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Plant community changes in the steppe zone in Mongolia

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ABSTRACT

The steppe zone is an ecosystem under intense human pressure and prone to land degradation, and its plant community structure has considerably changed in recent years. Long-term studies on vegetation communities in arid areas are vital for understanding their dynamics and for describing potential changes in plant communities caused by climate change in the future. The objective of this study was to describe the changes in plant communities in the dry steppe zone over an extended period. In these steppe communities, we selected a reduction in species richness, diversity and plant cover as an indication of vegetation degradation. We conducted a long-term monitoring study at the permanent plots selected in the Rashaant and Gurvanbulag soums of Bulgan province and Burd soum of Uvurkhangai province from 2011 to 2023. As a result, a clear downward trend in species richness was observed in each monitoring plot, but it was not statistically significant. The average species diversity was 1.7 and ranged from 0.7 to 2.6. It fluctuated annually but gradually decreased from 1.8 to 1.4 on average during 2011-2023. For the vegetation cover, an increasing trend was observed at some monitoring sites, however, this was related to an increase in digression species cover. We concluded that the composition of plant communities has changed into degraded conditions, however, there are no directional changes in the vegetation communities.

Keywords: *Bulgan, Species composition, Diversity, Long-term study, Permanent plots, Vegetation dynamics*

Хуурай хээрийн ургамал бүлгэмдлийн өөрчлөлт

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ХУРААНГУЙ

Хуурай хээрийн бүс нь хүний үйл ажиллагааны нөлөөнд эрчимтэй өртдөг, газрын доройтолд эмзэг экосистем бөгөөд энд ургамал бүлгэмдлийн бүтэц, бүрэлдэхүүн мэдэгдэхүйц өөрчлөгдөж байна. Хуурай, гандуу бүс нутгийн ургамал бүлгэмдлийг урт хугацаанд судлах нь түүний динамикийг ойлгох, ирээдүйд учрах уур амьсгалын өөрчлөлтийн нөхцөлд ургамал бүлгэмдэл хэрхэн өөрчлөгдөх боломжийг тодорхойлох суурь болох юм. Бидний судалгааны ажлын зорилго нь хуурай хээрийн бүсэд ургамал бүлгэмдлийн өөрчлөлтийг урт хугацаанд судлахад оршино. Эдгээр хээрийн бүлгэмдлүүдэд зүйлийн баялаг, олон янз байдал болон тусгагийн бүрхцийн бууралтыг ургамал нөмрөгийн доройтлыг илэрхийлэх индикатораар сонгон ажигласан. Бид урт хугацааны мониторинг судалгааг 2011-2023 онд Булган аймгийн Рашаант, Гурванбулаг, Өвөрхангай аймгийн Бүрд сумдад сонгон авсан мониторинг цэгүүдэд хийж гүйцэтгэлээ. Судалгааны дүнгээр ургамлын зүйлийн бүрдэл нь бүх мониторинг цэгүүдэд мэдэгдэхүйц буурах хандлагатай байсан боловч энэ нь статистикийн хувьд ач холбогдолгүй байв. Зүйлийн олон янз байдал нь дунджаар 1.7 байх бөгөөд 0.7-2.6 хооронд хэлбэлзэнэ. Хэдийгээр зүйлийн олон янз байдал нь жил бүр харилцан адилгүй байх боловч судалгаа явуулсан 2011-2023 онд 1.8-аас 1.4 болж аажмаар буурсан хандлагатай байв. Ургамлын тусгагийн бүрхцийн хувьд зарим мониторинг цэгүүдэд нэмэгдэх хандлага ажиглагдсан нь доройтлын таниур ургамлын бүрхэц нэмэгдсэнтэй шууд холбоотой. Бидний судалгаагаар ургамал бүлгэмдлийн бүрэлдэхүүн нь доройтсон төлөвт шилжсэн байх боловч ургамал бүлгэмдэлд үндсэн өөрчлөлт гараагүй гэж дүгнэж байна.

Түлхүүр үгс: Булган, Зүйлийн бүрдэл, олон янз байдал, Урт хугацааны судалгаа, Байнгын мониторинг цэгүүд, Ургамлын динамик

1. INTRODUCTION

Mongolian grasslands account for about 2.5% of the world's total grassland area [1] and support the traditional livelihoods of nomadic herders and other sectors of society [2]. As some research results suggest, plant communities have changed dramatically under the influence of climate change and human impact in recent decades [3], [4]. The plant community structure in the steppe zone had considerably changed, the native steppe species have been invaded by digressive or weedy species [5] and the area with sparse vegetation had increased because of a decrease in the species composition, the loss of herbal plants replaced by more xerophytic shrub species [6], [7] in an arid zone of Mongolia including steppe and desert steppe.

A number of research studies have been conducted to identify driving factors on vegetation change in the Mongolian steppe. According to the results, the driving factors differ in various natural zones, however, major two factors are grazing and precipitation in the steppe zone [4], [8], [9]. Many research results illustrated that the rapidly increasing animal load in the past decades has disrupted the natural balance [10], [11] in semi-arid and arid ecosystems which has high vulnerability to degradation and desertification of Mongolia. Overgrazing causes decreased survival of forage plants; the appearance of species with less forage value; changes in the dominant plants; and, finally the complete destruction of original vegetation and its substitution either by ruderal plants or the appearance of bare land [12].

Hence, overgrazing is the major human-induced factor causing vegetation degradation in the Mongolian steppe, it is crucial to make accurate decision on sustainable land use, maintaining and restoring the integrity of this valuable ecosystem. Long-term study on plant community can be used as a basis for biological conservation and management purposes. In dry steppe, the rehabilitation of the plant community depends on its degradation level, it takes approximately ten years to get back healthy condition [12].

As an important component of ecosystem, the plant community can serve as a major indicator of land productivity and its alteration. But it is a dynamic system which depends on various biotic and abiotic factors, particularly in arid regions. In this reason, long-term observations at permanent monitoring sites is significant to detect tendency and response to other driving factors [13-15].

We conducted vegetation study in Central Mongolia during 2011-2023. The objective of this study was to describe the temporal changes in plant communities in the dry steppe zone over an extended period. We hope research results can serve as a basis for further research into the impact of climate change and human activities on vegetation, as well as the development of predictive models for future trends. Furthermore, it will contribute a making decision on restoration and land use management.

2. MATERIALS AND METHODS

The study was conducted on the territories of the Gurvanbulag and Rashaant soums of Bulgan province, the Burd soum of the Uvurkhangai province, Mongolia. It situated at 47-48°N and 103-104°E with altitude ranges from 1189 to 1378 m (Figure 1). The study sites exhibited a dominance of sandy soil, with pH levels ranging from 6.7 to 8.2. The humus content was found to range from 1.1 to 2% in the topsoil. The annual average temperature is 1.3°C, with precipitation averaging 203.4 mm and wind speeds averaging 1.8 m/s, according to data from the Rashaant meteorological station.

The study area represents a dry steppe region of Central Mongolia, which has been classified as the Middle Khalkha according to the phyto-geographical region of Mongolia [16]. All selected plots were subjected to intensive grazing.

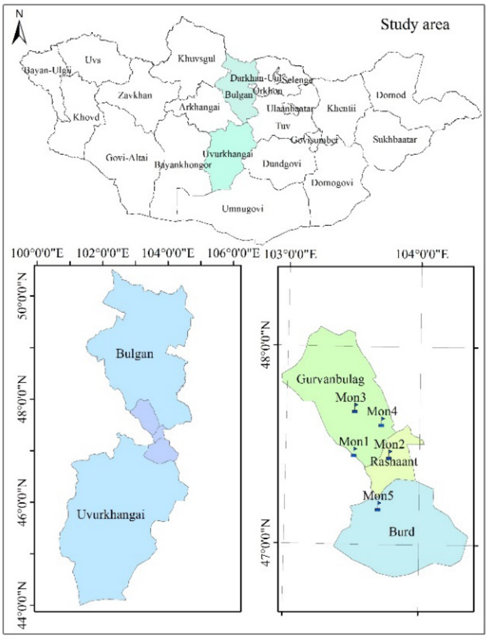

Figure 1. Study area map

We selected 5 sites in order to observe plant community change under climate change and human impact (Figure 1). We established permanent plots of 20m * 20m squares at each sites, with markers at 4 corners. Vegetation data were recorded using 1m * 1m subplots with repetition. We measured number of species, plant cover during the field work. Plots were investigated during the growing season, from July to August, in 2011-2023.

In order to detect change in the communities, we classified plant species into the native species and digression species based on former study results [12], [17]. The native species refers to those that naturally grow in an unchanged community while digression species are those that commonly distribute in degraded areas. This classification is mainly based on water consumption and habitat selection of species.

We calculated Shannon diversity index and all analysis was conducted in R software. We used V.I.Grubov's plant nomenclature [18].

3. RESULTS

Total of 114 species were recorded in the study plots in dry steppe region. Perennial plants dominated in species composition, constituting 83.3%, while annual/biennal plants comprised 16.7%. For the plant life-form, herbaceous plants were dominant in species composition, contributing 92.1%, semi-shrubs are 4.4%, shrubs were 2.6%, trees were 0.9%, respectively. According to ecological group, xerophyte and mezo-xerophyte plants compose 66.6%, petro-xerophyte was 6.1%, mezophyte was 11.4%, xero-mezophyte was 14%, and halophyte was 1.8%.

3.1. Change in species composition

Species richness was 12 at average in 1 m^2, ranging from 5 to 25 during study period. In the first year, richness was 19 ± 5.7, but it decreased to 8.4 ± 2.7 in 2023. The clear decreasing trend was observed at each monitoring plot, but it was not significant (Figure 2).

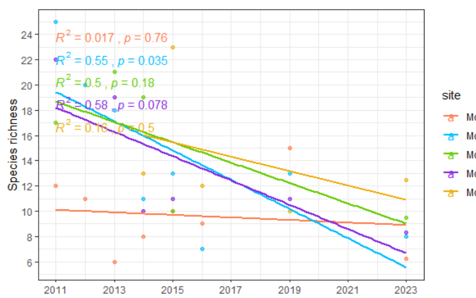

Figure 2. Change in species richness

Species diversity was 1.7, and average value ranged from 0.7 to 2.6. It fluctuated at each year, but gradually decreased from 1.8 to 1.4 during 2011-2023. Figure 3 shows change in species diversity at each plots, illustrating gradual decline of diversity (Figure 3).

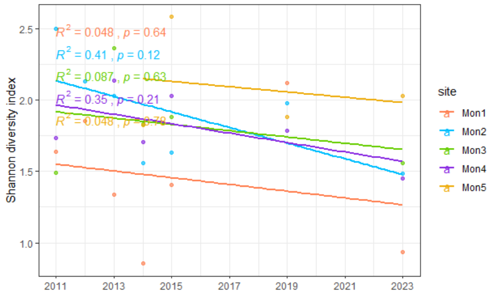

Figure 3. Change in species diversity

3.2. Vegetation cover

Vegetation cover was 45% at average, fluctuating from 20.7 to 77.8 in the steppe. It was 51% in the first year, but decreased to 44.3% in 2023. The change in vegetation cover exhibited distinct patterns across the monitoring plots. Two plots (Mon2 and 4) exhibited an upward trend in vegetation cover whereas three plots (Mon 1, 3 and 5) exhibited a decline (Figure 4). In order to clarify vegetation cover change, we examined participation of digression species in the community.

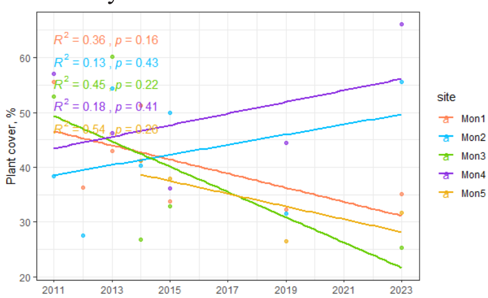

Figure 4. Vegetation cover change in monitoring plots

The proportion of digression species in the total plant cover was calculated at each monitoring plots. The proportion of digression species in total plant cover ranged from 44% to 98%, with an average of 79%. There were no significant changes observed at the three monitoring plots (Figure 5). However, there was a significant increase (p = 0.04) in monitoring plot 4, while significant decrease (p = 0.01) in monitoring plot 3.

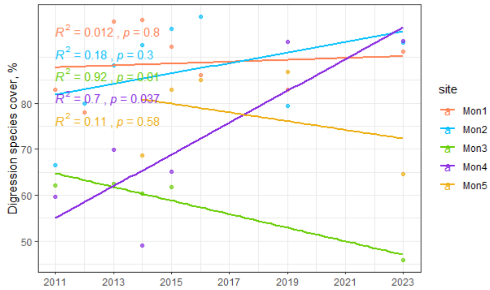

Figure 5. Proportion of digression species in total cover

In 2011, the cover of digression species including *Carex duriuscula, Artemisia frigida, A.scoparia, Chenopodium acuminatum* constituted 60% of the total cover, however, it reached at 93.4% by 2023 at monitoring plot 4. Conversely, a declining trend was observed at the monitoring plot 3, which was caused by a reduction of *Cleistogenes squarrosa* and *Artemisia frigida*.

3.3. Plant communities in the steppe

Mon 1: *Artemisia adamsii – Carex duriuscula* community. Species richness was 8.7 at average, ranging from 6 to 15. It was 12 in 2011, but decreased to 7 in 2023. The plant species such as *Agropyron cristatum, Ajania achilloides, Allium bidentatum, Astragalus galactites, Iris lactea* were not recorded in recent years at this plot. The mean vegetation cover was 42.5%, with a range of 28.6% to 55.6%. *Artemisia adamsii* was predominated and *Carex duriuscula* was subdominant in this community. The cover of *A.adamsii* was exhibited a 25% in 2011, reaching at 40% in 2014 and decreased to 21% in 2023. Monodominance of this species indicate severe degradation of community. This species is a xerohalophyte, which is capable of reproducing through rhizomes and increasing in abundance as soil salinity rises.

Mon 2: *Stipa krylovii – Cleistogenes squarrosa - Artemisia frigida* community. The average species richness was 13.1, fluctuating from 7 to 25. The number of species has declined dramatically, from 25 in 2011 to 7 in 2023. The forbs (*Dianthus versicolor, Gallium verum, Ptilotrichum canescens, Veronica incana* etc) and tussock species (*Festuca lenensis, Koeleria macrantha*) were not occurred in the recent several years. Vegetation cover recorded from 27.5% to 58%, with an average of 48.5%. The plant cover in this plot tended to increase, reaching 58% in 2023. The dominant plant was *Stipa krylovii* in 2011, but *Cleistogenes squarrosa* became dominant in this community in some years. The cover of *A.frigida* and *C.duriuscula,* which are one of the digression species, was initially 0.5% each, but had gradually increased to 12% and 6%, respectively. The rise of total plant cover depended on both cover of digression and native dominant species.

Mon 3: *Cleistogenes squarrosa - Stipa krylovii – Carex duriuscula* community. The species richness was 14.3 in average, fluctuating from 8 to 21. In the initial year, richness was 17, but subsequently declined to 8 in 2023. The onions (*Allium anisopodium, A.leucanthum*) and forbs (*Dontostemon integrifolius, Echinops latifolius, Heteropappus hispidus, Lappula intermedia*) were recorded on only one occasion, or at the most, on the first year. The vegetation cover ranged from 20.7% to 60.2% with an average of 37.3% in this community. It declined from 53% in 2011 to 20.7% in 2023, representing a decrease of almost twice as much. In 2011, the dominant species was *C.squarrosa*, and*S. krylovii* was the subdominant. However, in 2023, *C.duriuscula* became the dominant species in this community.

Mon 4: *Cleistogenes squarrosa – Stipa krylovii – Artemisia frigida* community. The average species richness was 12.3, ranging from 5 to 22. The forbs (*Chamaerhodos erecta, Dontostemon integrifolius, Echinops latifolius, Lappula intermedia, Pulsatilla bungeana, Thalictrum squarrosum*) mainly disappeared from this community and some annual species (*Chamaerhodos erecta, Dontostemon integrifolius, Lappula intermedia*) were episodically recorded throughout the study period. This resulted in a decline in species richness. The vegetation cover fluctuated from 36.1% to 68% with an average of 53% and, it had decreased from 57.1% in 2011 to 36.1% in 2015. However, it has gradually risen and reached at 68.2% in 2023. *Cleistogenes squarrosa* was the dominant species, with a cover of 25%, while *Stipa krylovii* was subdominant with 15% in first years of study. As a consequence of the progressive reduction of this species, however, the dominant species of this community altered by *C.duriuscula* and *A.frigida*.

Mon 5: [Caragana stenophylla] - *Artemisia frigida – Stipa krylovii* community. The species richness exhibited considerable interannual variability with, values ranging from 10 to 23 and an average of 13.8 throughout the study period. But decreasing trend was observed in this plot. The average vegetation cover observed 41.1%, ranging from 27.7% to 41.1%. In 2014, plant cover was 41.1%, reaching at its maximum value, and gradually decreased to 27.7% in 2023. The dominant species of this community was *A.frigida*, followed by *S.krylovii* in the first year. But cover of those species had decreased and altered by *C.squarrosa* in 2023.

4. DISCUSSION

As a result of our study in dry steppe, plant community indicators tended to decrease during study period. Species composition notably decreased in the all monitoring sites. This change mainly related to forb species including *Ajania achilloides, Dianthus versicolor, Echinops latifolius, Pulsatilla bungeana, Allium sp., Thalictrum* *squarrosum, Scabiosa comosa, Sibbaldianthe adpressa* and also annual species including *Salsola collina, Lappula intermedia, Setaria viridis, Chamaerhodos erecta, Dontostemon integrifolius,* grasses such as *Koeleria macrantha, Agropyron cristatum, Stipa sibirica and Festuca lenensis.* Those species were recorded in the first few years of study or occurred just 2-3 years during the study period. Other studies showed same results with species decrease [19], [20].

For the vegetation cover, increasing trend was observed at some monitoring sites, however, this was related to an increase in digression species cover. In those plots, the cover of *Carex duriuscula* and *Artemisia frigida* have risen in recent years while major plant species including *Stipa krylovii, Cleistogenes squarrosa* have decreased. An increase of semi-shrub species in the community is a evidence of land degradation and this results were observed in the steppe [20], [21]. Communities dominated by Carex indicate that soil has light mechanical composition with a small content of humus [6].

At two monitoring plots dominant species replaced by another plant species was observed. Native community species invaded by digression species which are unpalatable and xerophyte. Same research result in Darkhan was illustrated that dominants are replaced by subdominants and semi-shrubs like *Caragana pygmaea, C. microphylla* and *Artemisia frigida* increased in community [20], [23]. Changes in plant community mainly related to precipitation and overgrazing in Mongolia, thus, further study of other driving factors should be conducted in this region.

5. CONCLUSION

Our study in Central Mongolian steppe suggests that the vegetation degradation is occurring in these steppe communities in 2011-2023. This is indicated by a reduction in species richness, diversity and plant cover. The observed decline in species richness in recent years was largely attributable to the disappearance of forbs from the communities during study. The vegetation cover observed variously in different years, but increasing trend was explained by an invasion of digression species. We concluded that composition of plant communities have changed into degraded condition depends on human and climate impact, however, there is no directional changes in the vegetation communities.

REFERENCES

[1]. R. P. White, S. Murray, M. Rohweder, S. D. Prince, and K. M. Thompson. “Grassland ecosystems”. Washington, DC, USA: World Resources Institute. 2000.

[2]. J. Addison, M. Friedel, C. Brown, J. Davies, S. Waldron. “A critical review of degradation assumptions applied to Mongolia’s Gobi desert”. Rangel. J, №34, pp. 125-137, 2012. https://doi.org/10.1071/RJ11013.

[3]. K. Jamiyansharav, M. E. Fernández Giménez, J. P. Angerer, B. Yadamsuren, & Z. Dash. “Plant community change in three Mongolian steppe ecosystems 1994–2013: applications to state and transition models”. Ecosphere, 9(3). 2018. https://doi.org/10.1002/ecs2.2145.

[4]. T. Hilker, E. Natsagdorj, R. H. Waring, A. Lyapustin, & Y. Wang. “Satellite observed widespread decline in Mongolian grasslands largely due to overgrazing”. Global Change Biology, 220(2), pp. 418-428. 2022. https://doi.org/10.1111/gcb.12365.

[5]. E. V. Danzhalova, S. N. Bazha, & E. Ariunbold. “The Structure of Plant Communities in the Dry Steppes of Central Mongolia and their Response to

Irrigation”. Arid Ecosystems, 1(3): pp. 171–176, 2011. https://doi.org/10.1134/S2079096111030024.

[6]. M. A. Zharnikova, Z. B. Alymbaeva, B. Tsydypov, A. A. Ayurzhanaev, E. Z. Garmaev, & A. K. Tulokhonov. “The Current State of Steppe Ecosystems in the Arid Zone of Mongolia (a case study of the model site of Mandalgovi)”. IOP Conference Series: Earth and Environmental Science, 012047-012047. 2018. https://doi.org/10.1088/1755-1315/211/1/012047.

[7]. S. N. Bazha, P. D. Gunin, E. V. Danzhalova, Y. I. Drobyshev, T.I. Kazantseva, E. Ariunbold, D. Myagmarsuren, S. Khadbaatar, & G. Tserenkhand. “Invasive successions as the indicator of desertification of dry steppe by way of example of Central Mongolia”. Russian Journal of Biological Invasions, 4(6): pp. 223–237, 2015.https://doi.org/10.1134/S2075111715040025.

[8]. K. Jamiyansharav, M.E. Fernández Giménez, J. P. Angerer, B. Yadamsuren, & Z. Dash. “Plant community change in three Mongolian steppe ecosystems 1994–2013: applications to state and transition models”. Ecosphere, 9(3), e02145. 2018. https://doi.org/10.1002/ecs2.2145

[9]. Y. Y. Liu, J. P. Evans, M. F. McCabe, R.A. De Jeu, A. I. van Dijk, A. J. Dolman, I. Saizen. “Changing climate and overgrazing are decimating Mongolian steppes”. PloS one, 8(2), e57599. 2013. https://doi.org/10.1371/journal.pone.0057599.

[10]. S. N. Bazha, P. D. Gunin, E. V. Danzhalova, Y. I. Drobyshev, A. V. Prishcepa. “Pastoral degradation of steppe ecosystems in Central Mongolia. Eurasian Steppes. Ecological problems and livelihoods in a changing world”. Springer, Dordrecht, pp. 289–319, 2012. https://doi.org/10.1007/978-94-007-3886-7_10.

[11]. D. Bulgamaa, S. Sumjidmaa, B. Brandon, U. Budbaatar. “National Report on the Rangeland Health of Mongolia: Second Assessment”. Ulaanbaatar, pp. 16, 2018. (In Mongolian).

[12]. O. Chognii. “Characteristic of change and restoration of degraded pasture in forest steppe and steppe zone in Mongolia”. Ulaanbaatar, pp. 179–300. 2001.

[13]. N. P. Dunnett, A. J. Willis, R. Hunt, and J. P. Grime. “A 38-year study of relations between weather and vegetation dynamics in road verges near Bibury, Gloucestershire”. Journal of Ecology, 86(4), pp.610-623, 1998. https://doi.org/10.1046/j.1365-2664-2001.00621.x

[14]. A. R. Watkinson, and S.J. Ormerod. “Grasslands, grazing and biodiversity: editors' introduction”. Journal of applied Ecology, pp.233-237, 2001.

[15]. F. M. Fischer, K. Chytrý, J. Těšitel, J. Danihelka, and M. Chytrý. “Weather fluctuations drive short term dynamics and long term stability in plant communities: a 25 year study in a Central European dry grassland”. Journal of Vegetation Science, 31(5), pp.711-721, 2020. https://doi.org/10.1111/jvs.12895.

[16]. V. I. Grubov. “Key to the vascular plants of Mongolia (with an atlas)”. Leningrad, Nauka: p. 442, 1982. (in Russian)

[17]. I. Tuvshintogtokh. “Vegetation of Mongolian steppe”. Ulaanbaatar, pp. 42–47, 2014.

[18]. V. I. Grubov. “Key to the Vascular

Plants of Mongolia". 2008. Ulaanbaatar, Mongolia. Gan print.

[19]. I. Tuvshintogtokh, B. Ankhtsetseg, A. Batbaatar. "Structure and composition of steppe subtypes and their changes". Scientific Proceedings Institute of Botany, №24, pp. 97-107, 2012.

[20]. Ya. Baasandorj, S. Badrakh. "Some issues of grazing ecology in the steppe zone". Ulaanbaatar, pp. 64-84, 2010.

[21]. D. Bulgamaa, D. Burmaa. "Some results of grazing effect on rangeland health in several natural zones". Pasture study – new era, Mongolian Society for range management, pp. 25-32, 2010.

[22]. O. Munkhzul, Ch. Khosbayar, B. Bayarjargal. "Dynamics of forb-grass community in mountain-steppe". Scientific Proceedings Institute of Botany, №24, pp. 76-87, 2012.

[23]. B. Dashnyam. "Flora of Eastern Mongolia". Institute of Biology, Mongolian Academy of Sciences. 1974.