UNITED NATIONS UNIVERSITY

UNU-LRT

Land Restoration Training Programme
Keldnaholt, 112 Reykjavik, Iceland

Final project 2013

VEGETATION CONDITIONS IN VARIOUS PLANT COMMUNITIES IN KHONGOR DISTRICT, DARKHAN-UUL PROVINCE IN MONGOLIA

Tserennadmid Bataa
Mongolian Agricultural University of Darkhan-Uul province
New Darkhan, old district, 14th bag, Darkhan-Uul province, Mongolia
nadia_1014@yahoo.com

Supervisors
Jarngerdur Gretarsdottir
Agricultural University of Iceland
jarngerdur@lbhi.is

Groa Valgerdur Ingimundardottir
Lund University, Sweden
groa.valgerdur@gmail.com

ABSTRACT

The main part of the Mongolian ecosystem is natural grassland. Because of the increasing effects of humans and animals on the natural grassland, the vegetation cover has been changing considerably. Overgrazing of livestock is the main cause of land degradation in Mongolia, resulting in more bare ground and lower species diversity. Few extensive grassland steppes remain in Eurasia, where wildlife and domestic livestock co-exist. One of these steppes is the Mongolian Daurian steppe in North-east Mongolia. The goal of this project was to assess the vegetation conditions in eight different plant communities in the Khongor district, Darkhan-Uul province, which is located in the north-western part of the Mongolian Daurian steppe, and to investigate vegetation dynamics in the communities for the years 2009 – 2012. Vegetation data were collected, using phytosociological methods, from 40 stands in eight areas crossing approximately 300 km and covering a large proportion of the south-east part of the Khongor district. The results showed that regarding ecological groups, most species in the study sites belonged to mesophytes (38 %), xerophytes (26 %) and mesoxerophytes (23 %), but different groups were important in different communities. The results revealed also a variation between study sites in canopy cover, species richness and vegetation height, but minor changes in cover, richness and height between the four study years. A DCA ordination revealed groupings of eight phytosociological communities based on vegetation composition. The changes observed in species composition in the eight plant communities between study years were only small and no trends were observed in the direction of change. The minor changes observed in species richness between study years could possibly be connected to the low precipitation in the year

2010. The vegetation parameters measured in this study did not show signs of a degrading condition of the plant communities observed.

Keywords: Vegetation composition, plant communities, vegetation cover, dominant species, species richness, grasslands, Mongolian Daurian steppe.

This paper should be cited as:

Bataa T (2013) Vegetation conditions in various plant communities in Khongor District, Darkhan-Uul province in Mongolia. United Nations University Land Restoration Training Programme [final project] http:// http://www.unulrt.is/static/fellows/document/ bataa2013.pdf

TABLE OF CONTENTS

1. INTRODUCTION

Mongolia is in north central Asia and it shares borders with Russia in the north and China in the west, south and east. It has a total area of 1 565 000 km^2 and is the world's second largest landlocked country with a population of 2.8 million people and is the most sparsely populated country in the world (Batima et al. 2005). The country has an extreme continental climate consisting of four seasons, characterized by long, cold winters, and dry, hot summers with distinct springs and autumns (Marin 2010). Land degradation is a large problem in Mongolia and human activity and climate change are the main causes for the degradation (Batkhishig 2012).

The human impact is mostly through overgrazing of livestock, which is still increasing. Grassland ecosystems have already been severely affected by this factor (Jigjidsuren & Johnson 2003) which is the main cause of land degradation (Sergelenkhuu et al. 2012), resulting in more bare ground, and lower species diversity (Mongolian Third National Report 2006). According to Batkhishig (2012), 1 184 000 km^2 (75.8 %) of Mongolia are suitable for agricultural and pastoral livestock production. It has been reported that 70% of Mongolian grasslands are overgrazed (Cheng et al. 2008) and that a large percentage of Mongolian traditional pasture vegetation has degraded. During the last 40 years pasture biomass has decreased by two thirds and the vegetation composition has significantly changed (Batkhishig 2012). But drought has also had its effect on Mongolia's grasslands, including plant species composition and root system distribution (Shinoda et al. 2010). Many Mongolian reports estimate that as much as 70 – 90% of Mongolian rangelands are vulnerable to desertification and land degradation (Batjargal 1997; Batkhishig 2012; Tuvshintogtokh & Ariungerel 2013).

Plant communities in Mongolia have evolved and adapted to sustain grazing pressure from animals, both wild and domesticated (Jigjidsuren & Johnson 2003). Mongolia has a long history of rangelands but accelerating degradation, and climate and land-use changes threaten the balance that has long existed on the rangelands. The temperate rangelands of Mongolia are a uniquely unfragmented example of one of the world's most threatened terrestrial ecosystems and it is important to understand the factors affecting system resilience and vulnerability (MSRM [Mongolian Society for Range Management] and SADC [Swiss Agency for Development and Cooperation] 2010).

Over 57% of total arable land in Mongolia is located in the north-central areas of Tuv, Selenge and Darkhan-Uul provinces. Many researchers emphasize that since the establishment of Darkhan-Uul, it has been developing into a city with a large population, numerous industries and agriculture but, in recent years, due to climate change in addition to human and livestock effects, many changes in weather and vegetation cover have been noticed and the desertification rate has increased. (Batjargal 1997; Chognii 2001; Batkhishig 2012). Therefore, it is pressing to conduct scientific studies of the features and dynamics of the flora of this area.

1.1 The Mongolian Daurian forest-steppe

Mongolia is located in the prominent transition belt that lies north and west of the Gobi desert and south of the Siberian taiga forest so the vegetation of this area is particularly sensitive to changes of external conditions (Batima & Dagvadorj 1998). The main resource for nomadic husbandry development in Mongolia is pastureland and the pasture capacity, features, dominant species and species composition are different for each ecological zone (Bolortsetseg et al. 2000). Mongolia has six major ecological zones in terms of different topography, elevation, temperature, rainfall, soil and vegetation (Ulziikhutag 1985; Marin 2010). The forest-steppe, typical steppe, desert, and desert-steppe zones range from north to south; the alpine and high alpine zones are found in western Mongolia (Jigjidsuren & Johnson 2003) (Fig. 1). In addition, Grubov (1982, 2001) divided the country into 16 phytogeographical regions based on an earlier classification by Junatov from 1950. According to these classifications, the Darkhan-Uul province is located in the north-western part of the Mongolian-Daurian forest-steppe, a phytogeographical subdivision of the Eurasian steppe (Yunatov 1950; Grubov 1982; Ulziikhutag 1989) (Fig. 1) and forests, meadows and mountain forest-steppes occur in this region.

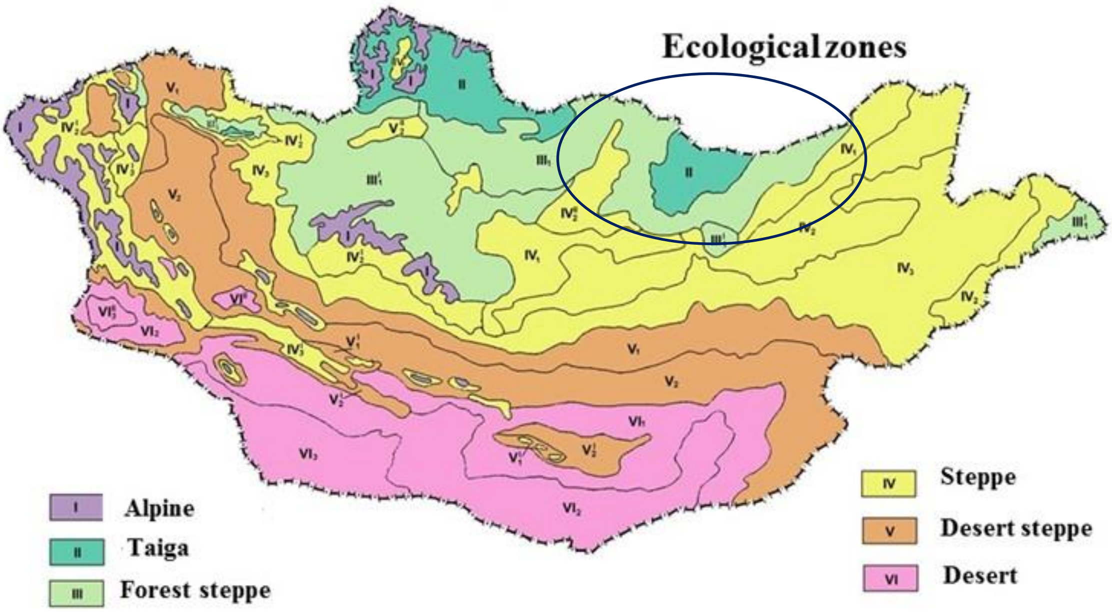


Fig. 1. *Mongolia's six major ecological zones. The Mongolian Daurian forest-steppe, where Darkhan-Uul province is located, is within the circle on the map (source: Ulziikhutag 1989; Grubov 2001).*

The Mongolian Daurian steppe is one of the few extensive grassland steppes remaining in Eurasia, where wildlife and domestic livestock co-exist (Mongolian National Commission for UNESCO/World Heritage Centre 2013). Forest types that are found in this ecoregion include Siberian larch forest with numerous herbs; mixed forests of birch and pine; and birch and larch; in addition to birch and shrub forests. The distribution of the 484 species of vascular plants found in Darkhan-Uul province has been registered according to phytogeographical region and ecological zones. Species belonging to the following phytogeographical regions dominated: forest, mountain steppe, typical steppe and meadow (80% of all plants or all species). They are mostly dominant in the Mongolian Daurian, Khangai and Khentii regions as well (Dariimaa et al. 2009). Due to the intensive migration of herder families in the last 10 years from western provinces to the surrounding area of Darkhan-Uul province, the communities are changing, and especially vegetation composition and dominant species shifts are increasing (Tserennadmid & Odonchimeg 2012). A detailed study of the flora and the change of the plant species composition of the Darkhan-Uul area will give valuable information about the condition of the land.

The aim of this study

The goal of this project was to analyse and describe vegetation patterns in various plant communities in Khongor district, Darkhan-Uul province in Mongolia. More precisely, the purpose of the project included assessing the vegetation conditions in eight different plant communities and investigating vegetation dynamics in the communities in the period 2009 – 2012.

The specific research questions that could be answered in the project to reach these goals were the following:

1. What is the vegetation condition in the eight plant communities in terms of parameters such as: Total vegetation cover, vegetation composition, species richness, dominant species and vegetation height?
2. Has the vegetation composition changed in the period 2009 – 2012? Are the size and direction of changes similar in different plant communities?
3. Does ordination contribute to the understanding of the main patterns in my vegetation data?

2. LITERATURE REVIEW

Various schemes are available for the classification of Mongolian plant communities. Russian scientists invented comprehensive descriptions of the Mongolian vegetation, including a coarse land cover map (1:1 000 000) of the entire country (Gunin & Vostokova 1995). A comprehensive classification system was proposed by Hilbig (1995) and has since become the benchmark reference on the vegetation of Mongolia.

In recent years there have been very few follow-up studies of the vegetation cover in Darkhan-Uul province but there is historical material on the Mongolian flora and the vegetation cover. Historical material from the Mongolian-Daurian region provides valuable information for vegetation studies of the Darkhan-Uul province.

In 1940, I. A. Tsetsenkin led a Mongolian rangeland study expedition team of Soviet researchers. During expeditions of the Mongolian Commission of the USSR Academy of Sciences in the 1930's, detailed floristic studies were carried out by Baranov, Desyatkin and others in different regions of Mongolia (Gunin et al. 1999). In the period between 1942 and 1947, A. A. Yunatov, one of the expedition members, organized a vegetation cover survey in all the natural zones in Mongolia. This survey covered the areas near Darkhan-Uul province as well. There have been many studies related to the flora of Darkhan-Uul province including research of the meadows in the Selenge and Orkhon river basin area by Desyatkin (Desyatkin 1936); a study of Northern Mongolian weed plant characteristics; a vegetation survey of Zuunkharaa, Selenge province by M. Badam and J. Ochir in 1957 – 1961; and a joint Soviet-Mongolian biological expedition in the Orkhon and Selenge river basin in the Shaamar district of Selenge province in 1975 – 1986 (Tserenbaljid 1987). Since 1955, the collaborative study of Mongolian and Soviet botanists has continued and a collaborative biological study expedition that started in 1970 has resulted in a more detailed study of meadow communities in Shaamar district, Selenge province.

Yunatov (1950) and Dashnyam (1979) carried out a vegetation survey in the Mongolian Daurian region and they found the dominant communities to be steppe communities: (*Forb* –

grass and *Cyperales – intermediate grass* [bunchgrass]). The most dominant plants in forest-steppe were *Poa attenuata, Festuca sibirica, Koeleria cristata, Carex pediformis, Artemisia commutata, Scabiosa comosa, Schizonepeta multifida, Stellera chamaejasme, Polygonum angustifolium,* and *Rumex acetosella.* The various communities found in the mountain steppe were *Caragana – Stipa grandis – Cleistogenes squarrosa; Stipa grandis – Cleistogenes squarrosa* and *Stipa grandis – Potentilla* that occurs in sandy and brown soil.

In the mountain steppe, the most dominant plants are *Festuca lenensis, Koeleria cristata, Agropyron cristatum* and *Poa botryoides*. *Leymus chinensis, Stipa krylovii, Cleistogenes sguarrosa* occur less frequently, but they grow in more abundance in the lowest part of the mountain steppe. *Caragana microphylla* is abundant in the dry steppe of the mountainside but *Spiraea aguilegifolia* grows commonly in the bottom of the gullies where it is moister. The subshrubs *Artemisia frigida* and *Arenaria capillaris* usually grow in soil that is more gravelly. *Thymus gobicus;* the onions *Allium bidentatum, A. senescens*; and the sedges *Carex duriuscula, C. korshinskyi* and *C. pediformis* are common in this area. Sanchir (1968) wrote that *Caragana* usually grows combined with grass and he described the *grass – Caragana* and *Caragana –* communities in the Gobi and forest steppe region. In this area, alignments, which are bush dominant, occur commonly in the mountain steppe, like *Caragana – grass* and *Caragana microphylla – Cleistogenes squarrosa* steppe communities. Steppe plants like *Caragana microphylla* grow in the *grass – Artemisia frigida* community.

The *Stipa – Potentilla* community is dominant in the west and central part of the Darkhan and Khongor districts. Besides, steppe plant communities are subject to overgrazing and agriculture so they are becoming a hogweed *(Artemisia)* steppe (Tserennadmid & Odonchimeg 2012). Other plants that are very dominant in the mountain steppe flora include *Koeleria cristata, Poa botryoides, Agropyron cristatum, Carex pediformis* and similar plants. *Stipa grandis* and *S. krylovii* are the most dominating species and the second most dominating species is *Cleistogenes squarrosa* in the mountain valley in the mountain steppe. Also, the forbs *Potentilla acaulis, Serratula centauroides, Pulsatilla bungeana, Bupleurum scorzonerifolium* and *Heteropappus hispidus* in addition to the graminoids *Poa attenuata, P. botryoides, Agropyron cristatum, Stipa grandis, S. krylovii, Cleistogenes squarrosa, Elymus Gmelinii, E. sibiricus, E. dahuricus* and *Koeleria cristata* are very common in the mountain-steppe. The sedges *Carex duriuscula, C. pediformis* and *C. korshinskyi* in addition to the forbs *Artemisia frigida, A. scoparia, Potentilla acaulis, P. bifurca, Thymus gobicus, Veronica incana, Pulsatilla Turczaninovii, Galium verum, Polygonum angustifolium, Scabioso comosa, Cymbaria dahurica, Alyssum lenense, Stellera chamaejasme, Dianthus versicolor, Silene repens, Filifolium sibiricum, Bupleurum scorzonerifolium, Serratula centauroides, Allium senescens, Astragalus fruticosus* and *Oxytropis myriophylla* always occur (Dariimaa et al. 2009). When soil moisture increases the steppe's community quickly changes into meadow communities in the transition zone. *Cleistogenes squarrosa – Stipa grandis and Stipa grandis – Artemisia frigida* communities are most dominant in the hill slopes (Ochir 1985). An *Achnatherum splendens* meadow community is found in the Kharaa and Shariin Gol river basins and is very common on the riverbanks all the way up to the hilltop. *Carex duriuscula* and *Agropyron repens* grow among the strong straw intermediate grass (*Achnatherum splendens*) in this area.

In the east part of the Darkhan Uul province, the vegetation becomes denser and mountain meadow steppe with grass and meadow is less frequent. It occurs along the Shariin Gol river, Khuitnii river, Kharaa river and the Great Kharganat narrow holm, and its dominant species are e.g. *Carex duriuscula, Thalictrum simplex, Geranium pratense, Bromus inermis, Iris lactea, Ranunculus sceleratus, Taraxacum officinale, Potentilla anserina, Filipendula ulmaria* and

Achillea asiatica. Birch and pine forest grow beyond the mountains called Rich, Great pine, Black grassland, Tree urumt, Great Darkhan, Black goat, and Pig mount that are located in the western part of the province. Common species in the forest include. *Majanthemum bifolium, Allium victoralis, Lilium dahuricum, Polygonatum odoratum, Anemone crinita, A. silvestris, Thalictrum petaloideum, Spiraea flexuosa, Fragaria orientalis, Vicia unijuga, V. cracca, Lathyrus humilis* and *Trollius asiaticus*. However, species such as *Rosa acicularis, Cotoneaster melanocarpa, Dasiphora fruticosa* and *Campanula glomerata* are dominant in the forest edge (Dariimaa et al. 2009).

Darkhan-Uul province is in the western part of the Khentii Mountains, close to the Mongolian Daurian forest-steppe to the west and the central part of the Khentii Mountains to the east. There are no high mountains in Darkhan-Uul province, but there is a continuous forest, which is at 1200 – 1500 m above sea level, with low small mountains with many spurs. (Tsegmid 1969). They usually have dense forest in the north but in some places where the river interrupts, like in the mountain foothill, there is no forest. The vegetation is found in a river valley: wet meadow, boggy meadow, dry meadow, salty meadow and holm forest. Meadow and mountain vegetation comes up where Kharaa river channel's leach soil is very moist (Ochir 1985). There is almost only one brushwood forest in the river valleys, its dominant species being *Salix miyabeana, S. pseudopentandra* and *S. bebbiana.* Normal pine (*Pinus sylvestris*) is in some places with sandy soil and dwarf elm (*Ulmus pumila*) grows in clay loamy soil. In holm meadows, there are jointed grasses like *Poa pratensis*, *Bromus inermis*, *Alopecurus arundinaceus, Agrostis trinii* grow together with the forbs *Orchis salina, Polygonum viviparum, Ranunculus repens, Potentilla anserina, Trifolium lupinaster, Vicia amoena, Lathyrus pratensis, Geranium pratense, G. pseudosibiricum, Primula nutans, Achillea asiatica, Sanguisorba officinalis, Cirsium esculentum, Inula britannica, Taraxacum officinalis* and *Thalictrum simplex* are also found there. Besides that, in salty meadows next to the salty lakes there are plants like *Plantago salsa, Glaux maritima, Oxytropis salina, Halerpestis salsuginosa, H. sarmentosa, Suaeda corniculata* and *Triglochin maritimum.* In river valleys, in the mountain steppe and the forest zone, there are patches with meadows. On a smooth surface, the jointed grasses are dominant. Where the landscape is heterogeneous, with gullies and plains, it is possible for various plants to grow so the area is relatively rich in plant genera and species.

The flora of Darkhan-Uul province has special features because of its geographical location and environment. Vegetation cover and plant communities firstly depend on the landscape, soil typology and water supply (Tserenbaljid 1987).

Since 2005, research work on features of the flora and vegetation communities in Darkhan-Uul provinces area was conducted with samples of 478 species from 65 families and 256 genera from Darkhan-Uul province (Dariimaa et al. 2009). Consequently, the newly registered flora of Darkhan-Uul province was enriched by 25 vascular plant species (Tserennadmid & Odonchimeg 2012).

3. METHODS

3.1 Geography and landscape of study area

Fig. 2. *A map of the Darkhan-Uul province in Northern Mongolia. (www.Darkhan-Uul aimag.infomongolia.com)*

Darkhan-Uul province is located in northern Mongolia, in the eastern valley of the Kharaa river and in the central part of Selenge province in the middle of the mountainous Khangai and Khentii areas. The province's territory is 700 – 1500 meters above sea level and lies between the latitudes of 49°07'N and 49°54'N, and longitudes of 105°50'E and 106°49'E (PADCO [Planning and Development Collaborative International] 2005). The total area of the province is about 3275 km^2. It consists of small mountains, low hills and hillocks, rivers, valleys and holms (Fig. 2). Administratively the province is divided into four districts: Khongor, Orkhon, Sharyn Gol and Darkhan. The Khongor district is the largest district in Darkhan-Uul province. More than 74 500 ha of Khongor district are covered by forest steppe, 33 000 ha by cropland and 160 000 ha are a rangeland with 103 900 livestock. Darkhan-Uul province is considered an important agricultural area in the country (PADCO [Planning and Development Collaborative International] 2005).

3.2 Soil

According to the soil and geographical classification of Dorjgotov (2003), Darkhan-Uul province belongs to the brown soil type of alpine forest-steppe in Khangai-Khentiin regions. The dominant soil type of the province is brown soil of the steppe in Darkhan-Uul and meadow soil spread over the valley of the River Kharaa (Narmandakh 2009). The most part of the province is covered with brown mountain soil, dark forest soil and sandy clay loam with gravel soil (Dorjgotov 2003).

3.3 Climate

The Darkhan-Uul province belongs to the Central Khangai zone. It has an extreme continental climate with long-term average annual temperatures ranging between - 2.5 to 3 °C, the summer temperatures reaching 25 to 30 °C and winter temperatures between - 10 to - 30 °C (Table 1). However, sometimes the cold winter with the accompanying ground frost continues for a long time and in the summer the daytime can get very hot, though cooling at night. With the wind speed higher during the day and slackening at night, it usually leads to poor precipitation (Narmandakh 2009). These are the characteristics of a harsh continental climate, which promote the growth of particular vegetation. A maximum temperature of 44 °C was recorded in Khongor district of Darkhan-Uul province on 24 July 1999 (Batima et al. 2005). The average annual precipitation is 322 mm (Table 2). It falls as rain in the summer season and monthly rainfall reaches a maximum in August (Hilbig 1995; Natsagdorj 2000; Van Staalduinen & Werger 2007).

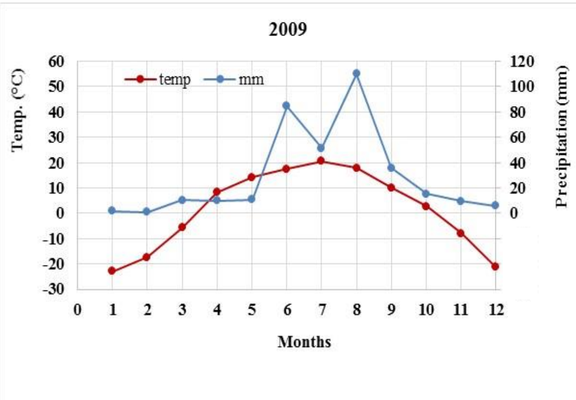
Table 1. *Average air temperature (°C) in Darkhan-Uul province for the years 2009 – 2012 (Data from Darkhan Meteorological station in Mongolia, 1984 – 2012).*

Years	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2009	-22.8	-17.3	-5.6	8.2	14.3	17.5	20.6	17.9	10.1	2.7	-8	-21.2
2010	-25.8	-24.9	-10.4	-1	12.5	19.5	22.1	17.5	12.3	3.5	-7.1	-20.5
2011	-27.4	-16.3	-6.6	7	9.9	19.8	19.7	19.2	9.9	4.8	-9.5	-21.8
2012	-26.4	-20.1	-6.1	4.4	12.5	17.2	19.4	17.2	13	2.2	-10.4	-19
Average 1984 – 2012	-22.1	-24.7	-6.9	3.9	11.9	17.6	20	17.5	10.5	-1.9	-9.3	-19.7

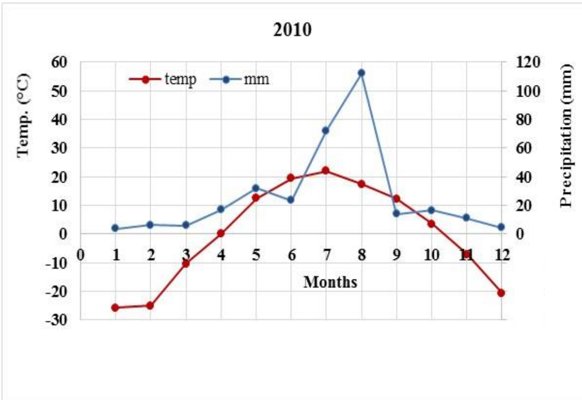
Table 2. *Average precipitation (mm) in Darkhan-Uul province for the years 2009 – 2012 (Data from Darkhan Meteorological station in Mongolia, 1984 – 2012).*

Years	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
2009	1.8	0.9	10.4	10	10.9	84.8	51.3	110	35.9	15.4	9.6	6.1	347.1
2010	4	6.2	6	17	32	23.7	72.3	112.2	14	16.5	11.3	4.4	319.6
2011	1.9	4.7	10.4	46.4	81.8	37.5	47.5	107.1	38.1	5.1	6.4	3.9	390.8
2012	3.4	0.7	0.7	12.8	51.9	96.8	73.8	95.8	8.1	25.1	11.7	5.8	386.6
Average 1984 – 2012	4.2	3.2	4.1	10.8	23.3	57.9	77.4	77.1	37.6	13.8	7.8	5.3	322.5

Darkhan-Uul province has over 260 sunny days per year (Narmandakh 2009). It has a borderline humid continental climate, close to the more typical subarctic climate of northern Mongolia, which is found at higher elevations near the Darkhan-Uul province; and it is only marginally wet enough to avoid qualifying as a semi-arid climate. A climate diagram for the study years 2009 – 2012 can be seen in Fig. 3. The diagrams are according to Walter and Lieth (1960), where temperature and precipitation are given on a 1:2 scale to determine the duration of drought (i.e. 20 mm precipitation corresponds to 10 °C air temperature).



A



B

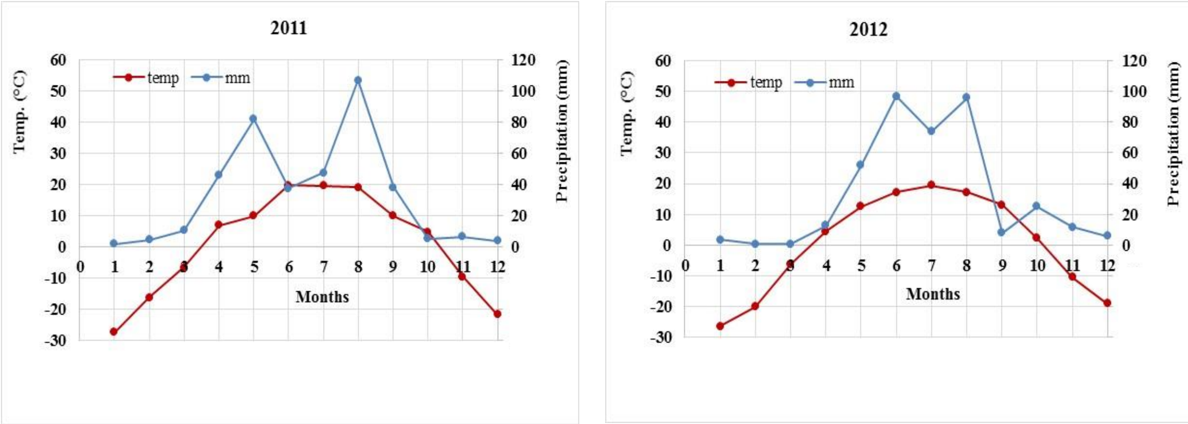


Fig. 3. *Climate diagrams for Darkhan-Uul province in Mongolia. Numerical values are taken from the Darkhan climate station for the period 2009 – 2012. When the precipitation curve blue line) is below the temperature curve (red line), there was a drought season and when it is above there was a humid season.*

3.4 Vegetation data

Vegetation data were sampled during the period August 1 – 7 in 2009 – 2012 for the study area of Khongor district in Darkhan-Uul province, Mongolia. Geobotanic recording was used for the vegetation analysis in order to study change in plant species dynamics in the vegetation cover (Fig. 4). At each of the eight sites selected (Table 3), five 1 m^2 plots (Fig. 4 – h) were laid out for measurements and the plant communities registered. These measurements were repeated each study year, except for the site Zeder B where measurements were made only in 2011 – 2012. The vegetation data sampled included total canopy cover, abundance of each vascular plant species, plant height and plant community types that were identified based on the 1 – 2 most dominant species. In addition, the variables altitude, soil type and landform were registered. At least two herbarium specimens were prepared for all species, including unidentified species and those belonging to difficult groups (e.g. *Fabaceae*). Canopy cover measurements followed Ramensky (1971) and species were identified following the Grubov (1982) classification. Scientific names of plants follow Grubov (2001). The location of sampling sites was recorded with a Global Positioning System (GPS) receiver (Table 3). A report of Darkhan-Uul province (Narmandakh et al. 2012) was used to find out how large an area particular plant communities covered and the size of the area was registered when possible.

Table 3. *Names and general condition of the study sites in Khongor district, Darkhan-Uul province in Mongolia.*

Sites name	**Vegetation type**	**Location**	**Altitude (m)**	**Soil type**	**Land form**	**Community names**
Ikh Darkhan	Mountain steppe	N 49°16'099 E 106°24'971	1239	Gravelly, brown soil	The nab of mountain	*Festuca lenensis*
Zeder_A	Mountain steppe	N 49°33'487 E 106°31'300	855	Gravelly, Brown soil	The bottom of hill	*Stipa sibirica – Galium verum*
Zeder_B	Mountain steppe	N 49°33'487 E 106°31'300	855	Brown soil	Slope	*Stipa sibirica – Lespedeza dahurica*

Deltiin Khundii	Steppe	N 49°32'108 E 106°13'313	705	Brown soil	Valley	*Stipa grandis – Cleistogenes squarrosa*
Ugluu Uul	Mountain steppe	N 49°12'269 E 106°11'144	1225	Brown soil	The bottom of mountain	*Stipa grandis*
Bichigt Khad	Mountain meadow	N 49°27'691 E 106°41'091	1029	Brown soil	Mountainside and slope	*Leymus chinensis – Bromus inermis*
Khawtgain Dawaa	Mountain meadow	N 49°14'477 E 106°39'797	1203	Dark-brown soil	Grass-plat	*Stipa sibirica – Achillea asiatica*
Temeen Olom	Meadow	N 49°33'542 E 106°15'228	720	Meadow brown soil	Riverside	*Potentilla anserina – Agropyron repens*

Plant species were classified as to ecological groups according to Ulziikhutag (1989) classification and the species were grouped into mesophytes, xerophytes, mesoxerophytes, xeropetrophytes, mesohalophytes and halophytes (Table 4).

Table 4. *Ecological groups of plant species in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	Description
Mesophytes	Mesophytic species mostly grow in humid condition and are adapted to environmental conditions with high humidity and enrichment of soils by mineral nutrient.
Xerophytes	Plants that are adapted to an arid environment. Many xerophytes have thin, narrow leaves, or even thorns, for minimizing water loss.
Mesoxerophytes	Mesohalophytes grow in moderate humid and moderate arid conditions.
Xeropetrophytes	Plants adapted to living in a dry arid habitat and growing in a gravelly soil.
Mesohalophytes	Plants growing in an environment having a moderate amount of moisture and saline soil.
Halophytes	Plants adapted to living in saline soil, along the seashore or in salt flats. Mangroves, salt-marsh grasses, and saltbushes are halophytes.

The Raunkiaer (1934) classification was used for the description of the plant species (Table 5).

Table 5. *Life forms of plant species in Khongor district, Darkhan-Uul province in Mongolia.*

Life forms	Description
Therophytes	Annual plants without persistent vegetative organs and propagated by seed during one favourable season.
Hemicryptophytes	Perennial plants whose buds are located at ground level.
Chamaephytes	Perennial plants whose buds are located close to the ground.
Geophytes	Perennial plants whose buds are set in the ground.
Phanerophytes	Perennial plants whose buds are located more than 50 cm above ground.

Fig. 4. *The study sites in Khongor district, Darkhan-Uul province in Mongolia. A: Ikh Darkhan, b: Zeder_A, c: Zeder_B, d: Deltiin Khundii, e: Ugluu Uul, f: Khavtgain Dawaa, g: Bichigt Khad, h: Temeen Olom. (Photos: B. Tserennadmid (a – c), N. Lkhagvasuren (d) and B. Odonchimeg (e – h)).*

3.5 Statistical analysis

Descriptive statistics were used to give an overview of the changes in canopy cover, species richness and vegetation height. The ordination multivariate technique was used to explore the overall vegetation patterns of the vascular plant species data and to detect changes in the vegetation between the study years. Ordination arranges objects (in this case study plots) along axes based on composition data (in this case plant species). It arranges plots with similar species composition close to each other and plots with different composition far from each other (Jongman et al. 1995). The ordination method detrended correspondence analysis (DCA) was used to analyse the data as recommended when the longest gradient exceeds 4.0 standard deviation units (the extent of species turnover) (Lepš & Šmilauer 2003). The ordinations were performed using the statistical program CANOCO for Windows, version 5.

4. RESULTS AND DISCUSSION

4.1 Floristic description of the study areas

A total of 141 species belonging to 104 genera and 29 families were recorded in 40 plots (see Appendix). Mean species richness per 1 m^2 plot ranged from 7 to 20 species, and averaged 13. The most dominating families were Asteraceae (19 %), Poaceae (16 %), Fabaceae (11 %), Rosaceae (9 %) and Ranunculaceae (6 %) (Table 6).

Table 6. *Number and proportions of genera and species belonging to different families in Khongor district, Darkhan-Uul province in Mongolia.*

Families name	Number of genera	%	Number of species	%
Equisetaceae	1	1	1	1
Poaceae	15	15	23	16
Cyperaceae	1	1	3	2
Liliaceae	3	3	5	4
Iridaceae	1	1	2	1
Polygonaceae	1	1	2	1
Chenopodiaceae	2	2	2	1
Caryophyllaceae	3	3	4	3
Ranunculaceae	6	6	9	6
Brassicaceae	3	3	3	2
Crassulaceae	2	2	2	1
Rosaceae	8	8	13	9
Fabaceae	11	11	16	11
Geraniaceae	1	1	2	1
Polygalaceae	1	1	1	1
Thymelaeaceae	1	1	1	1
Onagraceae	1	1	1	1
Apiaceae	4	4	4	3
Primulaceae	2	2	2	1
Plumbaginaceae	1	1	1	1
Gentianaceae	1	1	1	1
Boraginaceae	1	1	1	1
Lamiaceae	5	5	5	4
Scropulariaceae	4	4	4	3
Plantaginaceae	1	1	1	1
Rubiaceae	1	1	3	2
Dipsacaceae	1	1	1	1
Campanulaceae	2	2	2	1
Asteraceae	20	19	26	18

Total	104	100	141	100

According to Raunkiaer (1934) the life forms hemicryptophytes (70%), followed by the geophytes (15%) and the therophytes (8%), dominated in the study areas. According to the Ulziikhutag (1989) division into ecological groups most species in the study sites were mesophytes (38%), xerophytes (26%) and mesoxerophytes (23%) (Table 7).

Table 7. *Eco- and biomorphological spectrum of the plants in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	No.	%	Life forms	No.	%	Functional groups	No.	%
Mesophytes	53	38	Phanerophytes	3	2	Shrubs	3	2
Mesoxerophytes	32	23	Chamaephytes	7	5	Sub shrubs	7	5
Xerophytes	36	26	Hemicryptophytes	99	70	Perennial plants	120	85
Xeropetrophytes	13	9	Geophytes	21	15			
Halophytes	3	2	Therophytes	11	8	Annual plants	11	8
Mesohalophytes	4	3						
Total	**141**	**100**		**141**	**100**		**141**	**100**

4.2 Vegetation dynamics

Variation in canopy cover between sites and within sites for the 2009 – 2012 is shown in Figure 5. The highest canopy cover was observed in Temeen Olom and Hawtgain Dawaa with mean canopy cover ranging between 75 – 80% and 72 – 75%, respectively. The lowest canopy cover was observed in Ikh Darkhan with a mean canopy ranging from 35 to 38%.

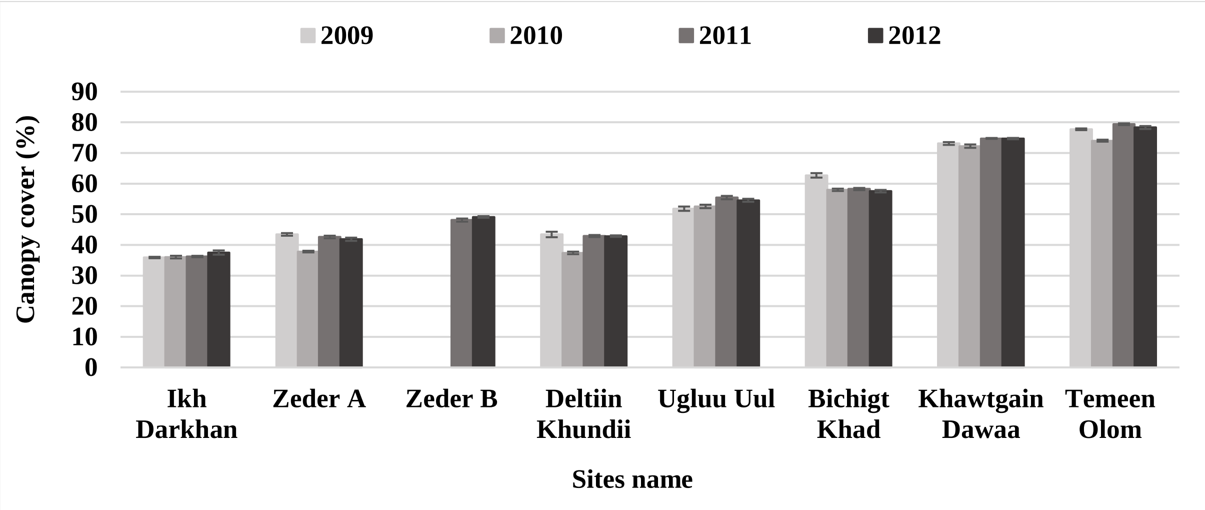


Fig. 5. *Change of mean canopy cover (± 1 SE) between sites and within sites from 2009 – 2012 in Khongor district, Darkhan-Uul province in Mongolia.*

The differences in canopy cover between study years were small at all sites. There were three sites (Zeder A, Deltiin Khundii and Temeen Olom), however, where the canopy cover was notably smallest in 2010, which might be connected to the low precipitation that year (Table 2). Variation (shown as standard errors) between the five plots each year was low in all cases.

The results showed that the dry areas had less canopy cover than the more humid one as the cover at the study sites ranged from 35 – 38% in the mountain steppe community at Ikh Darkhan up to 75 – 80% cover in the meadow community at Temeen Olom (Fig. 5).

The changes in plant species richness in the 1 m^2 plots between sites and years is shown in Figure 6. The highest richness was observed in Bichigt Khad, Ugluu Uul and Khawtgain Dawaa with mean species richness of about 19 species. Deltiin Khundii site had the lowest richness with only nine species (means for the years 2009 – 2012).

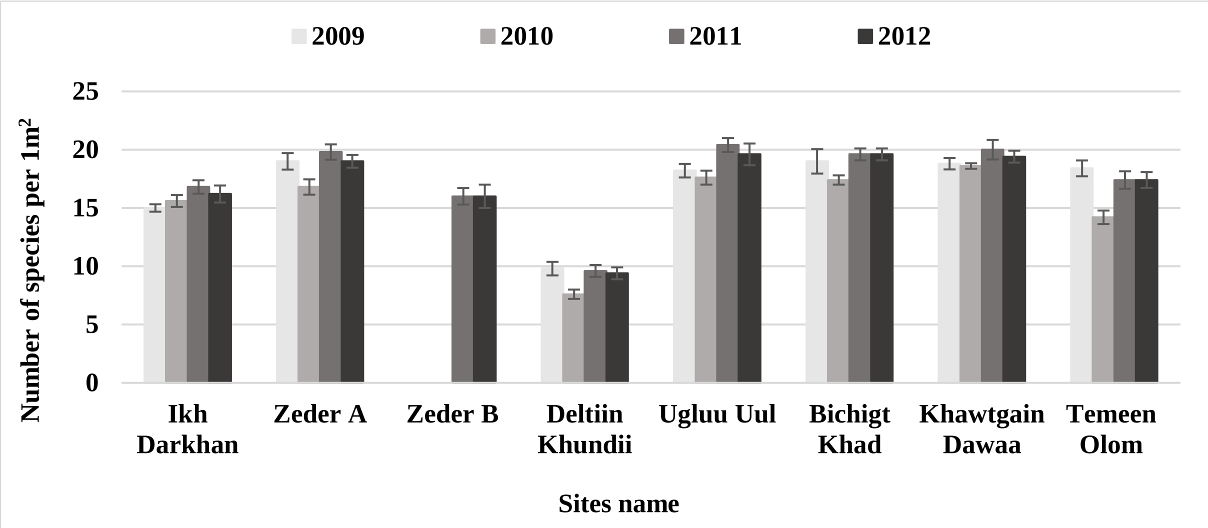


Fig. 6. *Variation in mean floristic richness (± 1 SE) between sites and within sites from 2009 – 2012 in Khongor district, Darkhan-Uul province in Mongolia.*

The differences in species richness between study years were small at all sites. There were five sites (Zeder A, Deltiin Khundii, Ugluu Uul, Bichigt Khad and Temeen Olom), however, where the species richness was smallest in 2010 compared to the other years. Four sites had the highest species richness in 2011 (Fig. 6). In Temeen Olom, for example, there were 18 species documented in 2009, 14 species in 2010 and 17 species in 2011 and 2012. This might also be connected to the amount of precipitation, which dropped that year. Based on the weather information from Darkhan-Uul province the precipitation during the growing season (April to August), the average was 267 mm in 2009, lowest in 2010 or 257 mm, 320 mm in 2011 and 331 mm in 2012 (Table 2).

Variation in plant height between sites and years is shown in Figure 7. The greatest height was observed in Bichigt Khad (50 – 52 cm) and Khawtgain Dawaa (50 – 52 cm). The lowest height was recorded in Ikh Darkhan (14 – 16 cm) and Temeen Olom (19 – 22 cm).

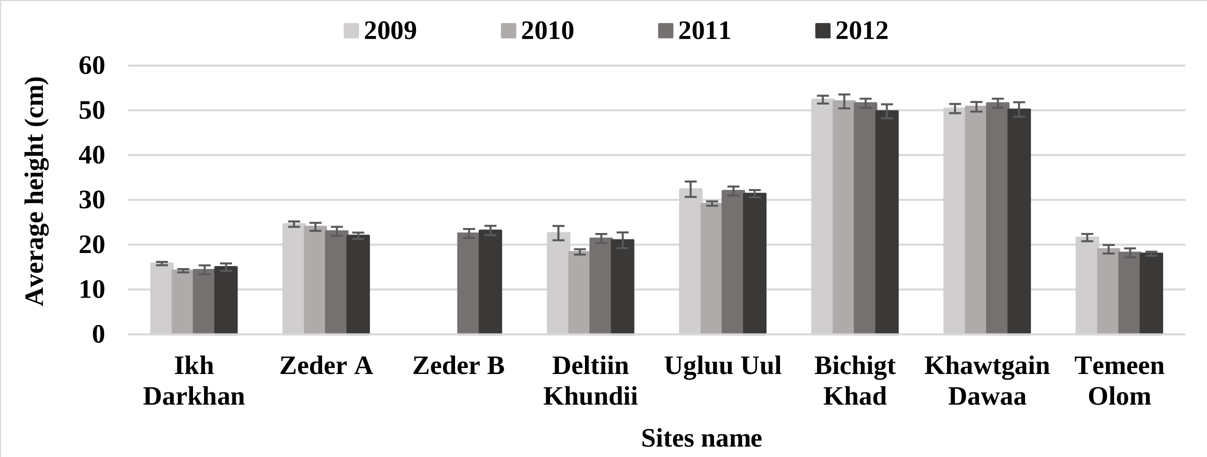


Fig. 7. *Change of mean vegetation height (± 1 SE) between sites and within years between sites in 2009 – 2012 in Khongor district, Darkhan-Uul province in Mongolia.*

The plant height was similar between years within sites (Fig. 7). At the three sites Bichigt Khad, Khawtgain Dawaa and Temeen Olom the conditions were more humid. Therefore, species richness and canopy cover were high compared to the dry sites. However, the plant height was low in Temeen Olom. This was probably connected to grazing since in 2010 the proportion of the grazing resistant species such as *Leymus chinensis*, *Chenopodium aristatum* cover had increased and species such as *Agropyron repens, Alopecurus brachystachyus, Geranium pratense, Inula britannica, Poa pratensis* and *Medicago falcata* had decreased.

Overall, the results showed a large variation between study sites in the vegetation parameters of canopy cover, species richness and vegetation height, but minor changes in cover, richness and height during the four study years from 2009 to 2012.

4.3 Identification of the patterns of vegetation

The DCA ordination of the species composition data in 40 plots including 141 vascular plant species is presented in Figure 8. A large part of the total variation, or 39.8%, was explained by the first two axes and the gradient length of the first axis was 8.37. Axis 1 discriminated between steppe communities near the base of the axis, and meadow communities near the far end of the axis. Between these communities, the DCA ordination situated the mountain meadows at Khawtgain Dawaa and Bichigt Khad. Axis 1 with the highest eigenvalue (0.88), variance (23.37%) and gradient length 8.37 explained most of the variation in the vegetation data and reflected the underlying humidity and geomorphology gradients. Additionally, axis 1 ranged from having xerophytes like *Festuca lenensis*, *Potentilla acaulis* and *Cleistogenes squarrosa;* and xeropetrophytes such as *Arenaria capillaris*, *Potentilla sericea* and *P. leucophylla*at its extreme left; to having mesophytes like *Potentilla anserina*, *Agropyron repens* and *Ranunculus scleratus*; and mesohalophytes like *Halerpestis salsuginosa*, *Glaux maritima* and *Hordeum brevisubulatum* at its extreme right. Between them were mesoxerophytes that included *Potentilla tanacetifolia*, *Stipa sibirica*, *Galium verum*, *Shizonepeta multifida*. (Fig. 9).

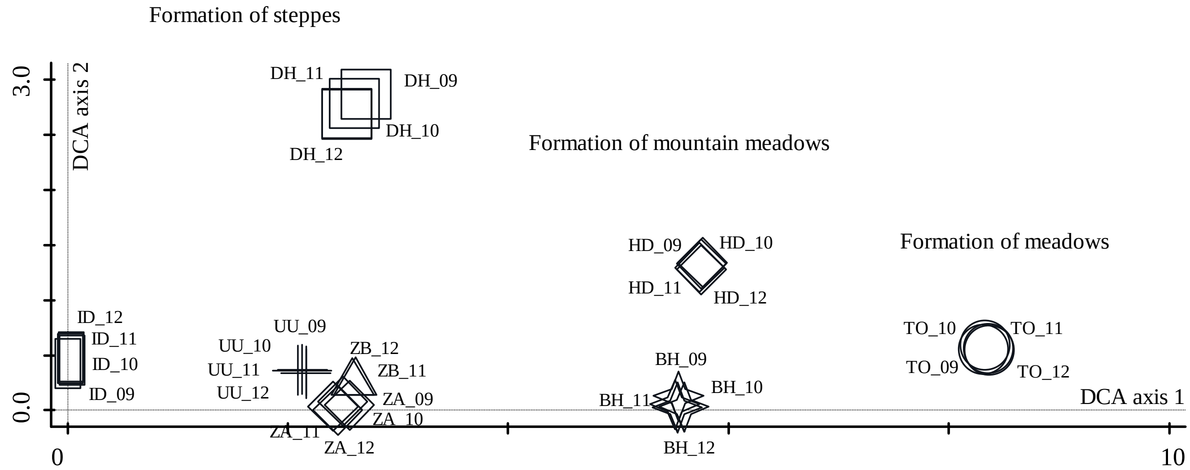


Fig. 8. *DCA ordination diagram of all plots for the years 2009 – 2012 from the eight study sites in Khongor district, Darkhan-Uul province in Mongolia. Ordination axes 1 and 2 are shown. The different symbols represent different plant communities and the letters represent the site name and year of observation of plots. (Such as ID_09: vegetation composition in plots from Ikh Darkhan Uul for the year 2009).*

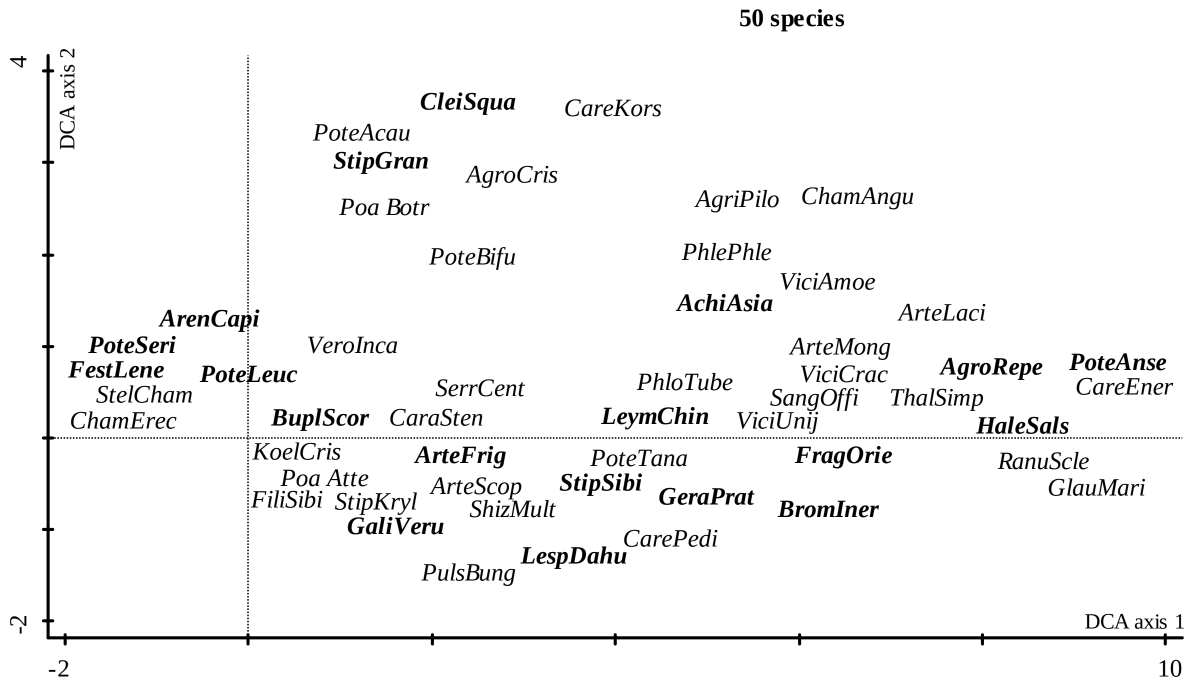


Fig. 9. *DCA ordination diagram showing vascular plant species in Khongor district, Darkhan-Uul province in Mongolia on DCA axes 1 and 2. All species with more than four occurrences are shown (50 species). The bold italic letters demonstrate the dominant species. Abbreviation and the full names of the species are given in the Appendix.*

Overall, the DCA ordination revealed the grouping of eight phytosociological plant communities based on vegetation composition. It positioned the steppe communities to the left of the diagram and the meadows to the right (Fig. 8). It showed also that the three mountain steppe communities, Zeder_A, Zeder_B, Ugluu Uul, were the most similar communities, as the plots from these communities lie very close in the ordination space. The ordination showed also that the most different communities were the mountain steppe at Ikh Darkhan and the meadow at Temeen Olom. At those two sites, almost no species were common between them as species turnover was more than eight SD units (see also the Appendix). This is because at those two sites ecological conditions and vegetation composition were very different. For example, *Festuca lenensis* community is a steppe dominated by grass established on the hills of Ikh Darkhan Mountain where the soil is gravelly and brown coloured and dominated by xerophytes (47 %) and xeropetrophytes (21%), which reveal the arid condition of the community. The *Potentilla anserina – Agropyron repens* community is a meadow dominated by grass established on the riverside of the Temeen Olom, the soil type is brown loamy and the community is dominated by mesophytes (65%). An intermediate position in the ordination space set the plots apart from the mountain meadow communities on the hill slopes (Fig. 8).

4.4 Plant communities of the steppe formations

The DCA was run in the second stage with plots including 84 species recorded on the steppe formations to focus on changes between study years. Axis 1, which presented the highest values of eigenvalue, variance and gradient length, explains much of the variation (Table 8). As shown by the DCA graph, five plant communities were discriminated: *Festuca lenensis* (FELE_Forb); *Stipa sibirica – Galium verum* (STSI_Forb); *Stipa grandis* (STGR_Forb); of *Stipa sibirica – Lespedesa dahurica* (STSI-LEDH) and *Stipa grandis – Cleistogenes squarrosa* (STGR_CLSQ) (Fig. 10)

Table 8. *Eigenvalues, cumulative variance and gradient of the 4 axis of the DCA.*

Axes	1	2	3	4
Eigenvalues	0.69	0.22	0.03	0.01
Cumulative explained variation	36.32	47.63	48.98	49.66
Gradient length	3.77	2.44	0.71	0.61

There were only small changes in species composition between different study years and without any particular direction of change (Fig. 10). All plant communities showed similar small changes between years.

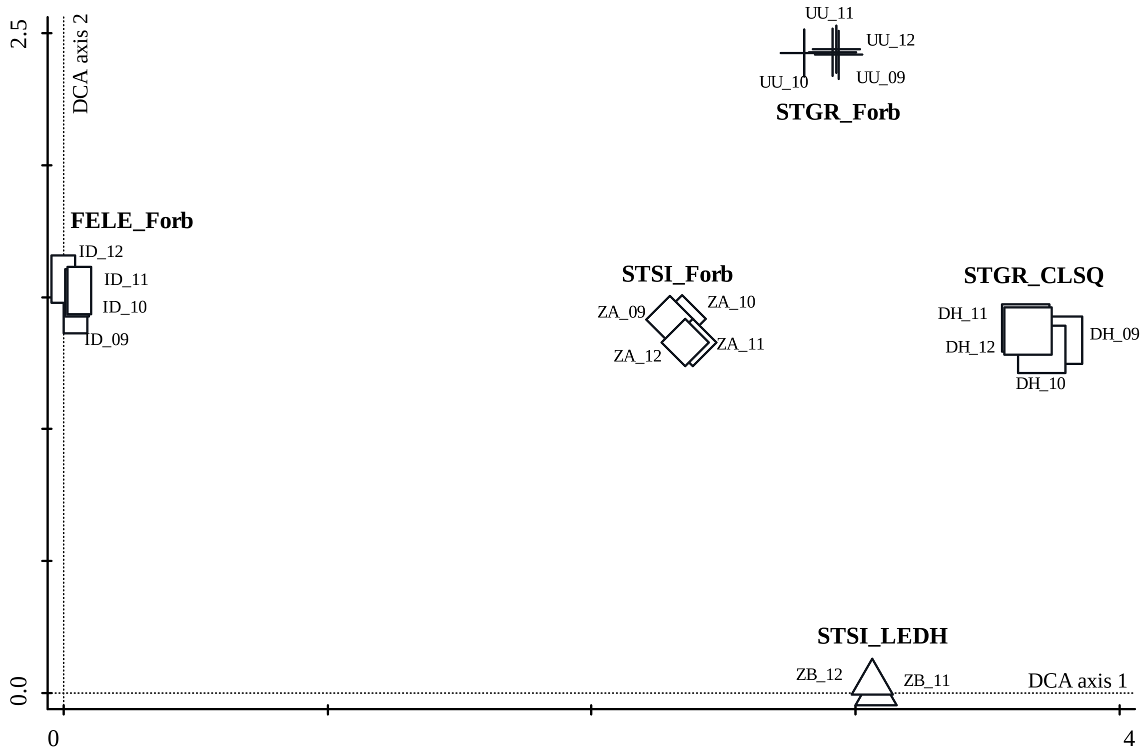


Fig. 10. *DCA ordination diagram of the plots from steppe communities in Khongor district, Darkhan-Uul province in Mongolia for 2009 – 2012. Ordination axes 1 and 2 are shown. The different symbols represent different plant communities and the letters represent the site name and year of observation of plots. (Such as ID_09: vegetation composition in plots from Ikh Darkhan Uul for the year 2009). See text for explanation of abbreviations for the plant communities.*

4.5 Plant communities of the meadow formations

Finally, the DCA was implemented in the third stage with the plots including 86 species recorded on the meadow formations. Axis 1, which presented the highest values of eigenvalue, variance and gradient length, explains much of the variation (Table 9). The graph revealed three plant communities, including *Stipa sibirica – Achillea asiatica* (STSI_Forb) community; *Leymus chinensis – Bromus inermis (*LECH_BRIN_Forb); and *Potentilla anserina – Agropyron repens* (Forb_grass_sedge) (Fig. 11).

Table 9. *Eigenvalues, cumulative variance and gradient of the 4 axis of the DCA.*

Axes	1	2	3	4
Eigenvalues	0.78	0.20	0.03	0.02
Cumulative explained variation	58.41	72.98	75.20	76.47
Gradient length	3.89	2.06	1.24	0.61

The graph (Fig. 11) showed that there were only small changes in species composition between years and without any particular direction of change. However, one plant community (BH: Bichigt Khad) showed somewhat larger changes between years compared to the others.

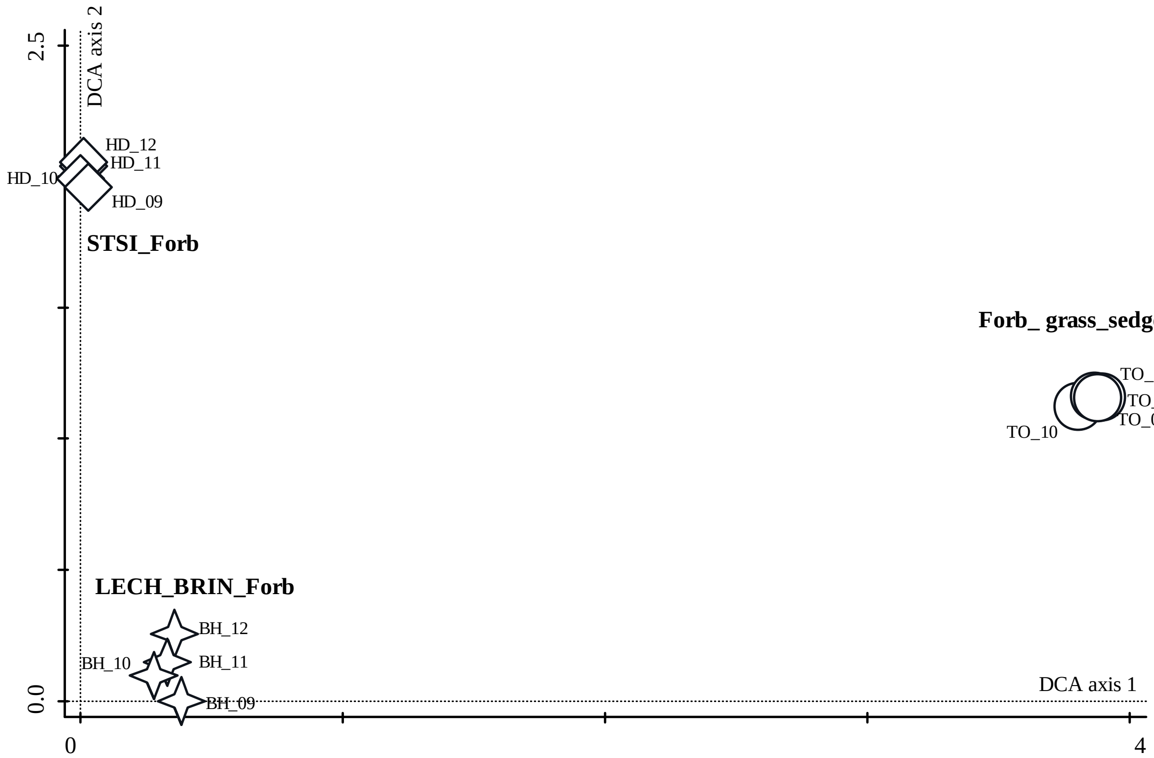


Fig. 11. *DCA ordination diagram of the plots from meadow communities in Khongor district, Darkhan-Uul province in Mongolia for 2009 – 2012. Ordination axes 1 and 2 are shown. The different symbols represent different plant communities and the letters represent the site name and year of observation of plots. (Such as TO_09: vegetation composition in plots from Temeen Olom for the year 2009). See text for explanation of abbreviations for the plant communities.*

4.6 Phytosociological description of the plant communities

4.6.1 *Festuca lenensis* community

The *Festuca lenensis* community is a steppe dominated by grass established on the hills of the Ikh Darkhan Mountain, 1239 meters above sea level. Ikh Darkhan Mountain is located between the Khongor and Shariin Gol districts. The community covered a total of 1756.4 ha but 414.6 hectares of this community occurred in rocky terrain on mountainsides and tops. The *Festuca lenensis* mountain steppe can be recognized by the blue colour of the short bunchgrass *Festuca lenensis*, which dominates the vegetation along with *Festuca lenensis*, *Stipa grandis*, *Filifolium sibiricum* and *Thymus gobicus*. Low growing species such as *Chamaerhodos altaica*, *Androsace incana* and *Arenaria capillaris* are characteristic and differentiate this community from the moister *Festuca sibirica* mountain steppe (Staalduinen & Werger 2005). On the hills where the soil is gravelly and brown in colour, there was a total of 38 species recorded in five plots, with an average of 29.5 ± 0.5, ranging from 29 to 30 species. While the xerophytes (47%) and the mesoxerophytes (32%) dominated the ecological spectrum of the community, hemicryptophytes (74%) dominated the biological spectrum of Raunkiær's classification (Table 10). Analysis of the ecological and biomorphological spectrum shows the dominance of xerophytes that reveals the arid condition of the community.

Table 10. *Eco- and biomorphological spectrum of the community of* Festuca lenensis *in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	No.	%	Life forms	No.	%	Functional groups	No.	%

Xerophytes	18	47	Phanerophytes	1	3	Shrubs	1	3
Mesoxerophytes	12	32	Chamaephytes	4	11	Sub shrubs	4	11
Xeropetrophytes	8	21	Hemicryptophytes	28	74	Perennial plants	30	79
			Geophytes	2	5			
			Therophytes	3	8	Annual plants	3	8
Total	**38**	**100**		**38**	**100**		**38**	**100**

4.6.2 *Stipa sibirica – Galium verum* community

The *Stipa sibirica – Galium verum* community covered 9399 ha and was dominated by *Stipa sibirica, Galium verum, Carex pediformis, Artemisia frigida* and *Veronica incana*. The community occurred on the hills of Zeder where the soil is a little gravelly and brown coloured. There was a total of 41 species recorded in five plots with a mean of 30.75 ± 1.47, ranging from 29 to 33 species. While the xerophytes (42%) and the mesoxerophytes (42%) dominated the ecological groups of the community, hemicryptophytes (66%) and perennial plants (83%) dominated the biological spectrum of Raunkiær's classification (Table 11). Analysis of the ecological and biomorphological spectrum shows the dominance of xerophytes that reveal the arid condition of the community.

Table 11. *Eco- and biomorphological spectrum of the community of* Stipa sibirica – Galium verum *in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	**No.**	**%**	**Life forms**	**No.**	**%**	**Functional groups**	**No.**	**%**
Xerophytes	17	42	Phanerophytes	2	5	Shrubs	2	5
Mesoxerophytes	17	42	Chamaephytes	3	7	Sub shrubs	3	7
Xeropetrophytes	4	10	Hemicryptophytes	27	66	Perennial plants	34	83
Mesophytes	3	7	Geophytes	7	17			
			Therophytes	2	5	Annual plants	2	5
Total	**41**	**100**		**41**	**100**		**41**	**100**

4.6.3 *Stipa sibirica – Lespedeza dahurica* community

Stipa sibirica – Lespedeza dahurica community occurs on tops and slopes of low hills of Zeder. The most dominant species are *Stipa sibirica, Lespedeza dahurica* and *Galium verum.* The soil type is brown and medium clay loamy, with a total of 24 species recorded in five plots and a mean of 23.5 ± 0.5, ranging from 23 to 24. While the xerophytes (54%) and the mesoxerophytes (33%) dominated the ecological spectrum of the community, hemicryptophytes (79%) and perennial plants (92%) dominated the biological spectrum of Raunkiær's classification (Table 12). Analysis of the ecological and biomorphological spectrum shows the dominant of xerophytes that reveal the arid condition of the community.

Table 12. *Eco- and biomorphological spectrum of the community of* Stipa sibirica – Lespedeza dahurica *in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	**Nr**	**%**	**Life forms**	**Nr**	**%**	**Functional groups**	**Nr**	**%**
Xerophytes	13	54	Phanerophytes	1	4	Shrubs	1	4
Mesoxerophytes	8	33	Chamaephytes	1	4	Sub shrubs	1	4
Xeropetrophytes	2	8	Hemicryptophytes	19	79	Perennial plants	21	92
Mesohalophytes	1	4	Geophytes	3	13			
			Therophytes	-	-	Annual plants	-	-
Total	**24**	**100**		**24**	**100**		**24**	**100**

4.6.4 *Stipa grandis – Cleistogenes squarrosa* community

The areas of Mongolian steppe examined were dominated by feather grass of the genus *Stipa, Cleistogenes squarrosa*, *Artemisia frigida*, *Agropyron cristatum, Koeleria cristata* and *Carex duriuscula* were also common (Cheng et al. 2008). The community is a steppe dominated by grass established on the plain of the Deltiin khundii, near Orkhon and Darkhan districts, at 705 meters above sea level. The most dominant species were *Stipa sibirica, Cleistogenes squarrosa* and occurred with *Caragana microphylla, Carex Korschinskyi* and *Potentilla acauls.* The soil type was brown, sandy loamy with a total of 23 species recorded in five plots and a mean of 16.25 ± 2.48, ranging from 12 to 18. While the xerophytes (78%) and the mesoxerophytes (13%) dominated the ecological spectrum of the community, hemicryptophytes (52%) and perennial plants (67%) dominated the biological spectrum of Raunkiær's classification (Table 13).

Table 13. *Eco- and biomorphological spectrum of the community of* Stipa grandis – Cleistogenes squarrosa *in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	No.	%	Life forms	No.	%	Functional groups	No.	%
Xerophytes	18	78	Phanerophytes	2	9	Shrubs	2	9
Mesoxerophytes	3	13	Chamaephytes	3	13	Sub shrubs	3	13
Xeropetrophytes	1	4	Hemicryptophytes	12	52	Perennial plants	16	70
Halophytes	1	4	Geophytes	4	17			
			Therophytes	2	9	Annual plants	2	9
Total	**23**	**100**		**23**	**100**		**23**	**100**

4.6.5 *Stipa grandis* community

The *Stipa grandis* community is a steppe dominated by grass established on the plain of Ugluu Uul, near Khongor district, at 1313 meters above sea level. The community covered 8672 hectares dominated by *Stipa grandis* and the subdominant species were *Bupleurun scorzonerifolium, Artemisia frigida.* The soil type was brown and loamy clay, with a total of 40 species recorded in five plots and a mean of 33 ± 2.45, ranging from 29 to 35. While the xerophytes (53%) and the mesoxerophytes (40%) dominated the ecological spectrum of the community, hemicryptophytes (70%) and perennial plants (88%) dominated the biological spectrum of Raunkiær's classification (Table 14).

Table 14. *Eco- and biomorphological spectrum of the community of* Stipa grandis *in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	No.	%	Life forms	No.	%	Functional groups	No.	%
Xerophytes	21	53	Phanerophytes	1	3	Shrubs	1	3
Mesoxerophytes	16	40	Chamaephytes	2	5	Sub shrubs	2	5
Xeropetrophytes	2	5	Hemicryptophytes	28	70	Perennial plants	35	88
Mesohalophytes	1	3	Geophytes	7	18			
			Therophytes	2	5	Annual plants	2	5
Total	**40**	**100**		**40**	**100**		**40**	**100**

4.6.6 *Leymus chinensis – Bromus inermis* community

The *Leymus chinensis – Bromus inermis* community is a mountain meadow dominated by grass established on the slope of the hills and plain of Bichigt Khad, at 1100 – 1400 meters above sea level. The community covered 7166 hectares dominated by *Leymus chinensis, Bromus inermis* and the subdominant species were *Geranium pratense, Fragaria orientalis, Vicia cracca, V. unijuga.* The soil type was brown and there was a total of 48 species recorded in five plots with a mean of 34.25 ± 1.29, ranging from 33 to 36. While the mesophytes (67%) and the mesoxerophytes (29%) dominated the ecological spectrum of the community, hemicryptophytes (81%) and perennial plants (96%) dominated the biological spectrum of Raunkiær's classification (Table 15).

Table 15. *Eco- and biomorphological spectrum of the community of* Leymus chinensis – Bromus inermis *in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	No.	%	Life forms	No.	%	Functional groups	No.	%
Mesophytes	32	67	Phanerophytes	-	-	Shrubs	-	-
Mesoxerophytes	14	29	Chamaephytes	1	2	Sub shrubs	1	2
Xerophytes	2	4	Hemicryptophytes	39	81	Perennial plants	46	96
			Geophytes	7	15			
			Therophytes	1	2	Annual plants	1	2
Total	**48**	**100**		**48**	**100**		**48**	**100**

4.6.7 *Stipa sibirica – Achillea asiatica* community

The *Stipa sibirica – Achillea asiatica* community is a mountain meadow dominated by grass established on the slope of Khawtgain Dawaa hills occurring south and east of Khongor district near a birch-pine forest. The community was dominated by *Stipa sibirica, Achillea asiatica* and the subdominant species were *Chamaenerion angustifolium, Phlomis tuberosa, Fragaria orientalis.* The soil type was brown with a total of 35 species recorded in five plots with a mean of 31.5 ± 1.8, ranging from 29 to 34. While the mesophytes (74%) and the mesoxerophytes (23%) dominated the ecological spectrum of the community, hemicryptophytes (77%) and perennial plants (94%) dominated the biological spectrum of Raunkiær's classification (Table 16).

Table 16. *Eco- and biomorphological spectrum of the community of* Stipa sibirica – Achillea asiatica *in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	No.	%	Life forms	No.	%	Functional groups	No.	%
Mesophytes	26	74	Phanerophytes	1	3	Shrubs	1	3
Mesoxerophytes	8	23	Chamaephytes	-	-	Sub shrubs	-	-
Mesohalophytes	1	3	Hemicryptophytes	27	77	Perennial plants	33	94
			Geophytes	6	17			
			Therophytes	1	3	Annual plants	1	3
Total	**35**	**100**		**35**	**100**		**35**	**100**

4.6.8 *Potentilla anserina – Agropyron repens* community

The *Potentilla anserina – Agropyron repens* community is a meadow found on the riverside of the Temeen Olom and occurs as well along the Shariin Gol, Orkhon, Khuitnii, Zulzaga rivers. The community covered 11978 ha and was mostly dominated by *Potentilla anserina* but the subdominant species were *Agropyron repens* and *Halerpestis salsuginosa.* The soil type was brown loamy, with a total of 37 species recorded in five plots with a mean of 30.2 ± 1.9, ranging from 27 to 32. While the mesophytes (65%) and the mesoxerophytes (13%) dominated the ecological spectrum of the community, hemicryptophytes (62%) and perennial plants (82%) (Table 17) dominated the biological spectrum of Raunkiær's classification.

Table 17. *Eco- and biomorphological spectrum of the community of Potentilla anserina – Agropyron repens in Khongor district, Darkhan-Uul province in Mongolia.*

Ecological groups	No.	%	Life forms	No.	%	Functional groups	No.	%
Mesophytes	24	65	Phanerophytes	-	-	Shrubs	-	-
Mesoxerophytes	5	13	Chamaephytes	-	-	Sub shrubs	-	-
Mesohalophytes	3	8	Hemicryptophytes	23	62	Perennial plants	30	82
Halophytes	3	8	Geophytes	7	18			
Xerophytes	2	5	Therophytes	7	18	Annual plants	7	18
Total	**37**	**100**		**37**	**100**		**37**	**100**

The fact that these eight communities described here differed in floristic composition could represent a gradient of soil moisture depending on the relative elevation and soil types (Table 3; Fig. 4, 8 and 9). Meso-, xero- and mesoxerophytes dominated the study sites or about 75% of the species. The occurrence of these ecological groups reveals the semi-arid condition of the study areas. Overall, the vegetation communities exhibited little change in the four study years (Fig. 8 – 11). There were, however, some changes at Deltiin Khundii, Zeder A and Temeen Olom where canopy cover and species richness was lower in 2010 than in the other years. However, although the vegetation communities did not change markedly, some species in the canopy cover changed, most probably connected to the precipitation during the growing season. For example, the *Stipa grandis – Cleistogenes squarrosa* community's total vegetation cover was 43% in 2009, 37% in 2010, 43%, in 2011 and in 2012, 43% in Deltiin Khundii site (Fig. 5). In addition, the dominant species (*Stipa grandis, Cleistogenes squarrosa*) cover was lowest in 2010, compared to the other years. Moreover, compared to other years of the study, the cover of *Potentilla bifurca* and *Veronica incana* increased in 2011 and became the subdominant species in the community that could have been caused by overgrazing. According to Chognii's (2001) research, the community state dynamics of mountain steppe rangeland tightly depends on the canopy cover, yield and life form of the key species of a particular community. Therefore, any community shift from one type to another is based on a species composition shift where a certain species cover and abundance decreases while another species cover and abundance increases. The results showed that the species number in the steppe community did not decrease much due to the xerophytes' resistance to grazing impact. Many studies have shown negative changes in vegetation conditions in recent years in Darkhan-Uul province (Batjargal 1997; Chognii 2001; Batkhishig 2012), but in this study the measured vegetation parameters of canopy cover, species richness, vegetation height and vascular plant species composition showed only minor changes in 2009 to 2012. However, the study period was only for four years, which is probably too short a time for grazing effects to appear.

5. CONCLUSIONS

The Mongolian Daurian steppe, where Darkhan-Uul province is located, is an ecologically important area and the study of its natural environment gives valuable information about the conditions of the land. In this research a total of 141 plant species were recorded in 40 plots in the study. The most dominant families were Asteraceae (19%), Poaceae (16%), Fabaceae (11%), Rosaceae (9%) and Ranunculaceae (6%) and mean species richness per 1 m^2 plot ranged from 7 to 20 species with an average of 13. Regarding ecological groups, most species in the study sites belonged to mesophytes (38%), xerophytes (26%) and mesoxerophytes (23%). These same groups, apart from mesoxerophytes, are dominant in Mongolia as they fit well with the climate, soil and geography of this area. The domination of xerophytes and mesoxerophytes is a strong indicator of steppe and mountain steppe, which are abundant in this area.

The assessment of the vegetation conditions and dynamics of eight different plant communities in Darkhan-Uul province revealed variation between study sites in canopy cover, species richness and vegetation height, but minor changes in cover, richness and height between the four study years of 2009 to 2012. A DCA ordination revealed groupings of eight phytosociological communities based on vegetation composition. The observed changes in species composition in the eight plant communities between study years were small and no trends were observed in the direction of change. The minor changes observed in species richness between study years could possibly be connected to the low precipitation in 2010. The vegetation parameters measured in this study did not show signs of a degrading condition of the plant communities observed.

ACKNOWLEDGEMENTS

I am extremely grateful to many people for helping me during this research work. First, I would like to extend my sincere thanks to my supervisors Járngerður Grétarsdóttir and Gróa Valgerður Ingimundardóttir, for their encouragement, enthusiasm and good comments. In addition, they have contributed to my statistical data analysis and ideas to the whole of my writing process.

I am also extremely grateful to my Mongolian supervisors Dariimaa Shagdar (Sc.D.) and Oyuntsetseg Chultem (Sc.D), for their invaluable guidance throughout the entire period of research during my field work in Mongolia.

I would like to express my gratitude to the UNU-LRT programme and especially to Programme Director Hafdís Hanna Ægisdóttir, Deputy Programme Director Berglind Orradóttir, Specialist, personal coaching by Brita Kristina Berglund and Office Manager Halldóra Traustadóttir. Thank you very much, all of you, for the opportunity accorded to us to attend the six-month training programme on Land Restoration and Sustainable Land Management**.**

I would like to thank all of my UNU-LRT-2013 fellows for sharing knowledge and experience during the last six months when we were together and developed an unforgettable friendship. Especially I am very grateful to Idrissa Soumana for his contribution and helpful advice during my project work.

My warm thanks go to all of the lecturers and people who shared their knowledge and experiences and helped me during this programme and who helped me as well on field trips and with the ideas that are the background for this report.

REFERENCES

Batima, P., and D. Dagvadorj. 1998. *Climate Change and its Impacts in Mongolia*. JEMR Publishing, Ulaanbaatar.

Batima, P., L. Natsagdorj, P. Gombluudev, and B. Erdenetsetseg. 2005. *Observed Climate Change in Mongolia*. New York: AIACC Working Paper.

Batjargal, Z. 1997. *Desertification in Mongolia. RALA Report No. 200,* www.forum.mn/res_mat/Desertification%20in%20Mongolia.pdf [accessed on 31 July 2013].

Batkhishig, B. 2012. *Community-based rangeland management and social-ecological resilience of rural Mongolian communties.* Colorado State University, Fort Collins CO. USA.

Bolortsetseg, B., S. Bayasgalan, B. Dorj, L. Natsagdorj, and G. Tuvaansuren. 2000. Impacts on agriculture. *Climate Change and its Impacts in Mongolia***:**97-199.

Cheng, Y., T. Tsendeekhuu, N. Narantuya, and T. Nakamura. 2008. Phytosociological study of steppe vegetation in Mongolia. *Grassland Science* **54:**107-116.

Chognii, O. 2001. *The fFature of Regeneration Grassland with Using Nomadic Grazing in Mongolia*. Mongol sudlal, Ulaanbaatar.

Dariimaa, S., B. Altantsetseg, and B. Tserennadmid. 2009. Classification, distribution and ecology of vascular plant flora in Darkhan-Uul aimag, Mongolia. MSUE. *Treatise of Natural Sciences* **2:**98-109.

Dashnyam, B. 1979. *Flora and Vegetation of Eastern Mongolia*. Ulsiin Khevleliin Gazar, Ulaanbaatar.

Desyatkin, B. L. 1936. *Grasslands at the Confluence of the Orkhon and Selenga Rivers within the MPR.* Mongolian Commissioners of the USSR. Leningrad.

Dorjgotov, D. 2003. *Soils of Mongolia.* Admon, Ulaanbaatar.

Grubov, V. I. 1982. *Key to the Vascular Plants of Mongolia*. NAUKA, Leningrad.

Grubov, V. I. 2001. *Key to the Vascular plants of Mongolia.* NAUKA, Leningrad.

Gunin, P., and E. Vostokova. 1995. *Ecosystems of Mongolia (map)*. Published by the Joint Russian-Mongolian Complex Biological Expedition with assistance from UNEP, Moscow.

Gunin, P. D., E. A. Vostokova, N. I. Dorofeyuk, P. E. Tarasov, and C. C. Black. 1999. *Vegetation Dynamics of Mongolia*. Kluwer Academic Publishers, London.

Hilbig, W. 1995. *The Vegetation of Mongolia*. SPB Academic Publishing, Amsterdam.

Jigjidsuren, S., and D. A. Johnson. 2003. *Forage Plants of Mongolia*. Admon, Ulaanbaatar.

Jongman, R. H., C. J. Ter Braak, and O. F. Van Tongeren. 1995. *Data Analysis in Community and Landscape Ecology*. Cambridge University Press.

Lepš, J., and P. Šmilauer. 2003. *Multivariate Analysis of Ecological Data Using CANOCO.* Cambridge University Press.

Marin, A. 2010. Riders under storms: contributions of nomadic herders' observations to analysing climate change in Mongolia. *Global Environmental Change* **20:**162-176.

Mongolian National Commission for UNESCO/World Heritage Centre, 2013. URL whc.unesco.org/en/tentativelists/5779/ [accessed on 31 July 2013]

Mongolian Third National Report, 2006. URL www.cbd.int/doc/world/mn/mn-nr-03-en.doc [accessed on 31 July 2013]

MSRM [Mongolian Society for Range Management] and Sadc [Swiss Agency for Development and Cooperation]. 2010. *Livelihood Study of Herders in Mongolia.* Selengepress Co.,Ltd, Ulaanbaatar.

Narmandakh, A. 2009. *Land Use Planning of Darkhan-Uul Province*. Sergelen press, Darkhan.

Narmandakh, A., G. Nyamdorj, B. Munguntogos, D. Batchuluun, and B. Bayarmaa. *The Report of Land Information of the Darkhan-Uul Province*. 2012. URL http://www.info.e-darkhan.com/images/hyanalt/GHBHBG.pdf [accessed on 11 September 2013]

Natsagdorj, L. 2000. *Climate Change; Climate Change and its Impacts in Mongolia*. Jemp Publishing, Ulaanbaatar.

Ochir, J. 1985. The vegetation and pasture of Western Khentei Mountain. Case study of flora and vegetation of Mongolian People´s Republic. *Biological Academy of Mongolia*, **5:**111-118.

PADCO [Planning and Development Collaborative International], 2005. URL worldbank.org/MONGOLIAEXTN/Resources/Mon_CDS_2_city_engl.pdf [accessed on 31 July 2013]

Ramensky, L. G. 1971. *Problems and Methods in the Study of the Plant Cover* (in Russian). Nauka, Leningrad.

Raunkiaer, C. 1934. *Life Forms of Plants and Statistical Plant Geography*. Oxford University Press, Oxford.

Sanchir, C. 1968. Some feature of plant composition of north and western of Mongolian Dahurian region. *News of Mongolian Academy of Sciences* **2:**78-85.

Sergelenkhuu, J., U. Nachinshonhor, O. Takashi, Y. Yoshihiro, J. Undarmaa, S. Keiji, and Y. Ken. 2012. Effect of Grazing Pressure on the Structure of Rangeland Plant Community in Mongolia. *Arid Land Studies* **22:**235 -238.

Shinoda, M., G. Nachinshonhor, and M. Nemoto. 2010. Impact of drought on vegetation dynamics of the Mongolian steppe: A field experiment. *Journal of Arid Environments* **74:**63-69.

Tsegmid, S. 1969. *Physical Geography of Mongolia*, Ulaanbaatar. Mongolian Academy of Sciences, Mongolia.

Tserenbaljid, G. 1987. Feature of Phytosociology Biological Academy of Mongolia. *Mongolian Biological Academy* **10:**7-14.

Tserennadmid, B., and B. Odonchimeg. 2012. Results of vegetation study of a mountain steppe in Khongor district, Darkhan-Uul province, Mongolia. Pp. 104-107. *Proceedings of the International Scientific-practical Conference Dedicated to the 60th Anniversary of the Faculty of Agronomy*. Ulan-Ude.

Tuvshintogtokh, I., and D. Ariungerel. 2013. *Degradation of Mongolian Grassland Vegetation Under Overgrazing by Livestock and Its Recovery by Protection from Livestock Grazing*. Pp. 115-130. The Mongolian Ecosystem Network. Springer, Japan.

Ulziikhutag, N. 1985. *Key of the Fodder Plants in the Pasture and Haymaking of Mongolian People´s Republic* (MPR). State Publishing, Ulaanbaatar.

Ulziikhutag, N. 1989. *Overview of the Flora of Mongolia*. State Publishing, Ulaanbaatar.

Van Staalduinen, M. A., and M. J. A. Werger. 2007. The steppes of Mongolia: The impact of herbivores in a Mongolian forest steppe. *Applied Vegetation Science* **10:**299-306.

Walter, H., and H. Lieth. 1960. *Klimadiagramm-weltatlas*. G. Fischer.

Yunatov, A. A. 1950. *Fundamental Characteristics of the Vegetation of the Mongolian People's Republic*. AS USSR Publishers, Leningrad.

www.Darkhan-Uul aimag.infomongolia.com [Accessed on 31/05/13].

APPENDIX

Vascular plant species list with abbreviations found in study sites in Khongor district, Darkhan-Uul province in Mongolia

Vascular plant	Abbrevation	Sites							
		ID	ZA	ZB	DH	UU	BH	HD	TO
Achillea asiatica	AchiAsia						x	x	
Aconitum barbatum							x		
Adenophora stenanthina						x	x		
Agrimonia pilosa	AgriPilo						x	x	
Agropyron cristatum	AgroCris	x	x	x	x	x			
Agropyron repens	AgroRepe						x		x
Agrostis mongolica									x
Allium bidentatum		x			x	x			
Allium linere			x					x	
Allium senescens						x			
Alopecurus brachystachyus								x	x
Alyssum lenense		x							
Amblynotus rupestris		x		x					
Androsace incana		x							
Arctogeron gramineum		x							
Arenaria capillaris	ArenCapi	x							
Artemisia dolosa		x				x			
Artemisia dracunculus			x			x	x		
Artemisia frigida	ArteFrig	x	x	x	x	x			
Artemisia Gmelini			x						
Artemisia lacinata	ArteLaci						x	x	x
Artemisia mongolica	ArteMong						x	x	x
Artemisia scoparia	ArteScop	x	x			x			x
Aster alpinus		x	x						
Astragalus adsurgens			x			x			x
Bromus inermis	BromIner				x		x	x	
Bupleurum scorzonerifolia	BuplScor	x	x	x		x			
Calamagrostis epigios									x
Campanula glomerata							x		
Caragana mocrophylla					x				
Caragana stenophylla	CaraSten	x	x	x	x	x			
Carduus crispus							x		
Carex inervis	CareEner								x
Carex Korshinskyi	CareKors			x	x			x	
Carex pediformis	CarePedi		x			x	x		
Carum carvi									x
Chamaenerion angustifolia	ChamAngu							x	
Chamaerhodos erecta	ChamErec	x							
Chenopodium aristatum					x				x
Cirsium esculentum									x
Cleistogenes squarrosa	CleiSqua	x	x		x	x			
Crepis crocea							x	x	
Cymbaria dahurica			x		x	x			
Delphinium grandiflorum			x				x		
Dianthus versicolor		x	x	x	x	x	x		
Dondostemon integrifolius		x			x				
Dragocephalum Ruishianum							x		
Elymus dahuricus							x	x	x

Appendix: Continued

		Sites							
Vascular plant	**Abbrevation**	**ID**	**ZA**	**ZB**	**DH**	**UU**	**BH**	**HD**	**TO**
Elymus Gmelini			x					x	
Elymus sibiricus							x		
Equisetum pratense									x
Festuca lenense	FestLene	x							
Filifolium sibiricum	FiliSibi	x	x	x					
Fragaria orientalis	FragOrie						x	x	
Galatelia dahurica								x	
Galium boreale							x	x	
Galium vailantii								x	
Galium verum	GaliVeru		x	x		x	x		
Gentiana decumbens							x		
Geranium pratense	GeraPrat						x		x
Geranium pseudosibiricum								x	
Glaux maritimma									x
Glycyrrhiza uralensis						x			
Goniolimon speciosum		x							
Halerpestis salsuginosa	HaleSals								x
Hemerocallis minor								x	
Herachleum dissectum								x	
Heteropappus hispidus		x		x		x			
Hordeum brevisubulatum				x				x	x
Inula britannica									x
Iris lactea									x
Iris tigrida			x	x	x	x			
Kochia prostrata					x				
Koeleria cristata	KoelCris	x	x	x		x			
Lactuca sibirica							x		
Lathyrus pratensis							x		
Leontopodium leontopodoides		x	x			x			
Lespedesa dahurica	LespDahu			x					
Leuzea uniflora			x						
Leymus chinensis	LeymChin				x	x	x		x
Lilium pumilum			x	x			x		
Linaria buriatica								x	
Medicago falcata							x		x
Medicago lupulina									x
Melilotus suaveolens			x			x			
Odontites rubra									x
Orostachys malocophylla		x							
Oxytropis oxyphylla			x			x			
Oxytropis salina									x
Phleum phleoides	PhlePhle						x	x	
Phlomis tuberosa	PhloTube		x				x	x	
Plantago major									x
Poa attenuata	Poa Atte	x	x			x			
Poa botryoides	Poa Botr	x		x	x	x			
Poa pratensis							x	x	x
Poa sibirica								x	

Appendix: Continued

		Sites							
Vascular plant	**Abbrevation**	**ID**	**ZA**	**ZB**	**DH**	**UU**	**BH**	**HD**	**TO**
Polygonum angustifolium		x							
Polygonum aviculare									x
Polygala hybrida		x							
Potentilla acaulis	PoteAcau	x	x	x	x	x			
Potentilla anserina	PoteAnse								x
Potentilla bifurca	PoteBifu			x	x	x	x		
Potentilla leucophylla		x							
Potentilla sericea	PoteSeri	x							
Potentilla tanacetifolia	PoteTana		x			x	x		
Ptilotrichum canescens					x	x			
Puccenella tenuifolia									x
Pulsatilla Bungei	PulsBung		x	x					
Pulsatilla Turschaninovii						x			
Ranunculus scleratus	RanuScle						x		x
Rosa acicularis							x	x	
Sanguisorba officinalis	SangOffi						x	x	x
Saposhnikova divaricata						x			
Saussurea salicifolia			x			x			
Scabiosa comosa		x	x						
Scutelleria scordifolia							x	x	
Sedum aizoon			x						
Seniceo erucifolius							x		x
Serratula centauroides	SerrCent					x			
Shizonepeta multifida	ShizMult	x	x	x		x	x		
Sibbaldiante adpressa			x	x		x			
Silene jenisseensis		x							
Silene repens							x		
Spiraea aquilegifolia			x						
Stelleria chamaejasme	StelCham	x							
Stipa grandis	StipGran				x	x			
Stipa Krylovii	StipKryl	x	x	x					
Stipa sibirica	StipSibi		x	x		x	x	x	
Tanacetum vulgare							x		
Taraxacum glaucanthum					x				x
Taraxacum officinalis									x
Thalictrum foetidum			x				x	x	
Thalictrum simplex	ThalSimp						x	x	x
Thalictrum squarrosum					x				
Thermopsis dahurica						x			
Thymus gobicus		x							
Trifolium lupinaster							x	x	x
Veronica incana	VeroInca	x	x	x	x	x			
Vicia amoena	ViciAmoe		x				x	x	
Vicia cracca	ViciCrac						x	x	
Vicia unijuga	ViciUnij						x	x	