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TESTING THE ECOLOGICAL SITE CONCEPT IN MONGOLIAN RANGELANDS

CASE STUDY IN UNDURSHIREET SOUM AREA

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ABSTRACT

Mongolian rangelands have degraded considerably within the last twenty years following an increase in the number of livestock and changed management. The current land management system has caused decreased herd mobility and overgrazing. This situation calls for new tools for rangeland management based on ecological knowledge, including knowledge on land condition, land potential and the underlying ecosystem functions, or what is collectively referred to as Rangeland Health. Only through such approaches can we expect to achieve sustainable land management. An Ecological Site is a particular area which has its own ecological potential for productivity. A State and Transition Model is a conceptual model describing plant community change pathways under certain sets of disturbances. This approach gives an opportunity to assess land condition and to detect possible changes. Furthermore, an integration of these two enable application of State and Transition Models to help identify states at risk of crossing irreversible ecological thresholds of land degradation and to find appropriate interventions for degraded lands. The purpose of this study was to validate the Ecological Site concept for selected Mongolian rangelands in the Undurshireet Soum area and to test a proposed State and Transition model developed for *Stipa Krylovii* dominating communities in the Undurshireet Soum area. The results support the main Ecological Sites as they are defined for the Undurshireet Soum area. However, they also suggest that the classification should be simplified to some degree. This is especially true for the calcareous soil sites. The results from reviewing the State and Transition model suggest that an alternative simpler model is more appropriate. Consequently, I suggest that field strategies should be revised in order to collect better data for testing the applicability of State and Transition Models, but the methodology applied here to verify previously defined Ecological Sites appears to be useful.

This paper should be cited as:

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1. INTRODUCTION

1.1 Mongolian rangelands

Mongolia is located in Eastern Asia with a land area over 1.5 million ha and a current population of 2.9 million people. Mongolia has been divided into six ecological zones: alpine, mountain taiga, forest steppe, steppe, desert steppe and desert. Approximately 30% of the Mongolian territory consists of steppe zones and they also carry the highest densities of people and livestock (Jigjidsuren & Johnson 2003; Angerer et al. 2008). These zones are not only crucial for the Mongolian animal husbandry and livelihood, but also in a global context as being the largest natural grassland ecosystems in the world (Liu et al. 2013). The steppe zone is located between the forest steppe and desert steppe zones and included in the arid and semi-arid climate region. The United Nations Convention to Combat Desertification has identified it at risk due to climate change and human activities, including overgrazing (UNCCD 1994).

The total number of Mongolian livestock is approximately 45 million in 2013 (National Statistical Office 2013). The majority of the country is rangelands and approximately 40% of its population is related to livestock production and thus rangelands (Damdinsuren et al. 2008). Mongolian rangelands have degraded considerably within the last twenty years and soil erosion is now common. About 70% of the arid zones of Mongolia are in a degraded state with most of it considered to be in a moderately to severely degraded state (United Nations Environmental Program 2002). Several studies have been conducted on grazing impacts in the different ecological zones of Mongolia (Stumpp et al. 2005; Kakinuma et al. 2013; Wang & Batkhishig 2014). Their common conclusion is that livestock grazing reduces vegetation cover and increases the risk of water erosion, partially due to potentially higher raindrop impact (Onda et al. 2007). Another noted consequence of intense grazing is the proportional increase of unpalatable plant species in the steppe zone of Mongolia (Cheng et al. 2011; Okayasu et al. 2012). Recent studies based on satellite observations (Liu et al. 2013; Hilker et al. 2014) indicate a decline in biomass from 1988 to 2008, hence supporting other findings on the effect of climate change and overgrazing in almost the entire Mongolian steppe region (Batima et al. 2005; Angerer et al. 2008)

For seventy years, until 1990, Mongolian herders were organized in collectives under Soviet communism. Under this system, the government was powerful and provided financial and logistic support to the herders. Moreover, grazing pressure was low due to controlled livestock numbers and mobility. After slashing this system, Mongolia shifted into a market economy and private ownership. The number of livestock has since increased from about 20 to 45 million within a time period of only twenty years. The current land management system has led to decreased mobility and increased overgrazing (Lkhagvadorj et al. 2013). The seasonal mobility has been an important part of traditional grazing management in Mongolia, and thus in a herder's life. Instead of herders and families relocating with their livestock depending on the seasons and land condition, they have increasingly settled down permanently, often near administrative unit centres (Ykhanbai et al. 2004). These changes have impacted grazing patterns, water point use and land tenure, and have consequently created high local grazing pressures and increased risk of land degradation (Sternberg 2008). Consequently, signs of rangeland degradation and soil erosion have become apparent in some areas (Figure 1).

Mongolian land degradation impacts on a continental scale. The Mongolian desert steppe and desert zones are now the main source for East Asian dust storms (Batjargal et al. 2006). Their increased intensity is traced to overgrazing, mining, deforestation and poor roads (Keshkamat et al. 2012). Dust storm severity depends on seasonal climatic conditions (Natsagdorj et al. 2003), but as the coal, copper and gold mining is increasing with improper restoration of mining areas, the storm intensities and frequencies are expected to increase (Farrington 2000). The number of dusty days in Mongolia increased three-fold from 1975 to 1999 (Natsagdorj et al. 2003). This intensifying detrimental situation has created an urgent need for action.

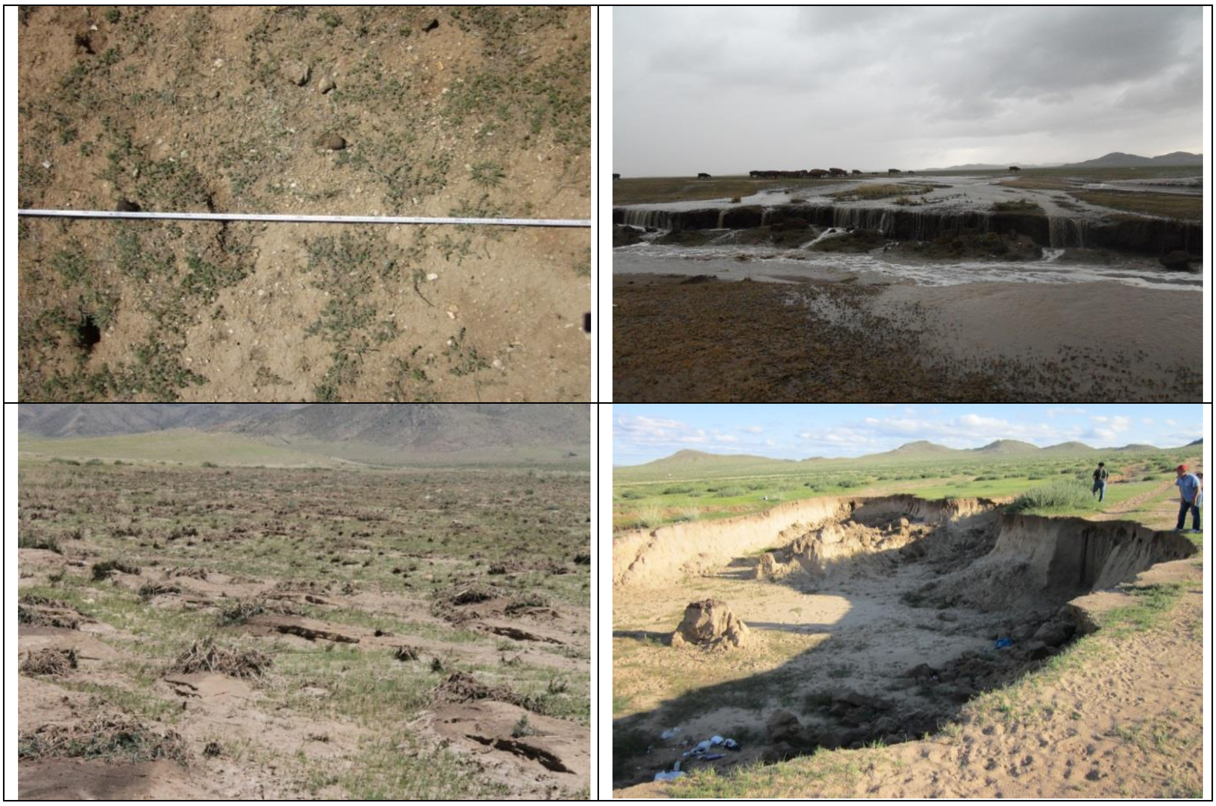

Figure 1. Examples of land degradation signs in Undurshireet Soum area. Top left: overgrazing has reduced vegetation cover and increased bare soil; top right: water erosion of soil by run-off; bottom left: soil surface erosion/sedimentation after heavy rain; bottom right: gully in sandy soil created by improper land management (Source: Green Gold Project 2013).

Mongolian rangeland research since the 1960's has focused on vegetation including flora, community types, dynamics and productivity by ecological zones (Yunatov 1976; Hilbig 1995; Gunin et al. 1999). According to vegetation changes in rangeland, Chognii (2001) has described changes on some widely distributed communities and their characteristics of recovery in forest steppe and steppe zones of Mongolia based on fencing studies excluding grazing animals. Tuvshintogtokh (2014) has compiled a steppe vegetation distribution map by reviewing previous studies and suggested some linear successional models to explain observed vegetation community changes. However, this is based on limited data as few studies are available on the vegetation changes over the last few decades.

1.2 Land management and models of vegetation change

The theoretical background of my project can be traced as far back as Clements (1916) and Gleason (1926). Until 1989 the Range Succession Model, derived from the Clementsian approach of plant ecology, has been used widely in the USA related to rangeland management issues (Dyksterhuis 1949). In this model, the rangeland succession of the plant community is a continuum which has one permanent climax state. The range condition is considered the equilibrium under grazing pressure and precipitation variability. Researchers suggested that the temporal changes in vegetation could be reversed through changes in management. But there were few observed examples of such land condition reversibility through land management and the changes were not continuous, reversible and permanent (Briske et al. 2003). This led to the development of an alternative range management model, now known as the State and Transition Model, by Westoby et al. (1989), where Gleason's ideas presented in 1926 were in fact adopted. The State and Transition Model takes into account the vegetation dynamics, the plant community changes are considered to be either reversible or irreversible depending on the state of various ecosystem processes, and hence land management can drive an area into an alternative state that is irreversible under the current land management regime.

The Range Succession model is based on an equilibrium system but the State and Transition models acknowledge the non-equilibrium nature of ecosystems. The transitions in the State and Transition Models are stimulated by abiotic and biotic factors through time and space. They consist of possible states (i.e. vegetation communities) and transitions between them (i.e. drivers changing one community type to another) (Westoby et al. 1989). The states may include different plant community phases and transitions between them (Stringham et al. 2003). State and Transition Models recognize the presence of thresholds between states which explain the potential irreversibility between them depending on biotic and abiotic factors and the interactions between them. State and Transition Models are useful tools to realize potential state shifts under a given disturbance or disturbance regimes.

Other models have also been proposed for rangelands, addressing management and land condition. Milton et al. (1994) developed a conceptual rangeland degradation model for arid lands. There, rangeland degradation and desertification are considered a “stepwise process” consisting of five steps. In the first step the plant community changes can only be described as small non-directional fluctuations driven by changes within seasonal weather. In the next step, the age structure of plants is affected and the cover of unpalatable plants is increased. The third step includes loss of species richness and reduction of biomass. In step four, long lived plant cover decreases, hence increasing bare soil surfaces with a corresponding increase in soil erosion processes. In the fifth and final step, the rangeland is converted into barren land without vegetation cover, rendering it useless as rangeland. Land in such condition has to be abandoned. Restoration is both very difficult and expensive if the degradation reaches that step. The need for detecting early stages of land degradation is therefore urgent.

Both Milton's Stepwise Model and Westoby's State and Transition Model should be considered complimentary as the former describes a trajectory that can easily be described by a State and Transition Model with irreversible thresholds between states.

Phelps and Bosch (2002) introduced the idea of combining the Range Succession Model and the State and Transition Model to create a vegetation dynamics model applicable for specific Australian rangelands. Their model acknowledged the degradation gradient proposed by Clements and used it to describe states in rangeland vegetation changes using ordination techniques on long term monitoring data. The Phelps and Bosch model is thus not linear as the Clemensian model predicts. Their approach can be seen as a further development of Westoby's and Milton's ideas as this model considers ideas presented by both Westoby's and Milton's groups.

1.3 The Green Gold project and improved land management in Mongolian rangelands

Land management should be based on ecological knowledge, including knowledge of land condition, land potential and the underlying ecosystem functions, or what is commonly referred to as Rangeland Health (Committee on Rangeland Classification 1994). Only through such approaches can we expect to approach sustainable land management. This requires new land potential-based tools for rangeland management. This has been the objective of the Green Gold project operating in Mongolia since 2004 (Green Gold project 2013). The project consists of four main components: collective action, applied research, extension and marketing.

Since 2009, the focal point of the applied research has been on the resilience based Ecological Sites concept, Rangeland Health methodologies and the application of State and Transition Models (Briske et al. 2005; Briske et al. 2008). An Ecological Site is a particular area which has its own ecological potential for productivity (Committee on Rangeland Classification (1994). Each Ecological Site differs by its response to a disturbance and management. The concept refers to specific land units identified for the purpose of rangeland management and/or restoration activity and must thus be predefined. This approach gives an opportunity to assess land condition and to detect possible changes. Each Ecological Site has a certain description focusing on soils, vegetation and landscape topography. These properties become the classification factors for each site (Bestelmeyer 2014). A State and Transition Model is a conceptual model based on best available data at any given point in time describing plant community change pathways under certain sets of disturbances (Stringham et al. 2003). It consists of possible alternative states which are connected by transitions and opportunities to restore degraded states to healthy ones (Westoby et al. 1989). Furthermore, the integrated application of State and Transition Models helps to prevent ecosystems from crossing ecological thresholds of land degradation and to find appropriate interventions for degraded lands.

These concepts and models have been shown to be potentially both helpful and useful in addressing rangeland management issues. This is the first time that the Rangeland Health concept and State and Transition Models have been applied in rangeland studies in Mongolia. One of the many areas the Green Gold's applied research team has worked in the Undurshireet Soum area. Key Ecological Sites have been identified for the area (see Table 1) based on topographic and soil data, and a State and Transition Model has also been proposed for *Stipa Krylovii* dominating plant communities (Figure 2 and Table 2). The number of livestock has increased in Undurshireet Soum within the last fourteen years (Figure 3) with consequent overgrazing problems (Green Gold project 2013, unpublished data). This observed trend needs further urgent attention and calls for new land management tools.

This rapid land degradation - along with the now available Green Gold data - makes this area ideal to test the applicability of both the Ecological Site concept and State and Transition Models.

In this project I sought to use data from the Green Gold project to see if the underlying assumptions on Ecological Sites and State and Transition Models can be supported. The focus of the study was on the Undurshireet Soum area. More specifically my objectives were:

- To validate the Ecological Sites concept for a selected Mongolian rangeland in the Undurshireet Soum area
- To test a proposed State and Transition model developed for *Stipa Krylovii* dominating communities in Mongolia in the Undurshireet Soum area

Table 1. A summary of pre-described Ecological sites in the Undurshireet Soum area and number of sites within each of them in the current study. Ecological sites were grouped into nine groups before analyses. Altitude range and slope range for the sites are shown in the table.

	Ecological sites	**Ecological site groups**	**Altitude**	**Slope**	**Number of sites**	**Site name**
1	Sub-irrigated	Sub-irrigated	1014-1022	0	3	P 12, 14, 16
2	Deep sandy	Deep sand	1050-1210	1-8	4	P 25, 26, 32, 33
3	Undefined	Undefined	1152	0	1	P 28
4	Loamy	Loamy	1151-1295	0-4	2	P 1, 22
5	Gravelly loam	Gravelly loam	1281	2.5	1	P 36
6	Gravelly loam upland	Gravelly loam	1288	12	1	P 35
7	Sandy upland	Sandy upland	1133	11	1	P 24
8	Mountain shallow ridge	Mountain shallow ridge	1290	2	1	P 5
9	Calcareous sandy	Calcic sandy	1022-1360	1-3	3	P 21, 27, 30
10	Calcareous sandy loam	Calcic sandy	1154-1362	2-7	4	P 3, 6, 8, 29
11	Calcareous sandy upland	Calcic sandy	1315-1339	9-18	2	P 2, 9
12	Calcareous loamy	Calcareous loamy	1060-1244	1-4	4	P 20, 23, 31, 34
13	Calcareous loamy upland	Calcareous loamy	1287-1331	11-17	2	P 17, 18
14	Calcareous gravelly upland	Calcareous gravelly	1336-1384	15-19	2	P 4, 19

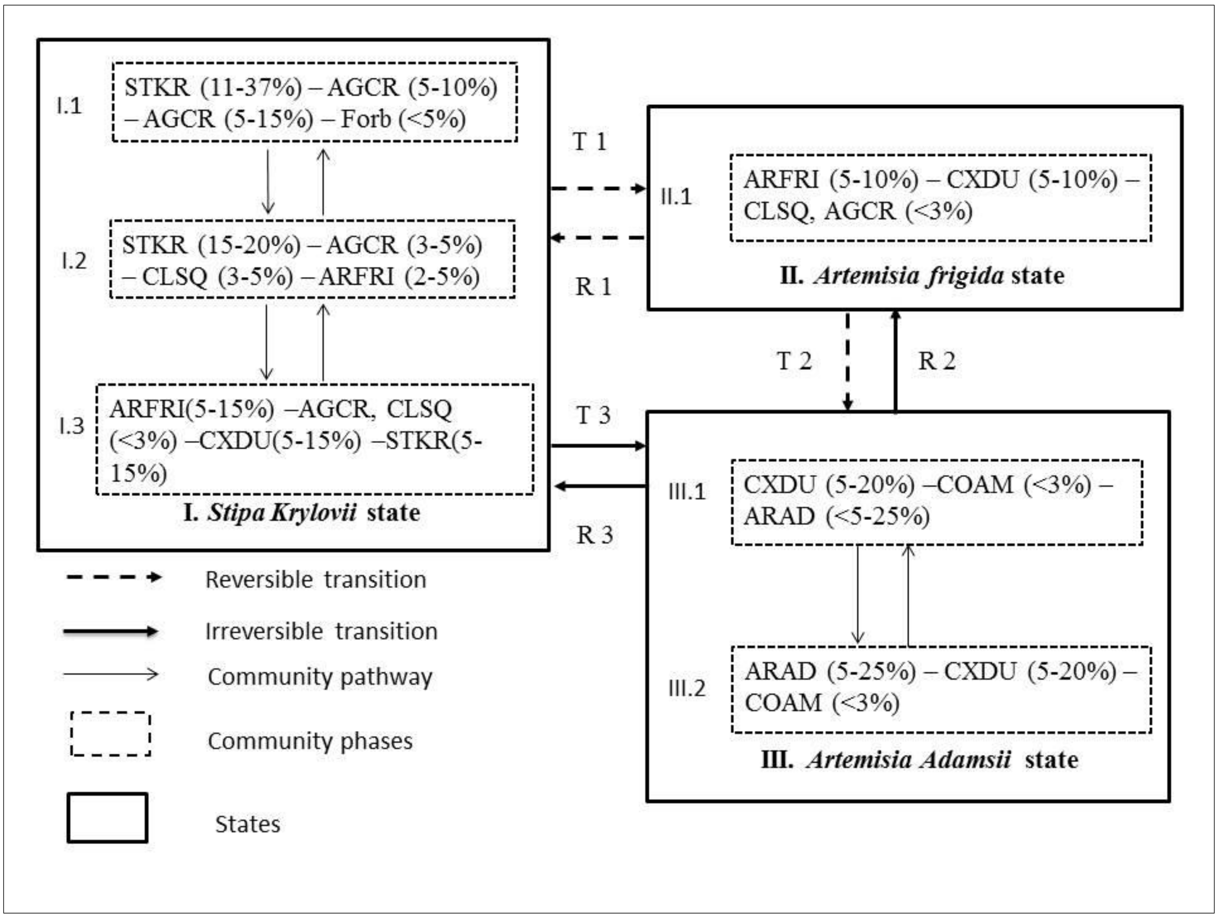

Figure 2. The proposed hypothetical State and Transition Model for *Stipa Krylovii* community of steppe zone in Mongolia. States (boxes) and transitions/restorations (T1/R1 to T3/R3) are described in Table 2.

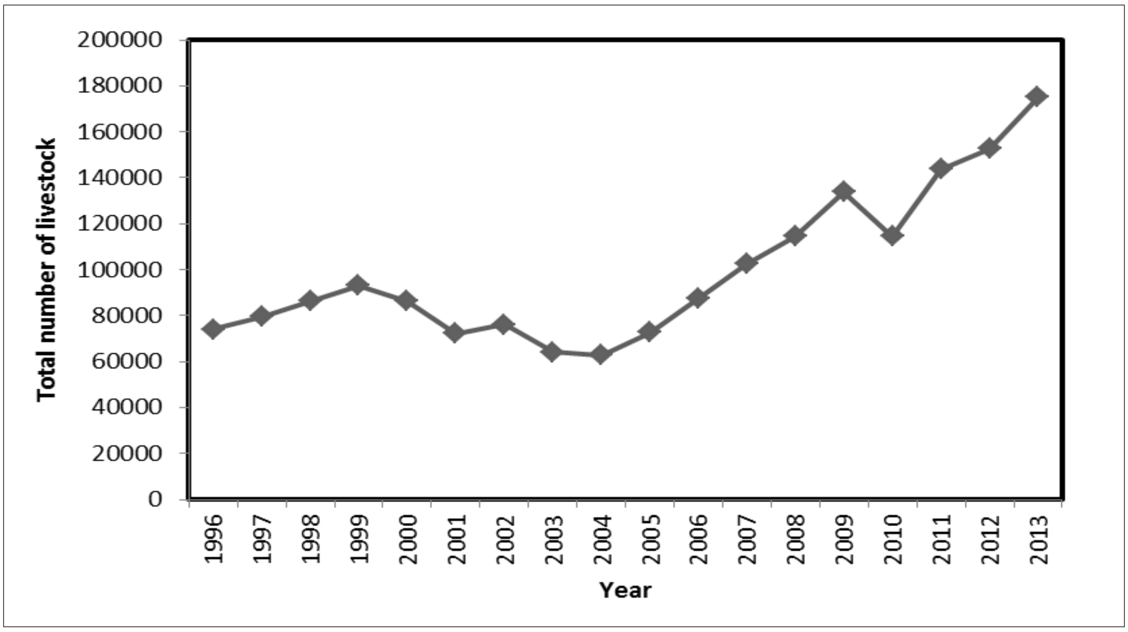

Figure 3. Annual livestock numbers in Undurshireet Soum from 1996 to 2013 (Source: Institute of Meteorology and Hydrology 2013).

Table 2. Detailed description of states and transitions in the State and Transition Model shown in Figure 2.

Catalogue of states	Catalogue of transitions	Catalogue of restorations
State I Palatable perennial grass *Stipa Krylovii* (STKR) dominant and co-dominance of small bunch grasses (SBG), perennial forb spp. Semi-shrub *Artemisia frigida* (ARFRI) and sedge *Carex duriuscula* (CXDU) rare.	*T 1* Continuous selective grazing above carrying capacity.	*R 1* Short time resting at seedling time and following key rainfall events or rotational grazing at recommended stocking rate.
State II Palatable semi-shrubs (ARFRI) dominate and little perennial grass cover.	*T 2* Heavy continuous selective grazing above carrying capacity.	*R 2* Similar to above
State III Unpalatable semi-shrub (ARAD) dominant and co-dominant sedge (CXDU). Unpalatable or annual forbs rare.	*T 3* Heavy continuous selective grazing above carrying capacity and drought.	*R 3* Active restoration including fertilizer and irrigation application and reseeding of palatable grass spp and removing unpalatable semi-shrub spp.

2. METHODS

2.1 Study area

The study area is located in the dry steppe zone of Mongolia. Mongolia is administratively divided into twenty-one provinces (*aimags*) which are further divided into districts (*soums)*. The data used in this study originated from the Green Gold project conducted in 2013 in the Undurshireet Soum in Tuv aimag (Figure 4). The total land area of Undurshireet Soum is 280,000 hectares and the total number of livestock was 290,540 (Green Gold project, unpublished data). The land management is traditionally based on a four seasonal pattern. The lower areas near to the Tuul River are grazed in summer and autumn while winter and spring pasture is situated in the mountainous area far away from the Tuul River. The natural rangeland is the main resource for the livelihood of nomadic people in Undurshireet Soum. The mean temperature in January is -21.5°C compared to 19.5°C in July. The mean annual precipitation is 225 mm (data from the Institute of Meteorology and Hydrology).

2.2 Data collection

Locations for 31 study sites were randomly selected from a map. In 2013, the study sites were located with the help of handheld GPS. Qualitative and quantitative data were collected for each site (Table 3) using the rangeland health monitoring and assessment indicators developed and used for semiarid and arid zones by Herrick et al. (2005). Soil properties were determined at the centre point of each site (GPS point) using general field methods (Schoeneberger 2002) and vegetation cover was measured using the line-point intercept method every 0.25 m along two 50 m transects placed parallel 20 m apart. A total of 200 points (vascular plant species, litter, bare ground, gravel or rock) were recorded along each transect, a total of 400 per site.

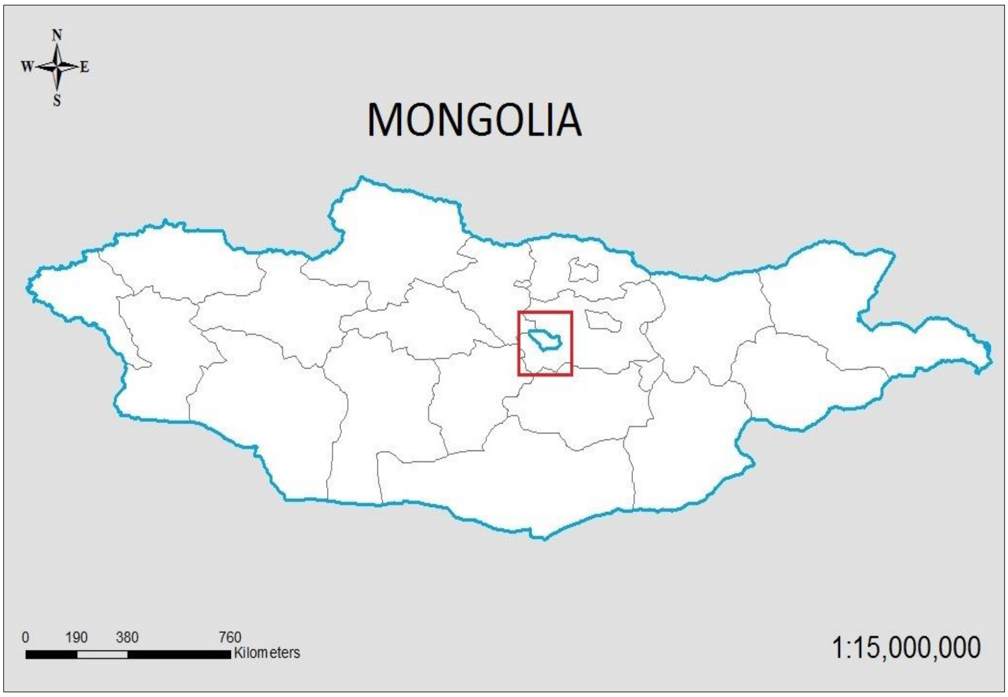

Figure 4. Map showing location of Undurshireet Soum in Mongolia (red box).

Table 3. Type of data collected for each site in the Green Gold Project in Undurshireet Soum.

	Data	**Method**
Topography	Location	GPS
	Altitude	GPS
	Landform	Description, general field method
	Aspect	Compass
	Slope	Clinometer
Soil properties	Horizon	General field methods
	Horizon depth	General field method
	Texture	General field method
	Structure	General field method
	Colour	General field method
	Calcic content	General field method
	Clay content	General field method
	Gravel content	General field method
Vegetation	Species richness	Line-point intercept
	Foliar cover of species	Line-point intercept
	Total foliar cover	Line-point intercept
	Total basal cover	Line-point intercept
	Litter amount	Line-point intercept
	Bare ground	Line-point intercept
Rangeland use history	Seasonal use	Developed metadata sheet
	Distance from water point	Developed metadata sheet
	Distance from camp	Developed metadata sheet
	Livestock numbers	Developed metadata sheet
	Carrying capacity	Developed metadata sheet

2.3 Data analysis

The data had been entered into a project database based on the Database for Inventory, Monitoring and Assessment (DIMA) System (Herrick et al. 2005) and stored in a Microsoft Access 2010 database (Microsoft Access 2010). All qualitative and quantitative data were prepared using Microsoft Excel 2010 (Microsoft Excel 2010).

Cover data for vascular species of all sites were ordinated using Detrended Correspondence Analysis (DCA). Environmental variables such as elevation and slope were used as explanatory variables for assisting in interpreting the results. Sites had already been assigned to Ecological Sites based on soil properties (Table 1). These were grouped into nine Ecological Sites groups (Table 1) prior to analysis and included as factorial variables. In this study species compositional data were used to verify the Ecological Sites classification. Classified case diagram was used to observe the relationship between vegetation composition and the Ecological Sites, and polygonal envelopes were drawn around members of each class.

Descriptive statistics were used to compare the cover of total foliar, total basal, litter, bare ground and individual species between different community phases (within states) of the proposed State and Transition Model for the *Stripa Krylovii* community of the steppe zone of Mongolia (Ankhtsetseg et al. 2014). The mean Shannon-Weiner diversity index (H´) (Magurran & Magurran 1988) and its variation were also calculated for these phases.

Fourteen of the 31 sites in the study were comprised of the *Stripa Krylovii* communities (Table 4). These were analysed separately using Principal Component Analysis (PCA) due to a short gradient reflecting less variation in this sub-dataset. The cover of the four characteristic species of the State and Transition Model were used as explanatory variables in the analysis.

Descriptive statistics were performed using SAS Version 6.1 (SAS Institute 2012) and for ordination Canoco Version 5 (ter Braak & Šmilauer 2012) was used.

3. RESULTS

3.1 Vegetation

A total of 48 vascular plant species were recorded in the study area, including three shrubs, four dwarf shrubs, 10 grass species, 20 perennial forbs, eight annual forbs, and three sedges. The most common species of each function group were, for shrubs, *Caragana microphylla* and *C. stenohylla,* for dwarf shrubs *Artemisia frigida* and *Kochia prostrata,* for grasses *Stipa Krylovii, Agropyron cristatum* and *Cleistogenes squarrosa,* for sedges *Carex duriuscula,* and for forbs *Convolvulus ammanii* and *Allium bidentatum*.

In the study area ranging from 1014 to 1384 m a.s.l., four main vegetation communities were identified: *Achnatherum splendens* meadow, *Caragana microphylla-Stipa Krylovii* dry steppe, *Stipa Krylovii* dry steppe and *Stipa Krylovii*-Forb mountain steppe, and they were present under different environmental conditions. The *Achnatherum splendens* community occurred in the lowest part of the Tuul River valley. This community is dominated by the perennial deep rooted, large and dense tussock grass *Achnatherum splendens*, the sedge *Carex duriuscula* and some forbs *Potentilla bifurca and Iris lactea*. The *Caragana microphylla-Stipa Krylovii* community was present between river and mountain valleys with sandy soils. It is dominated by a characteristic species of the steppe, the 1-2 m tall shrub *Caragana microhylla*, the perennial bunch grass *Stipa Krylovii* and the sedge *Carex duriuscula*. The most common plant community in the Undurshireet Soum rangeland was the *Stipa Krylovii* community, occurring in mountain valleys, alluvial plains and fans. It is dominated by a xerophyte bunch grass *Stipa krylovii*, the small bunch grasses *Agropyron cristatum*, *Cleistogenes squarrosa* and the dwarf shrubs *Artemisia frigida*. A *Stipa Krylovii*-Forb mountain steppe community was found in the mountainous part of the study area, on gravelly soils between 1280-1380 m a.s.l. In this community the *Stipa Krylovii* and petrophyte forbs *Haplophyllum dahuricum*, *Pulsatilla Turczaninovii* and *Cymbaria dahurica* were dominant.

3.2 Ecological sites and species composition

The two first axes of DCA explained most of the variation in the species data as seen in the eigen values of 0.57 and 0.27 for axis 1 and axis 2, respectively. The elevation was positively correlated with the first axis and Ecological Sites differed mostly along the first axis, although some variation occurred along the second axis (Figure 5). Sub-irrigated soils were at the lowest elevation while calcareous soils occurred at higher elevation. The most influential environmental/explanatory variables were the elevation and slope. Species composition varied amongst the pre-described Ecological Sites, although the difference varied depending on the different Ecological Sites, and sites classified as calcareous (CS, CL and CG on Figure 5) appeared to be more similar than some of the other types of Ecological Sites (Figure 5). A classified case diagram (Figure 6) clarified this further and showed that the three types of calcareous sites identified (CS, CL and CG) were located within the calcareous sandy group on the graph. The unclassified site (NN) was located amongst the Sub-irrigated group (Figure 6), reflecting the fact that its species composition was similar to those sites that had been described as sub-irrigated.

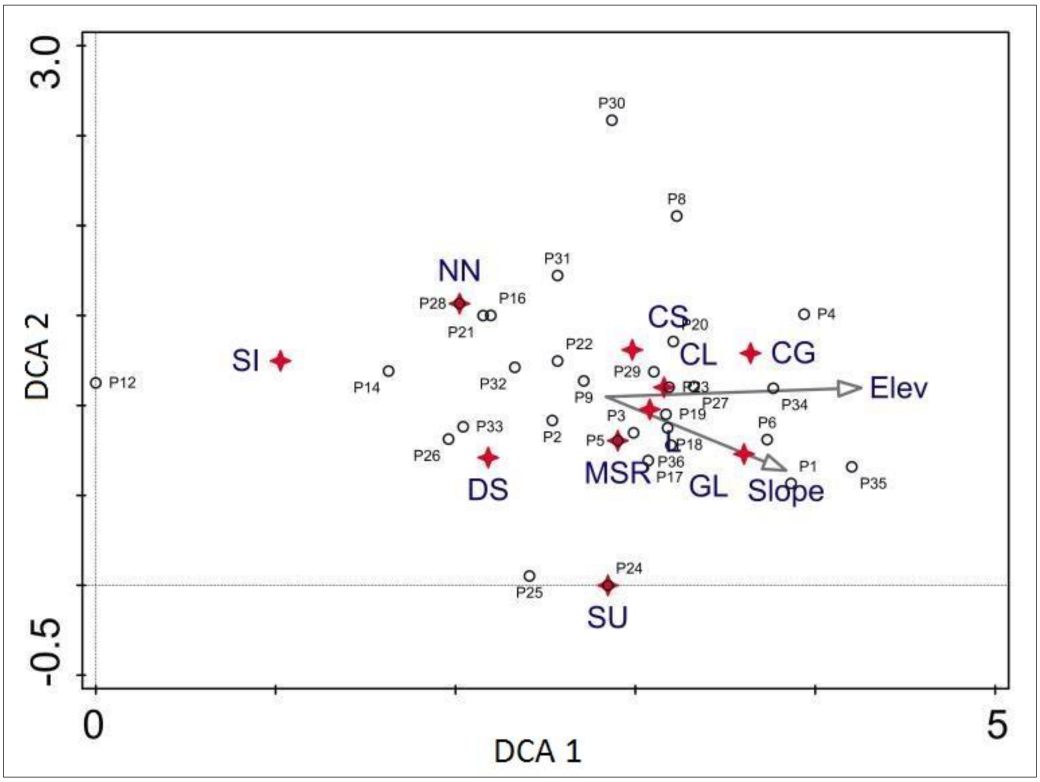

Figure 5. Detrended Correspondence analysis (DCA) for Undurshireet Soum using cover data of vascular plant species. The environmental variables included in the analysis as explanatory variables are shown as vectors (elevation, slope). Circles are study sites and red stars are Ecological Site groups. Ecological Site group name abbreviations: SI = Sub-irrigated; DS = Deep sandy; NN = Undefined; SU = Sandy upland; MSR = Mountain shallow ridge; GL = Gravelly loam; L = Loamy; CL = Calcic loamy; CS = Calcic sandy; CG = Calcic gravelly. See Table 1 for site names.

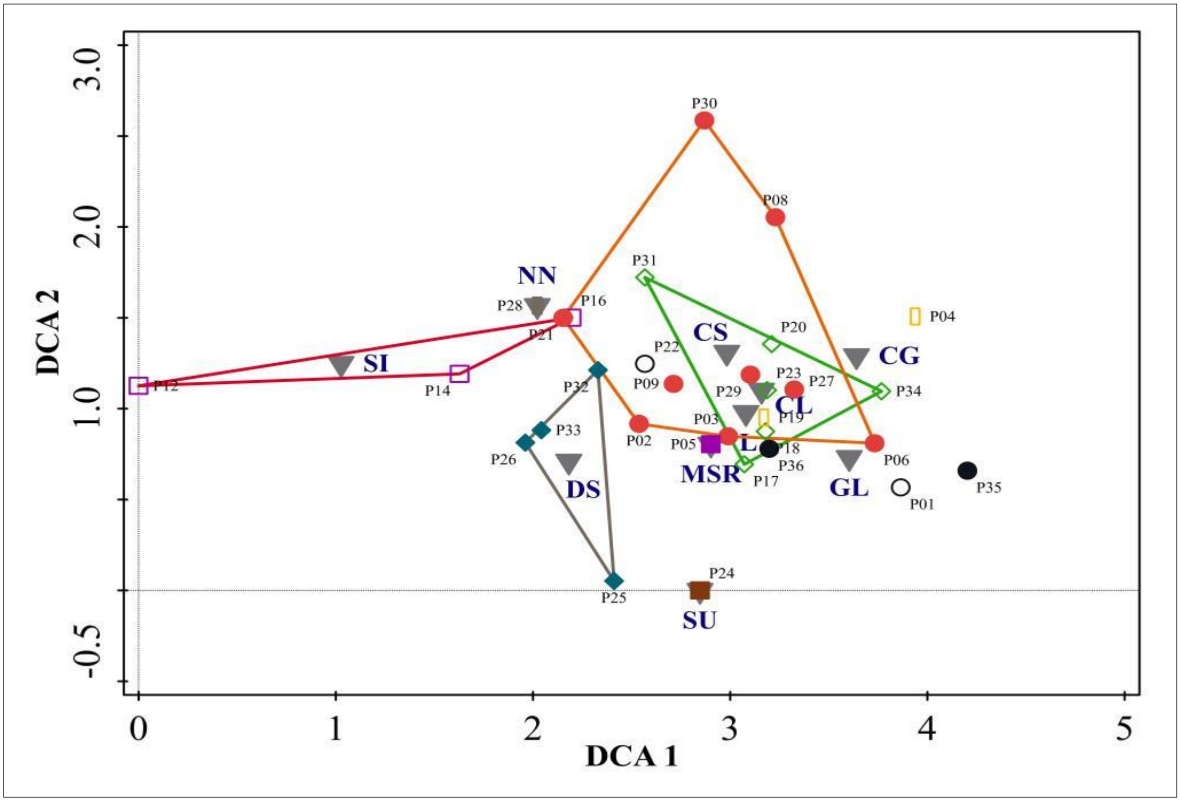

Figure 6. A classified case diagram of the DCA results for all study sites using the same data as in Figure 5. Each symbol represents different ecological site groups. See Figure 5 for legend and abbreviations.

3.3 *Stipa Krylovii* State and Transition Model in Undurshireet Soum

All 17 sites classified as calcareous soils belonged to the *Stipa Krylovii* dominating grassland in Undurshireet Soum. Based on the proposed State and Transition Model (Table 2 and Figure 2) these sites were assigned to two states and three community phases (Table 4), with 14 plots assigned to I.1 and two plots to I.3. State II and community phases I.2 and III.2 were absent within study plots and only one plot occurred in the first community phase of State III.

Table 4. Classification of study sites in Undurshireet Soum based on a State and Transition Model developed for *Stipa Krylovii* dominated grassland.

State	Community phases	Number of sites
I	I.1	14
	I.2	0
	I.3	2
II	II.1	0
III	III.1	1
	III.2	0
	Total	17

The total foliar and basal cover and litter decreased through the states/community phases while the amount of bare ground increased. In the best condition I.1, total foliar cover (61 ± 2.8) and litter amount (49 ± 3.6) were higher but bare ground lower (13 ± 1.5) than in the others. In the worst condition (III.1) total foliar and basal cover was a little higher in the previous phase (I.3) due to the biological characteristics of the dominant species in this phase (Figure 7). These differences could not be tested statistically. Foliar cover of the key species *Stipa Krylovii* declined from the best phase to the worst one, whereas the foliar cover of *Carex duriuscula* and *Artemisia Adamsii* increased (Figure 8). The species diversity (H' Shannon-Weiner index) was the highest in Phase I. 1, 2.09, followed by Phase I.3 (1.6) and Phase III.1 (1.1).

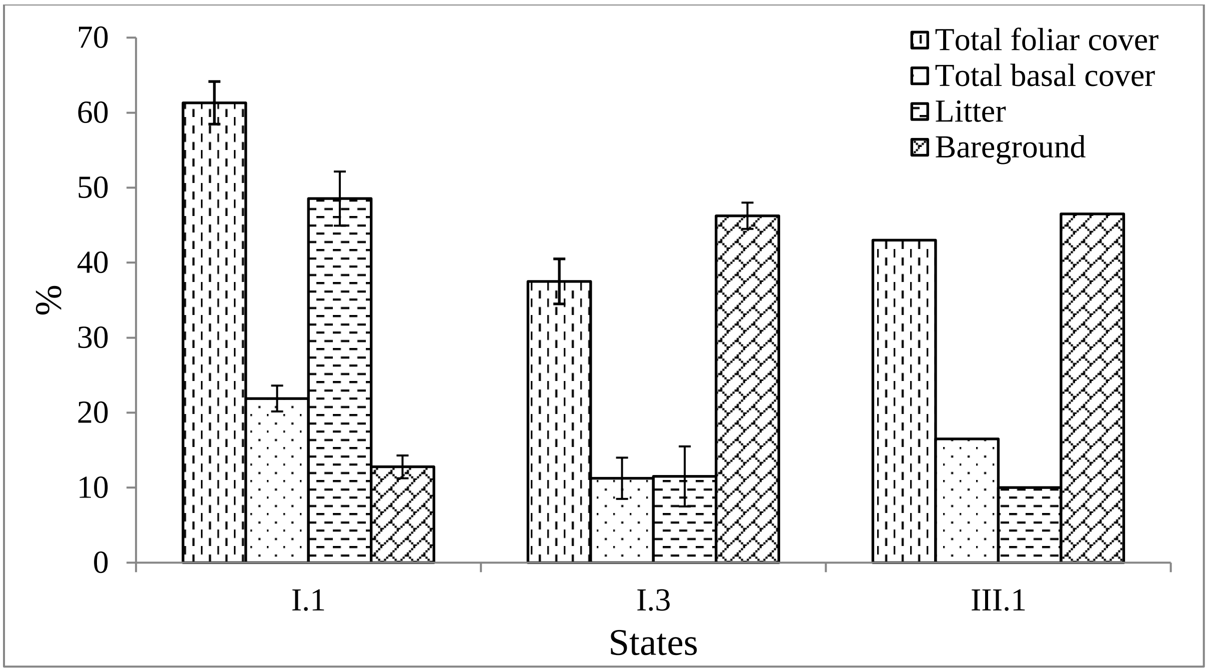

Figure 7. The mean total foliar and basal cover, litter and bare ground of three community phases belonging to two states in proposed State and Transition Model for the *Stipa Krylovii* community. N =14 for I.1, n=2 for I.3 and n=1 for III.1. Each bar represents mean ± SE.

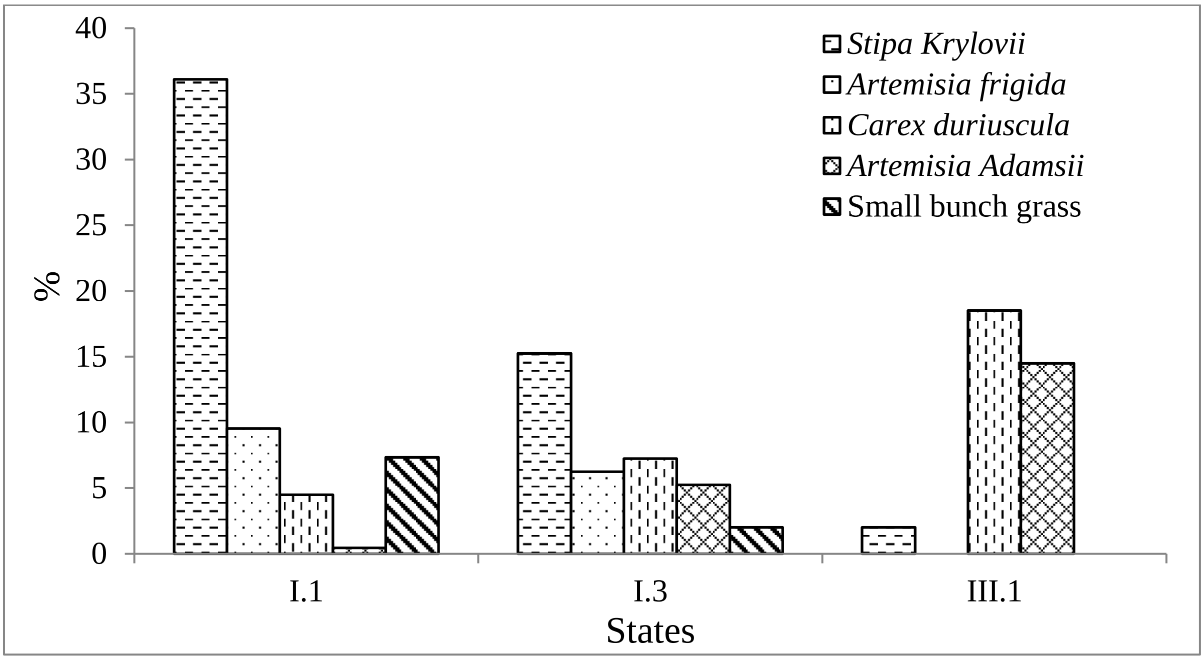

Figure 8. The mean of individual species cover of three community phases within two states in the proposed State and Transition Model for the *Stipa Krylovii* community.

The two first axes explained most of the variation in the PCA on the calcareous study sites in Undurshireet Soum, as seen in the eigen values of 0.23 and 0.21 for axis 1 and axis 2, respectively. The study sites show a pattern related to the four characteristic species (Figure 9). Seven sites were related to *Stipa Krylovii*, four sites to *Artemisia frigida*, and three sites to *Artemisia Adamsii* and *Carex duriuscula* (Figure 9).

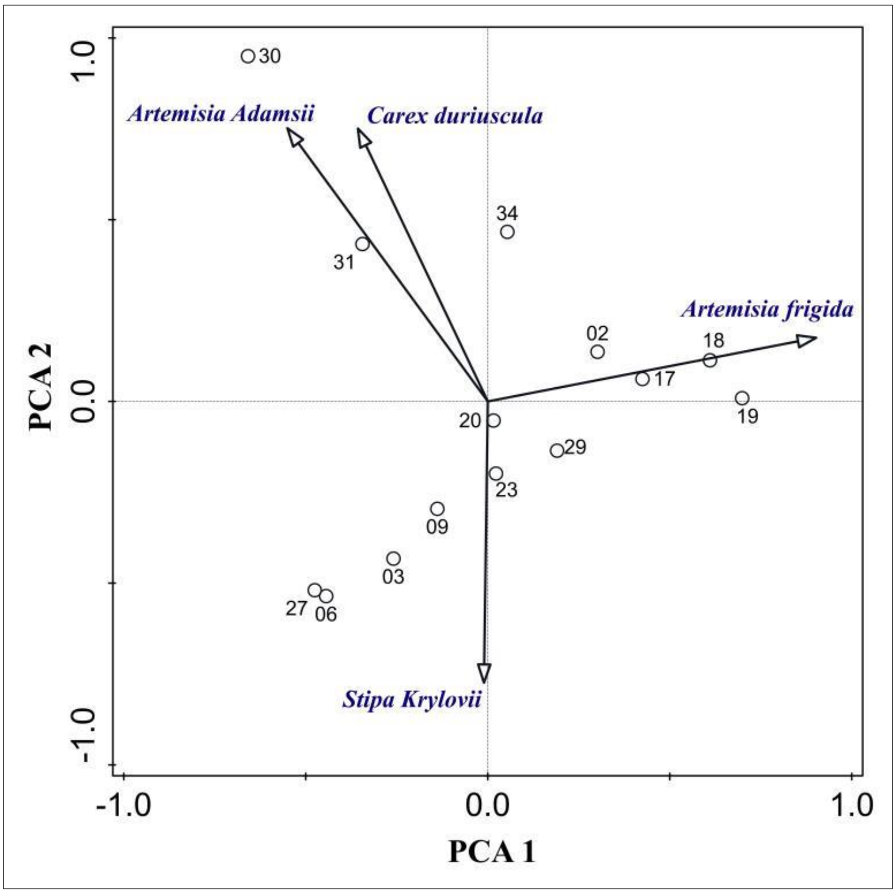

Figure 9. Cover data of vascular plant species at the calcareous sites in Undurshireet Soum ordinated by Principal Correspondence Analysis (PCA). The covers of the characteristic.

4. DISCUSSION

The ordination results support the main Ecological Sites as they are defined for the Undurshireet Soum area. However, they also suggest that the classification should be simplified to some degree. This is especially true for the calcareous soil sites. The data do not support as detailed classification for those sites as was originally proposed. The Ecological Sites approach depends on soil surveys for their identification and definition (Herrick et al. 2006). This study, however, used vegetation data to review the categorization. This is important as Ecological Sites are defined based on their response to land management, hence the vegetation will reflect short-term responses better than changes in soil properties. This does not exclude the possibility that the currently observed changes in vegetation properties will continue and may eventually reflect the soil properties better and thus be more in accordance with the original Ecological Site classification. It must be kept in mind that only 25 years have passed since the current management strategies were adopted. The changes on rangeland vegetation dynamics, including species diversity, are related to the climate and grazing history of the area. According to Milchunas et al. (1988) semi-arid rangelands, having a long-term evolutionary grazing history, show more gradual changes in plant species diversity than comparable sub-humid areas. The Mongolian rangelands may therefore still be in a transition phase.

The degree of detail within the soil data may pose a problem, as is reflected in the NN Ecological Site (Figures 5 and 6). The NN site shows both properties of the SI sites and calcareous sites and could therefore not be assigned to either of them with confidence. The DCA results, however, suggest that there are more similarities between the NN site and SI sites when the vegetation data are considered. I therefore suggest that this site should be assigned to the Sub-irrigated (SI) Site group (Figure 6).

The original State and Transition Model for *Stipa Krylovii* dominating community (Ankhtsetseg et al. 2014) is supported by successional models developed by Chognii (2001) and Tuvshintogtokh (2014). The data in my study were insufficient to test the State and Transition Model using ANOVA as was originally intended due to the fact that the Green Gold project data were not sampled with that purpose in mind. The numbers of plots were too limited in most phases and states (Table 4), allowing only for descriptive statistics together with PCA ordination (Figure 9). The results suggest though that an alternative simpler State and Transition Model would be more appropriate than the one originally proposed (Figure 10). The new proposed State and Transition Model consists of states without multiple seral stages and suggests somewhat more linear transitional pathways. The alternative model also omits the intermediate states suggested in the original model due to lack of supporting data. It needs to be pointed out that the PCA ordination is based on only a single year's data. The proposed new State and Transition Model is thus purely hypothetical, as such models always are. Empirical data may confirm them to some degree, and I suggest that field strategies should be revised in order to collect better data for that purpose.

Little has been published where the Ecological Site concept has been empirically tested. It is thus difficult to compare these results to other findings. Phelps and Bosch (2002) have developed the State and Transition model based on quantitative data for an Australian rangeland using ordination methods including DCA and PCA for identifying vegetation states along grazing gradients. Moreover they have used indicator species for modelling. The general steps were similar in the current study but they used a proposed Degradation Gradient Model with the State and Transition model.

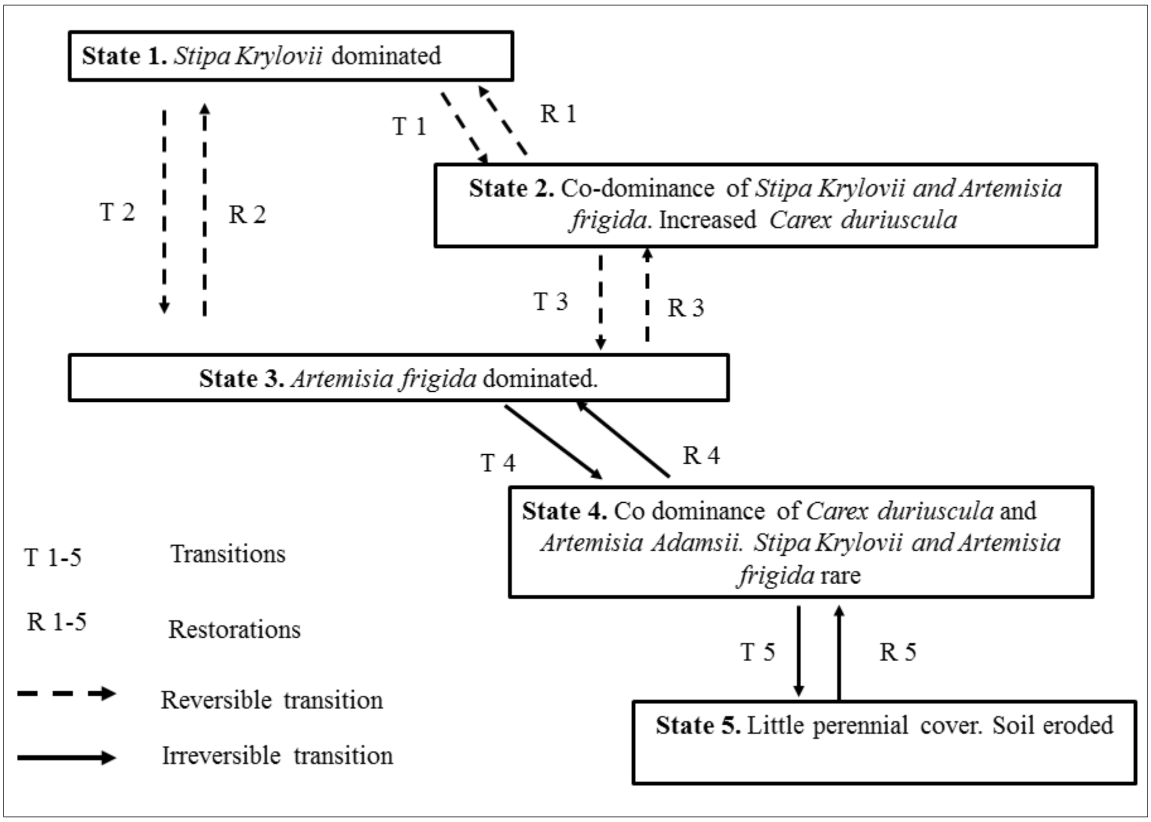

Figure 10. A new State and Transition Model for *Stipa Krylovii* dominating plant community in Undurshireet Soum.

5. CONCLUSIONS

The DCA ordination results suggest that the calcic Ecological Sites should be combined into fewer groups than was originally suggested. This means that their classification should be simplified. More than half of the study plots (17) were placed in calcic sites (calcic sandy, calcic loamy, calcic gravelly), and they contain the palatable perennial grass *Stipa Krylovii* dominated communities.

One Ecological Site represented by one site (the NN) appears to resemble the Sub-irrigated (SI) Ecological Sites and should be considered as belonging to that group.

DCA appears to be a useful tool to identify Ecological Sites but the data were too limited for quantitative statistical testing of the State and Transition Models for *Stipa Krylovii* dominating communities. Based on descriptive statistics and PCA ordination it is suggested that the proposed model should be simplified. For a proper testing of the State and Transition Model, a different sampling design such as stratified random sampling should be used in order to collect suitable data.

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