicum Hand.-Mazz.	pf	·	II +	II +−2	IV +−2	II +	26
Festuca rubra subsp. *arctica* (Hack)	pg	·	·	·	III +−3	I +−3	7
Potentilla chinensis Ser.	pf	·	·	III +−1	V +−4	III +−1	27
Carex duriuscula C.A.Mey.	pg	·	I +	·	II +−1	II 1	7
Triglochin palustre L.	pf	·	·	·	I +	II +−3	4
Blysmus sinocompressus Tang et Wang	pg	·	·	·	·	III +−1	7
Scirpus pumilus Willd. ex Kunth	pg	·	·	·	·	II +−4	4
Halerpestes ruthenica (Jacq.) Ovez.	pf	·	·	I +	I +	III +−5	9
Eleocharis sp.	pg	·	·	·	·	IV 1−4	9
Potamogeton intramongolicus Ma	pf	·	·	·	·	II 2−5	3

1) subsp. *lessingii* (Litvinov) Aellen

Life-forms; af = annual forbs, ph = perennial forbs, ag = annual graminaceous plants (grasses and sedge), pg = perennial graminaceous plants, dss = dwarf-shrubs/shrubs.

Roman numbers are appearance frequency; I = 1%-20%, II = 21%-40%, III = 41%-60%, IV = 61%-80%, V = 81%-100%. Symbols following appearance frequency indicate Braun-Blanquet's dominant scale (+, 1, 2, 3, 4, 5).

The other 80 phytosociological samples were subdivided into two categories (Fig. 3); namely, “A1” (*n* = 37) was characterized by differential species such typical psammophytes of short life-span as *Chenopodium album* and *Corispermum tylocarpum*, and for “A2” (*n* = 43), *Cleistogenes polyphylla* and *Plantago asiatica*, typical perennials tolerating grazing and trampling, were differential species.

Chenopodium album-Setaria viridis-Convolvulus arvensis community (“A1a”; *n* = 24) was constructed by many individuals of crops (*Solanum tuberosum*, *Zea mays* and *Avena sativa*) and annual weeds (e.g., *Chenopodium album*, *Setaria viridis*, *Corispermum tylocarpum*, *Fagopyrum tataricum* and *Chenopodium aristatum*; Table 2). All of phytosociological samples collected in cultivated and fallow fields were classified into this vegetation type.

Chenopodium album-Polygonum aviculare-Poa annua community (“A1b”; *n* = 13) were characterized by annual species commonly growing in the bare and dry habitats such as road-side verges and residential areas (e.g., *Polygonum aviculare*, *Poa annua* and *Lepidium apetalum*; Table 2).

Comparing with “A1,” two communities of “A2” seemed to escape from severe human impacts and, therefore, maintained relatively rich components of the Typical steppe (Table 2). Almost all of phytosociological samples of *Cleistogenes polyphylla-Medicago lupulina-Heteropappus altaicus* community (“A2a”; *n* = 34) collected in plantation woods and degraded semi-natural grasslands on the gentle hillock slopes. Perennial species such as *Cleistogenes polyphylla*, *Stipa krylovii*, *Heteropappus altaicus* and *Leymus chinensis*, and dwarf-shrubs such as *Thymus serpyllum* and *Artemisia ordosica* were important components.

On the other hands, *Potentilla chinensis-Elymus dahuricus* community (“A2b”; *n* = 9), detected on the river terraces of emergence and river bars, was characterized by perennial hygrophytes of the degraded “lowland meadow” (e.g., *Potentilla chinensis*, *Elymus dahuricus*, *Glaux maritime*, *Carex reptabunda* and *Festuca rubra* subsp. *arctica*; Table 2).

Ordination of degraded herbaceous vegetation

The ordination of 92 quadrats on the two principal axes of DCA is given by Fig. 4, in which five categories of vegetation types classified by TWINSPAN were overlaid. Table 3 shows correlations between DCA scores and parameters of stand characteristics.

Axis 1 (eigenvalue = 0.986) had negative correlations with altitude and vegetation height (Table 3; $P < 0.01$, Spearman’s ranking correlations). On the other hands, Axis 2 (eigenvalue = 0.837) had positive correlations with vegetation coverage, vegetation height and the number of species appeared (Table 3; $P < 0.05$, Spearman’s ranking correlations).

Along Axis 1, five vegetation types clearly followed the order: "A1a", "A1b", "A2a", "A2b" and "B" (Fig. 4). Comparing the distributional ranges of the vegetation types on the two principal axes, habitat divergence coping with the micro-scale landforms along the riverbed-hillcrest gradient was estimated to be the most fundamental factor to understand vegetation structure in the landscape perspective. Human impacts such as cultivation, pasturage, afforestation and residence, which have induced monoculture fields, degraded grasslands, plantation woods and bare-land, respectively, were also seemed to be major forces in the landscape transformation, especially of "upland grasslands" on the gentle hillock slopes.

Fig. 4: Detrended corresponding Analyses (DCA)-ordination of 92 quadrats (1m×1m) for the herbaceous vegetation in the Wufuhao study site (1.2km×2.0km).
The different vegetation types classified by TWINSPAN are overlaid. See Fig. 3 and Table 2 for vegetation types and the details.

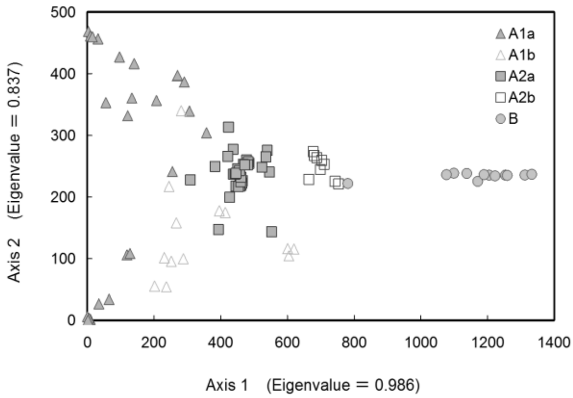


Table 3: Correlations between DCA-scores and parameters of habitat or vegetation characteristics.
Results of the Spearman's ranking correlations are also shown: * P＜0.05, ** P＜0.01, *** P＜0.001.

Ecological characteristics	DCA Axis 1	DCA Axis 2
Altitude (m)	-0.5789 ***	0.0806
Inclination (°)	0.0035	0.0394
Height of vegetation (m)	-0.2744 **	0.3534 ***
Coverage of vegetation (%)	-0.1223	0.438 ***
No. of species appeared (/m^2)	0.0441	0.247 *

CONCLUSIONS

Through the interdisciplinary research consisted of vegetation mapping and sociological censuses, we grasped the on-going desertification process in the Wufuhao Settlement study site, which is phyto-geographically located on the field/pasture-boundary traversing the *Stipa krylovii*/*Cleistogenes squarrosa*/*Leymus chinensis*-dominant steppe (Institute of Plants, Chinese Academy of Science, 1982; Xu, 2004) in Inner Mongolia. On-the-site indications of desertification which were clarified by the present study are summarized as; (1) decrease of the component species and coverage for wild plants, (2) growth of many species of crops, weeds and halophytes, (3) concentration of livestock grazing to the degraded semi-natural grasslands remaining along the riverbeds and to the restored undergrowth of *Populus*/*Ulmus*-plantation woods, (4) soil erosion by sheet-wash, gully elongation, flooding of wadis and winds, and (5) salinization over the inter-hillock riverbeds. Empirical investigations in order to examine the ability in autogenic restoration of vegetation and soil conditions, especially for the patchy remaining degraded semi-natural grasslands, might be useful for establishment of the sustainable landscape management.

By TWINSPAN and DCA, five types of herbaceous plant communities with difference in species composition and characteristic species were detected, and a variety of degradation pathways of the Typical steppe coupled with the difference in micro-scale landforms and human impacts was also suggested. A number of vegetational studies of the Typical steppe degradation in Inner Mongolia have been performed, but, as compared with the present intensive study in a small settlement located on the field/pasture-boundary, many of them were (1) local/regional-scale investigations using satellite remote sensing (e.g., Tong *et al*., 2004; Yue *et al*., 2005) or (2) evaluations of grassland conditions based on diagnostic species in the pastoral area (e.g., Kawanabe *et al.*, 1998; Nakamura *et al.*, 1998, 2000; Yiruhan *et al.*, 2001). Multi-scale studies which integrate phenomena and findings across various spatial and temporal scales might be desired to understanding dynamics of the Typical steppe ecosystem.

ACKNOWLEDGEMENT

We thank two anonymous reviewers for valuable comments on our manuscript, and are grateful to Koganezawa Takaaki, Sakaida Kiyotaka and Otsuki Yoshinori for cordial guidance throughout the present study. Sincere thanks are extended to residents of Wufuhao Settlement, Hao Runmei, Fong Jiangong, Kikuchi Akihito, Saixiyalatu, Yongmei, Sekine Ryohei, Saijo Kiyoshi and Araki Yuji for help during the survey. This study was supported financially by JSPS Grant-in-Aid for International Scientific Research (15401030, 17401003 and 20401005) and the Fukutake Fundation.

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* In Japanese.
† In Chinese and title was tentatively translated into English by the authors.
§ In Japanese with English summary.
‡ In Japanese and title was tentatively translated into English by the authors.
\# In Chinese.