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Evaluation of the Influence of Anthropogenic Disturbances on Pasture Grazing Capacity and Its Vulnerability in Arid and Semi-Arid Regions (A case study in Mongolia)

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ABSTRACT

This study aims to assess the impacts of both climate change and anthropogenic disturbances such as mining development and urbanization on pasture grazing capacity and its vulnerability in arid and semi-arid regions. To achieve the purpose, we have developed an integrated model to evaluate the pasture grazing capacity (*GC*), grazing pressure (*GP*) and vulnerability (*VI*). The model was applied to four target areas: an urban area (Ulaanbaatar) and steppe area (Altanbulag) in semi-arid regions and a mining area (Khanbogd) and desert (Manlai) in arid regions. The results revealed that *GP* greatly exceeded *GC* in the urban and mining areas, where presented higher vulnerability than other areas. The order of *GC*, *GP* and *VI* was: (1) *GC*: steppe area > urban area > desert area > mining area, (2) *GP*: urban area > steppe area > mining area > desert area, and (3) *VI:* urban area > mining area > desert area > steppe area. Finally, the change rate of *GC*, *GP* and *VI* in last two decades implied that comparing with climate change; anthropogenic disturbances had more significant impacts on pasture vulnerability.

Keywords: *Anthropogenic disturbances, climate change, pasture grazing capacity, vulnerability, Mongolia*

1. INTRODUCTION

The arid and semi-arid areas occupy about 41% of the earth's land area, there are more than 2 billion people living there. Climate changes have a large influence on water resources in such areas. Meanwhile, anthropogenic disturbances such as overgrazing, cultivation, mining development and urbanization have also significant effects on water resources [1] as well as the pasture ecosystems. Therefore, it is an urgent task to clarify those influences to propose effective adaptation strategies or polices for the sustainable management.

The first principle of pasture management is to balance the available forage supply with livestock demand. Grazing capacity (also known as carrying capacity) is the amount of forage available for grazing animals in a specific pasture or field. Site characteristics, such as soil, water, plant, and topography of the pasture, can impact grazing capacity. Forage production and availability for grazing can also affect carrying capacity [2]. In this study, we attempt to develop an integrated model considering those entire site characteristics mentioned above to evaluate the pasture grazing capacity (GC), grazing pressure (GP) and its vulnerability (VI) on the base of water resource under the influence of both climate change and anthropogenic disturbances.

2. METHOD AND CASE STUDY AREAS

The structure of our developed model was shown in Figure 1, in which the major indicators of *GC*, *GP* and *VI* can be estimated by the following equations:

$$GC = FY * hi * pi * ai / intake \quad (1)$$
$$GP = livestock / area \quad (2)$$
$$VI = GP / GC \quad (3)$$

Where, the forage yield (*FY*) was estimated by a remote sensing-based model based on the MOD17 algorithm, which can be found in the MOD17 User's Guide [3; 4]. The accessibility (ai) was cited from literature [5]; the harvest index (hi) and palatability (pi) were referred from local investigations [6].

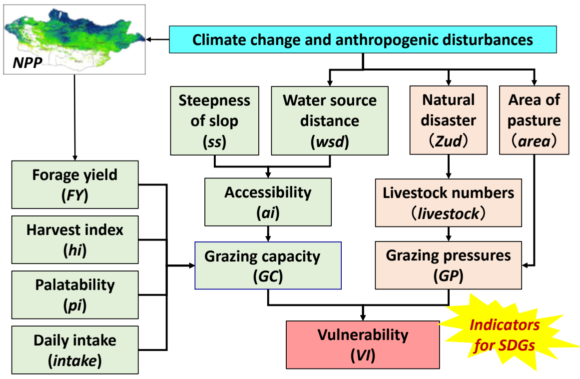

Figure 1. The structure of an integrated model to evaluate *GC*, *GP* and *VI*

The model was applied to four case study areas: an urban area (Ulaanbaatar) and a steppe area (Altanbulag) in semi-arid regions and a mining area (Khanbogd) and desert (Manlai) in arid regions (Figure 2). The input data included high-precision topographical data derived from ALOS World 3D–30m (Figure 3) to estimate the steepness of slop (*ss*) and the land-use data (Figure 4) derived from Landsat image to estimate the pasture area (*area*).

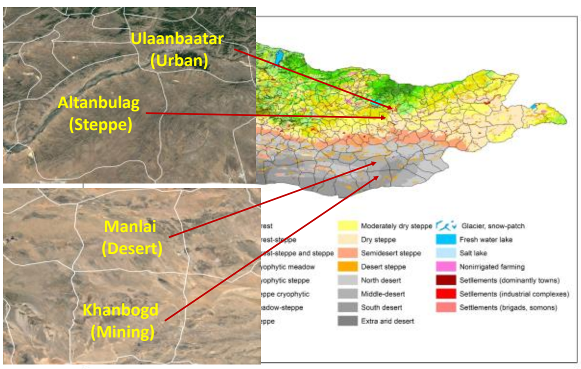

Figure 2. Case study areas: an urban area (Ulaanbaatar) and steppe area (Altanbulag) in semi-arid regions and a mining area (Khanbogd) and desert (Manlai) in arid regions in Mongolia

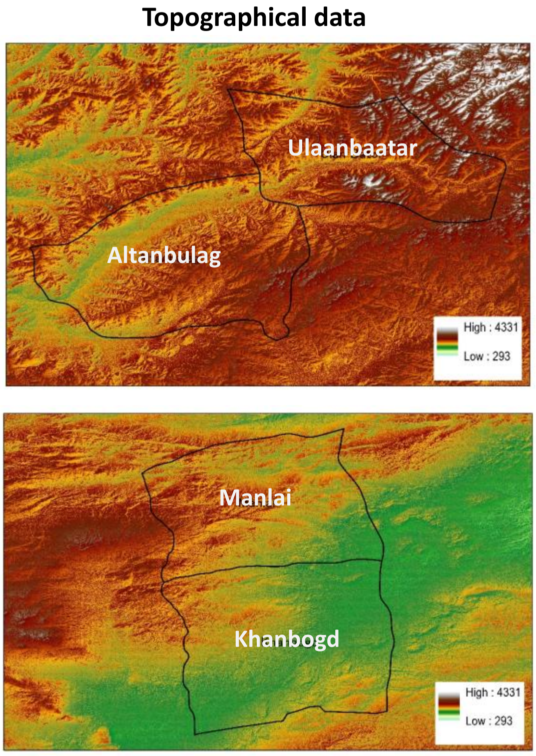

Figure 3. High-precision topographical data derived from ALOS World 3D–30m

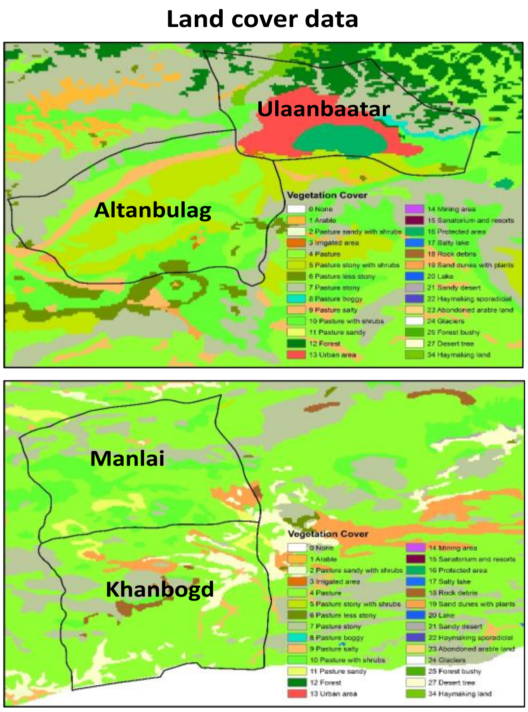

Figure 4. High-precision land use data derived from Landsat image

The meteorological factors, such as air temperature (*Ta*), precipitation (*P*), as well as the surface water deficit index (*WDI*) were derived from ECMWF (European Centre for Medium-Range Weather Forecasts) meteorological reanalysis data (Figure 5). Finally, the statistical data of livestock (e.g., cattle, horses, sheep, goats, camels) population were collected to estimate *GP*.

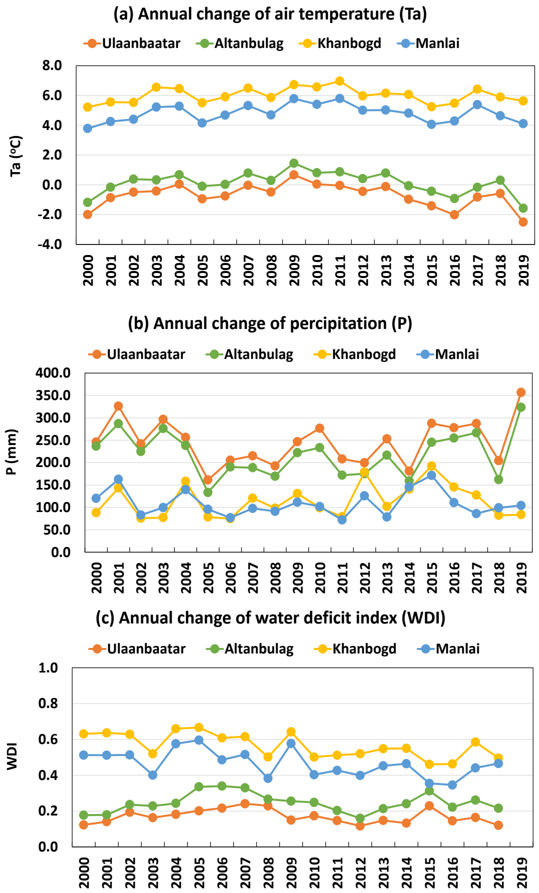

Figure 5. Annual changes of *Ta*, *P* and *WDI*

3. RESEARCH RESULTS

3.1. The regional differences of GC, GP and VI

The annual mean forage yield (*FY*) in four areas during 2000-2019 were estimated, which shows a great regional difference with the value of 829.7 kg C/ha, 1016.0 kg C/ha, 199.9 kg C/ha and 234.4 kg C/ha in Ulaanbaatar, Altanbulag, Khanbogd and Manlai respectively (Figure 6a). The corresponding theoretical grazing capacity (*GC*) were estimated as 0.49 SU/ha, 0.70 SU/ha, 0.06 SU/ha and 0.07 SU/ha, respectively. The steppe area (Altanbulag) in semi-arid regions shows the highest *FY* and *GC* compared with the other areas (Figure 6b).

Based on the data of livestock population (*livestock*) from Statistic Yearbook of Mongolia and the pasture area (*area*) estimated from the land-use data, the actual *GP* during 2000-2019 were estimated as 1.71 SU/ha, 1.24 SU/ha, 0.14 SU/ha and 0.14 SU/ha respectively, which showed a large regional difference between the semi-arid regions and arid regions (Figure 6c).

Finally, the vulnerability index (*VI*) during 2000-2019 was estimated, which shows that all these regions were severely overgrazed with the value of 353%, 173%, 211% and 197% respectively, in which the highest *VI* were occurred the urban area (Ulaanbaatar) in semi-arid regions (Figure 6d).

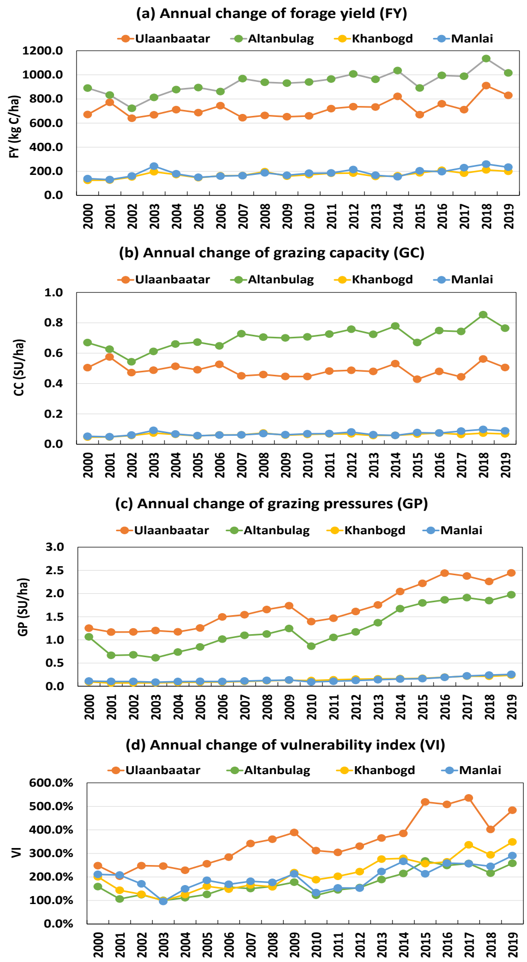

Figure 6. Estimated annual changes of *GC*, *GP* and *VI*

3.2. The change rate of GC, GP and VI

To compare the change rate of *GC*, *GP* and *VI* in four regions, we also estimated the slope of curves of these indicators from 2000 to 2019. The results showed that the change rates of *GC* were -0.001

SU/ha/year, 0.009 SU/ha/year, 0.001 SU/ha/year and 0.001 SU/ha/year in Ulaanbaatar, Altanbulag, Khanbogd and Manlai respectively, which shows that there were almost no significant changes in all regions. Because the change rate of *GC* was highly related to climate change, the result implied that the climate change has not caused the significant changes in *GC* in last two decades.

However, the change rates of *GP* were 0.072 SU/ha/yr, 0.070 SU/ha/yr, 0.009 SU/ha/yr and 0.007 SU/ha/yr, respectively. As a result, the annual change rates of *VI* were 15%, 8%, 11% and 5% respectively, in which both the urban area (Ulaanbaatar) and mining area (Khanbogd) had a larger increase rate compared with the steppe area (Altanbulag) and desert area (Manlai). Because the change rate of *VI* was highly related to human-induced grazing pressures, the result implied that anthropogenic disturbances have caused the significant changes in *VI* in last two decades.

4. CONCLUSIONS

To assess the impacts of both climate change and anthropogenic disturbances on pasture grazing capacity and its vulnerability, we have successfully developed an integrated model to evaluate *GC*, *GP*, and *VI*, which was applied to four target areas: an urban area (Ulaanbaatar) and steppe area (Altanbulag) in semi-arid regions and a mining area (Khanbogd) and desert (Manlai) in arid regions. The results revealed that *GP* greatly exceeded *GC* in the urban and mining areas, where presented higher vulnerability than other areas. The order of *GC*, *GP* and *VI* was: (1) *GC*: steppe area > urban area > desert area > mining area, (2) *GP*: urban area > steppe area > mining area > desert area, and (3) *VI:* urban area > mining area > desert area > steppe area.

Finally, the change rate of *GC*, *GP* and *VI* in last two decades implied that comparing with climate change, the anthropogenic disturbances had more significant impact on pasture vulnerability. We are now trying to use the integrated model to evaluate the efficiency of adaptation strategies, such as well construction to reduce the distance to water sources (*wsd*), forage planting to enhance the harvest index (*hi*), livestock population management to reduce grazing pressure (*GP*), and so on.

AUTHORS' CONTRIBUTIONS

Wang, Q-X designed the project, developed the theoretical framework, and wrote the manuscript with support from T.Okadera and T.Nakayama. O.Batkhishig, D.Battogtokh and U.Bayarsaikhan supported local investigation, research target area selection and data collection. All authors discussed the results and contributed to the final manuscript.

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REFERENCES

[1] Nakayama, T., Q-X. Wang, and T. Okadera. Evaluation of spatio-temporal variations in water availability using a process-based eco-hydrology model in arid and semi-arid regions of Mongolia. Ecol. Model., 440: 109404, 2021. DOI:https://doi.org/10.1016/j.ecolmodel.2020.109404

[2] Society for Range Management. 1998. Glossary of terms used in range management, fourth edition. Edited by the Glossary Update Task Group, Thomas E. Bedell, Chairman.

[3] Running, S., R. R. Nemani, F. A. Heinsch, M. Zhao, M. Reeves, and H. Hashimoto. A continuous satellite-derived measure of global terrestrial primary production. BioScience, 54(6): 547-560. 2004. DOI: https://doi.org/10.1641/0006-3568(2004)054[0547:ACSMOG]2.0.CO;2

[4] Zhao, M., F. A. Heinsch, R. R. Nemani, and S. W. Running. Improvements of the MODIS terrestrial gross and net primary production global data set. Remote Sensing of Environment. 95: 164–176. 2005. DOI: https://doi.org/10.1016/j.rse.2004.12.011

[5] Holechek, J.L., R.D. Pieper and C.H. Herbel. 2004. Range Management: Principles and Practices. Prentice Hall, New Jersey.

[6] Tibebu Kochare, Berhan Tamir, Yisehak Kechero. Palatability and Animal Preferences of Plants in Small and Fragmented Land Holdings: The Case of Wolayta Zone, Southern Ethiopia. Agri Res & Tech: Open Access J. 2018; 14(3): 555922. DOI: https://doi.org/10.19080/ARTOAJ.2018.14.555922