INVESTIGATING THE DRAWBACKS OF NOMADIC HERDING IN MONGOLIA: The Effect of Livestock on Pastoral Land Degradation by Species Type and its Potential Impact on Livestock Production

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Abstract

In this thesis, I examine the effect of livestock on pastoral land degradation in Mongolia by species type (horse, cattle, camel, sheep, and goat) and, conversely, the potential impact of pastoral land degradation on livestock production. For the analysis, I employ the Ridge regression analysis technique with a fixed effects model using panel data from 21 provinces over ten years (2012-2021). The panel regression models estimate that goats have the highest degrading impact on pastoral land degradation. A one percent increase in goat population leads to a 0.12 percent increase in degraded pastoral land (both measured as per hectare of non-degraded pastoral land), controlling for other factors. Moreover, it is estimated that a one percent increase in the degraded pastoral land in the previous period leads to a 0.9 percent decrease in the current year's livestock production, all else being equal.

Keywords: Pastoral land degradation, livestock, Mongolia

JEL Classification: Q15, Q24, Q51

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1. Introduction

The livestock sector is the key agricultural sector in Mongolia, accounting for about 90 percent of the country's agricultural production and employing 1 in 4 Mongolians (IMF, 2019). Yet, due to the uncontrolled rise in the number of livestock around the country, and underdeveloped pasture management standards, the country is experiencing rapid land degradation.

1.1. The Rise of the Livestock Population in Mongolia

Nomadism is an inseparable part of Mongolian cultural identity. For centuries the basic means of livelihood of the Mongolian people have been pastoral nomadism, namely, the herding of five kinds of animals (horses, cattle, sheep, goats, and camels) throughout the hilly steppes between Siberia and northern Mongolia (Humphrey, 1978). Herders in contemporary Mongolia continue to play a crucial role in the livelihoods of Mongols, following traditional ways of raising livestock by allowing them to graze freely in the open grasslands. They were able to maintain this practice in the contemporary world, partially because the Mongolian government did not impose any restrictions on land use and access in the plains of the rural area, thus allowing the herders to travel and graze their animals freely (an example of free herding is shown in Figure 1); and partially due to negligence from the country's government in the systematic development of the livestock sector, since the country transitioned into a market economy system in the early 1990s.

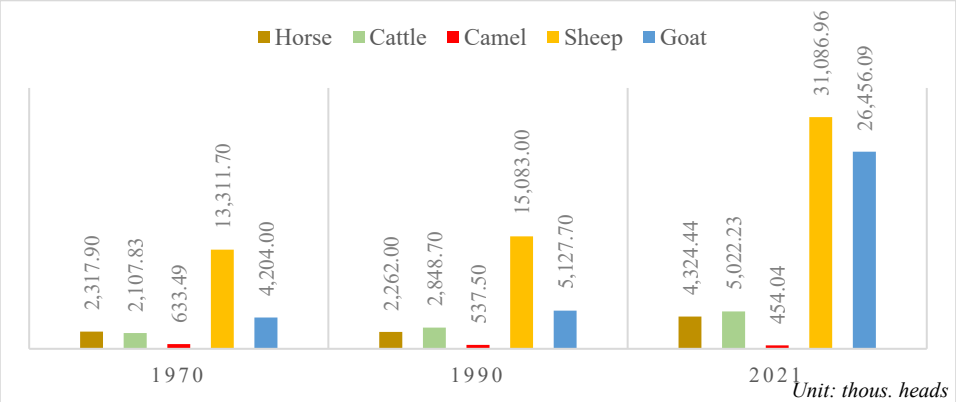
Figure 1. Young Mongolian Herder and Grazing Goats

Source: The Nature Conservancy (n.d.)

In 1995, the Mongolian Parliament passed the Law on Environmental Protection, and in 2002, the Law on Land, both of which regulates pastoral land use and protection of the land. Through the Law on Land, the right to regulate and protect the pastoral lands in the province is given to the legislative bodies of each province and village. Therefore, the implementation and effectiveness of these regulations vary by province and village and based on the current conditions, it is hard to tell how well these laws and regulations have been implemented.

Before the 1990s, Mongolia was under a socialistic regime and the livestock sector was directly regulated by the government. Therefore, overgrazing of grassland and the uncontrolled rise of livestock are relatively new issues in the country that came as by-products of the market economy. According to the National Statistics Office of Mongolia (2023), before and at the beginning of the market economy, between 1970 and 1990, sheep and goats populations ranged between 13-15 million and 4-5 million respectively. However, 31 years after the transition into a market economy (as of 2021) the number of sheep and goats spiked to 31 million and 26 million respectively (Figure 2).

Figure 2. Livestock Population by Type



Source: National Statistics Office of Mongolia (2023)

In addition to the market economy transition which enabled property privatization, the increase in the wool and cashmere market demands (Wei and Zhen, 2020) is one of the main driving

forces of the sheep and goats population skyrocketing. According to Ganchimeg B. (2023), Mongolia produces 48 percent of the total raw cashmere in the world.

Moreover, up until 2021, the Mongolian government continued a practice of rewarding the herders with the highest amount of livestock (also known as "a herdsman of thousands"), which was similar to the practice introduced in the 1940s to incentivize poverty-stricken herders to raise their livestock (Baatarkhuyag, 2010). While the amount of the award was not significantly large (less than 100 USD), the recognition and praise that was received with the award might have been one of the contributing factors that incentivized herders to increase and keep their livestock population at higher levels. In 2021, the government made changes to the rules of the award, incorporating the components of pastoral land capacity and quality and incentivizing herders to focus more on the quality rather than the quantity of their livestock (Mongolian Government Resolution No. 5 of 2021).

In addition, until January 2021, herders in Mongolia were exempt from taxes (historically, once in 1998, herders paid similar taxes. However, the law was valid only for one year), providing strong incentives for herders to raise and maintain their livestock population at higher levels. In 2020, the Parliament of Mongolia approved the Law on Livestock Population Taxation, which became effective in 2021. Through this law, herders are now required to pay taxes on each of their livestock heads, twice a year (in July and December). On average, based on the author's calculations using statistical data from the National Statistical Office (2023), the taxes on each head of a goat is 1000 tugriks (0.28USD; equivalent to 0.7% of the estimated market value of a goat as of 2022), on each head of a camel is 150 tugriks (0.04 USD; equivalent to 0.01% of the estimated market value of camel as of 2022), on each head of horse 800 tugriks (0.23 USD; equivalent to 0.07% of the estimated market value of the horse as of 2022), on each head of cattle 500 tugriks (0.14 USD; equivalent to 0.04% of the estimated market value of cattle as of 2022), and on each head of the sheep it is set at 900 tugriks (0.26 USD; equivalent

to 0.4% of the estimated market value of sheep as of 2022). The law dictates that the tax on each head of livestock species can be zero and should not exceed 2000 tugriks (0.57 USD).

1.2. Pastoral Land Degradation in Mongolia

Mongolia is a landlocked country located between Russia to the north and China to the south and has a vast land area of 1.5 million square kilometers (Sanders, 2023). The country's administrative division consists of 21 provinces (also known as "aimak"), each of which falls under one of the four rural regions (central, western, eastern, and the mountainous region which is called "khangai"), and the capital city of Ulaanbaatar (National Statistics Office of Mongolia, 2023).

According to the Land Evaluation Report (LER) of 2021 by the Agency for Land Administration and Management of Mongolia (ALAMM), 73 percent of the country's land is used for agricultural purposes. Within the agricultural land use classification, around 96 percent is used as pastoral land (LER, 2021). However, due to the unsustainable usage of pastoral lands, the quality of the land in Mongolia is rapidly decreasing.

Table 1. Pastoral Land Degradation

Classifications of Pastoral Land Degradation	**2017**	**2018**	**2019**	**2020**	**2021**
I - Preserved the natural appearance	30%	19%	17%	12%	12%
II - Slightly degraded	54%	38%	35%	43%	45%
III - Moderately degraded	12%	19%	22%	21%	18%
IV- Strongly degraded	4%	20%	21%	18%	17%
V - Significantly degraded	0%	4%	5%	6%	8%
Total	100%	100%	100%	100%	100%

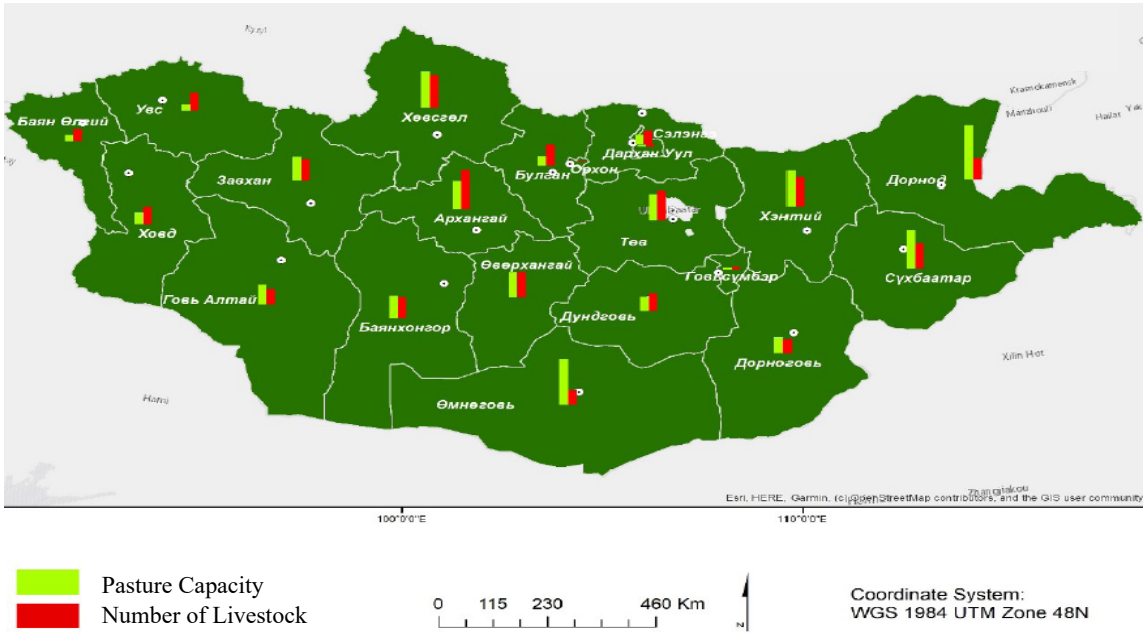
Source: Land Evaluation Report of Mongolia (2021)

As can be seen from Table 1, from 2017-2021, the proportion of significantly degraded land has increased from zero to 8 percent, while the proportion of land that preserved its natural appearance decreased by 60 percent.

1.3. Pastoral Land Capacity and the Role of Livestock

Although many different socioeconomic and environmental factors could be contributing to and systematically interacting with the rapid land degradation, the rise of livestock population that exceeds the capacity of pastoral land which then leads to overgrazing of animals is one of the main reasons behind land degradation (Batkhishig, 2013).

Figure 3. Winter and Fall Pasture Capacity of 2021-2022 (by sheep heads)



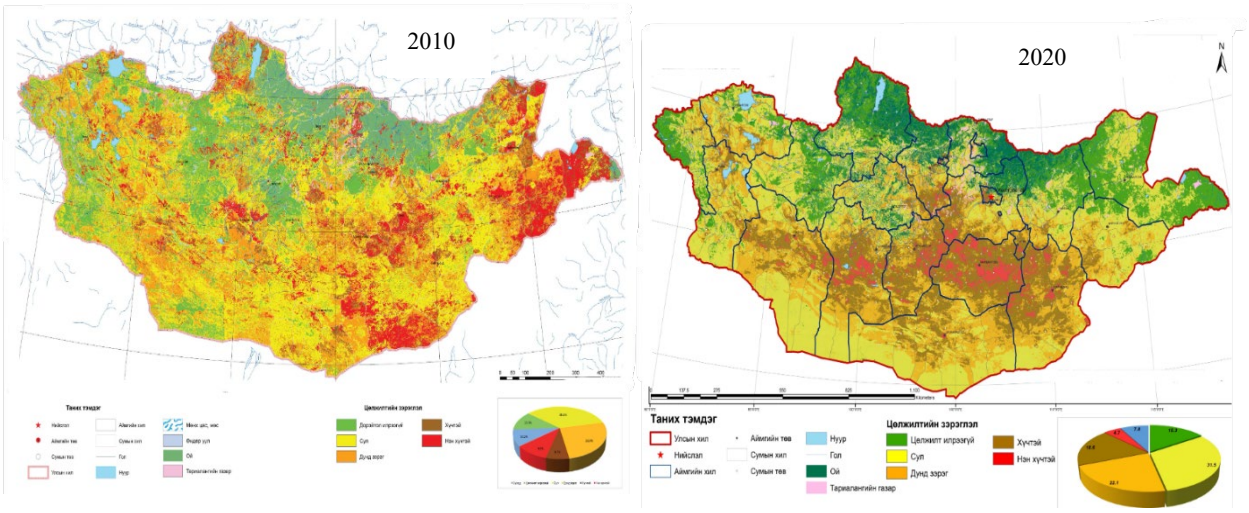
Source: Land Evaluation Report of Mongolia (2021)

Figure 3 shows the map of Mongolian territory by its administrative units. There are in total 21 provinces, on each of which the green shaded bar represents their pasture capacity while the red bars illustrate the livestock population in respective provinces. Based on this illustration, during the years 2021-2022, only 42 percent (9 out of 21) of the provinces appear to have a pasture capacity that is sufficient for the livestock population in the area. However, the majority of the provinces (58 percent) have a livestock population that far exceeds their pastoral land capacities.

1.4. Desertification Risks in Mongolia

Continued land degradation could eventually lead to desertification if no interventions are taken. Thus, desertification is one of the risks that Mongolia is currently facing. Figure 4 illustrates ten years comparison (2010 vs 2020) of desertification assessment throughout the country by their severity levels. Parts marked with red imply significant signs of desertification observed in the area, brown territories imply strong signs of desertification, orange implies moderate, yellow implies slight, and green implies no signs of desertification observed in the area.

Figure 4. Desertification Assessment, 2010 vs. 2020



Source: Desertification Information System, Ministry of Environment and Tourism of Mongolia (2020)

An interesting shift that is illustrated in these maps is that in 2010, many parts of the country have shown strong signs of desertification. However, ten years later, in 2020, the desertification signs have been switched from significant to strong and moderate levels. Moreover, the northern part of the country seems to have become greener. While this is a somewhat positive change, the majority part of the country is still showing slight to moderate signs of desertification. Thus, the country remains vulnerable to desertification. The comparison values of the assessment are shown in Table 2.

Table 2. Desertification Assessment (2010 vs. 2020)

Assessment Year	Areas Slight Signs	Areas with Moderate Signs	Areas with Strong Signs	Areas with Significant Signs	% of Total Area
2010	35.3	25.9	6.7	9.9	77.8
2020	31.5	22.1	18.6	4.7	76.9

Source: Desertification Information System, Ministry of Environment and Tourism of Mongolia (2020)

According to the assessment results shown in Table 4, in 2020, the total area that shows signs of desertification decreased by 0.9 percentage points compared to 2010. However, areas with strong signs of desertification increased by 11.9 percentage points. These results illustrate that the need for intervention in land degradation is crucial in order to mitigate the risk of desertification.

1.5. Climate Change in Mongolia

The issue of land and overall environmental degradation cannot be separated from the climate change issue, which is one of the most pressing issues currently facing humanity. Countries with dryland ecosystems like Mongolia are especially sensitive to climate change, thus, even small changes in temperature and precipitation can result in a major ecosystem response (Kowal et al. 2021). In fact, Mongolia is already experiencing a higher and faster temperature rise than the global average (2.5C° in Mongolia vs. 1.2–2.0C° worldwide), according to the 2020 report by the National Centers for Environmental Information.

1.6. Motivation for this Study

In the past few decades, many researchers have studied and identified the negative effect of overgrazing on pastoral lands in Mongolia and broader issues related to climate change and migration. However, there is a lack of research that focuses on the types of livestock species that might be having the most impact on land degradation. Thus, narrowing the study focus to livestock species types could help develop and implement policies and regulations that are

more efficient than those that focus on the overall amount of livestock population and do not differ across types.

Moreover, currently, to the author's knowledge, there appear to be no studies on how degraded pastoral land would potentially impact livestock sector production since most researchers focus on the opposite effect, which is the effect of the livestock sector's production on the environment. Therefore, the motivation of this study is to help raise public awareness about the different impacts that livestock have on pastoral lands depending on their species type and the impact of degraded pastoral land on livestock production, motivate other researchers to study this topic in-depth from different angles, and potentially help the policymakers in taking targeted policy measurements against pastoral land degradation and uncontrolled rise of livestock populations.

2. Literature Review

2.1. Overview of the Literature on Land Degradation and Livestock

Tragedy of Commons

Many countries around the world have experienced (and continue to experience) the issue of land degradation due to livestock overpopulation and grazing. However, the timing of these experiences may vary by country and region, and the cause of the land degradation issue may not simply and solely be related to the overgrazing of the animals. For example, in the United States (US), in particular, in the arid western part of the US, the issue of overgrazing and rapid land degradation arose, following the Supreme Court's decision in the 1890s, which declared the public lands of the US "free to the people who seek to use them where they are left open and unenclosed...." (Hess and Holecheck, 1995). In their 1995 study, Hess and Holecheck (1995) highlighted that free access for livestock to public lands leads to market inefficiencies in the form of the so-called Tragedy of the Commons[1] and is an obstacle to building and maintaining sustainable development practices. The issue of the tragedy of the commons was further challenged by authors in the late 1990s. Ward et al. (1998) conducted a study on communal (free grazing) vs. commercial pastoralisms in arid Namibia (Southern Africa) and found that communal farming is not more destructive than commercial farming.

Land Resilience

In 1998, Pamo (a researcher who studied the arid part of Central Africa, Cameroon), found that the productivity and composition of the rangelands might fluctuate in the short run, but in the long run, may adapt to the changed environment and become resilient. However, as Pamo

[1] The Tragecy of the Commons arises when individuals, acting in their own self-interest, consume a shared resource such as land, water, or air at an unsustainable rate, leading to depletion or degradation of the resource and harm to the collective good. More specifically, individuals optimize their land usage not taking into account the externalities of their actions, namely, the negative impact their usage has on land degradation and hence others' benefits of usage. In principle, regulation/tax/subsidy policies can help restore an efficient market outcome.

(1998) notes, this adaptation is sustained only within a certain range — if changes exceed critical thresholds, they may prevent or severely inhibit a later return to the original state.

The Cause of Land Degradation

Until the end of the 1990s, the majority of the research was focused on Northern and Southern Americas. From the beginning of the 2000s, the scope has been broadened to a global level and researchers around the world have started investigating the issue of land degradation and livestock grazing. Even though the studies were conducted in various parts and regions of the world, the studies of the 2000s continued to find similar results related to the common pool issue that was raised in the 1990s. Several of the early 2000s studies highlighted that the most likely cause of land degradation in their study regions (Nepal, Cuba, Kazakhstan, and Iceland) is the grazing of livestock (Wezel and Bender, 2004; Karnieli et al., 2008) and failure to remove domestic livestock before the end of the growing season (Simpson et al., 2001). In addition, Carmona et al. (2013) stated that "in dry habitats, differences in vegetation cover increased consistently along with grazing pressure" and Wang and Wesche (2016) further stated in their study that "heavy grazing reduced overall plant cover." In addition to soil degradation, Lulandala et al. (2022) found that overgrazing could override the positive influence of trees on infiltration capacity and eventually on drainage at deeper soil depth. However, in 2008, when Röder et al., conducted a trend analysis to monitor grazing impact in a rangeland ecosystem in Northern Greece, they were not able to establish a consistent relation between the development of animal stocking rates and vegetation cover, concluding that this could be due to specific characteristics of the grazing system, as well as to the community aggregation level corresponding to the available animal statistics.

Level of Land Degradation

It is often useful to distinguish the level of land degradation since the possibility of reversing the damage depends on the damage levels. Especially when the level of land degradation is at

its highest level, which usually occurs in the longer term, often the damage is irreversible. Upon conducting a study in Morocco, Kouba et al. (2018) stressed that in the areas with higher levels of land degradation due to high livestock pressure, there is little or no chance of recovering the land bringing it back to its initial stage. In the short term, however, the researchers (Maceroum and Chenchouni, 2022) found that vegetation by grazing has not affected the edaphic environment and therefore, urgent land restoration actions could reverse the damage. For example, in their study of the South African region, Kwaza et al. (2020) found that "short-term exclosure from grazing using brush pack trees resulted in increased above-ground presentation yields of grass, soil nutrients, C and N storage in communal rangelands".

Policy Impact on Land Degradation

Several researchers conducted research, focusing on the existing agricultural practices and policies that regulate the livestock sector. Thapa and Guadel (2000) in their study of Nepal revealed that under the existing management and traditional pastoral approach (free grazing), the number of livestock already exceeded the carrying capacity of the land and stressed the need for policy interventions. Simpson and others (2001) upon studying the case of Iceland, denoted that the lack of appropriate regulation of domestic livestock in common grazing areas can be attributed to the limited cultural knowledge of changing and rapidly fluctuating environmental conditions. In some cases (e.g., the grassland contract policy in Tibet and the case of three South African countries), however, grazing policies can fail (Cao et al. 2018) and these policies themselves could become the roots of the problems that they intended to solve (Rohde et al. 2006). Moreover, mitigation policies that provide subsidies to herders for decreasing the grazing intensity could fail, when profits from raising and selling the animals (when the market price is high) prevail over the subsidies that the government could provide in return (Hu, Huang, and Hou, 2019).

One other reason for a policy failure is when there is a lack of accurate data information on the land conditions, as well as limited knowledge of different land management practices, which would limit the effectiveness of land management interventions (Nellis et al. 2008). But this type of constraint can be mitigated with the help of technology. Tasumi et al. (2014) studied the Alpine Rangeland area in Northern India, which had no background data available, and showed that usage of satellite observation tools such as MODIS could be useful for initial evaluations. In their study of Southern Kenya Savanna, Hunter et al. (2020) highlighted that the use of satellite imagery technology like Sentinel-2 could allow assessment and monitoring across large scales at a low cost.

Domesticated vs. Wildlife Herbivores Effect on Land Degradation

When the focus of the study is extended to wildlife herbivores, some researchers find results that support a traditional (nomadic and free-range) way of pasturing practices. In their 2018 study of African Savanna, Russell, Tyrrell, and Western found that the traditional Maasai pastoralism, which allowed free-range movement and coexistence of domesticated and wild animals was more sustainable than sedentarisation.

Furthermore, the impact of domesticated livestock and wildlife herbivores on land and soil degradation might vary depending on their species type. Upon studying the dry land area in Australia and comparing the effects of cattle, sheep-goat, rabbit, and kangaroos on soil health, Eldridge et al. (2017) detected that “cattle exert twice the static pressure on the soil as sheep, and three times that of kangaroos, and would be expected, therefore, to cause substantial soil compaction.” In contrast, Lipson, Reynolds, and Anderson (2011) stated that while cattle tend to consume large amounts of vegetation which then leads to loss of vegetative cover, cattle can contribute to nutrient and resource cycling in farming systems. However, as Lipson et al. (2011) found, overgrazing by goats may have more severe effects on biodiversity than other livestock

species, and ecosystems in the marginal environments frequently grazed by goats are particularly susceptible to vegetation removal.

Other Factors of Land Degradation

Besides livestock grazing, many other (especially human-dependent) factors could be contributing to land degradation. In their study of Kuwait, Al-Dousari et al. (2019) found that grazing points and off-road vehicle tracks are highly correlated to each other, suggesting the need for a rangeland management plan for the country. In addition, the mining sector is one of the sectors that heavily contribute to the environmental damage in the area. In their 2008 study on Central Asian drylands, Karnieli et al. found that degradation occurred in some areas due to the exploration and exploitation of the gas and oil reserves in the region.

Economics of Land Degradation

Many will agree that raising livestock is often related to economic incentives that lie behind it. However, the economic damages that it creates can be far greater than the benefits it provides. In 2016, several researchers (Li and Deng; Moussa et al.; and Bouza et al.) studied the economics of land degradation in China, Niger, and Argentina. The researchers concluded that the total cost of land degradation (including cropland degradation) in China is 1% of China's 2007 GDP ($37 billion), the cost in Niger is 11% of its 2007 GDP ($0.75 billion), and in Argentina, it is 16% of its 2007 GDP ($75 billion). Thus, low grazing intensity can potentially lead to a comparatively higher economic value on the country-level average (Schaldach et al. 2013).

Recommendations on Pastoral Land Management

In summary, many researchers stress the need for inclusive (Weber and Horst, 2011) and sustainable land management practices with distinct targets (Kosmas et al. 2016; Piipponen 2022). Furthermore, Zhang, Wang, and Niu (2021) suggested that the systemic interactions of grazing intensity, livestock type, and climatic adaptability should be considered in the

development of sustainable land management practices. Mayer et al. (2022) also added that "future agricultural and environmental policies need to consider the complex interactions between the climatic, biophysical, and socioeconomic changes and farmers' decision structures that shape individual responses." In addition, Thornton and Elledge (2022) stated that "Sustainable grazing management should consider the production limitations of depleted soil and pasture resources to minimize land degradation."

2.2. Literature on Land Degradation and Livestock Issues in Mongolia

The Effect of Market Economy on Land Degradation

Over the past few decades, especially from the 2000s and afterward, several studies have been conducted on the issue of climate change impacts and the livestock sector in Mongolia. Primarily because until the 1990s, under the socialist regime, the government of Mongolia controlled the livestock sector thus, the livestock population remained relatively stable (Khishigbayar et al. 2015). However, Sternberg (2008) notes that the transformation to a market economy in the early 1990s along with limited state assistance has negatively impacted rural water supplies, reduced mobility, and increased overgrazing, which led to land degradation.

Domesticated vs. Wildlife Herbivores Effect on Land Degradation

In addition to domesticated grazers, wildlife grazers could contribute to land degradation. Thus, the regions that have both, domesticated and wildlife grazers, could experience more severe land degradation. When Yoshihara et al. (2010) studied the livestock grazing areas where marmots co-existed, they found that the effect of grazing on land degradation was even stronger, therefore, suggested lowering grazing intensity around marmot colonies.

Land Degradation and Desertification

The issue of land degradation is often discussed along with desertification. And Mongolia is prone to a higher risk of experiencing both issues. Therefore, there is a tendency to relate the

issue of livestock overgrazing to desertification. However, nature is a complex process, and many other factors could be counter-reacting with one another. In his 2013 study, Batkhishig noted that precipitation is one of the main factors that affect desertification. Moreover, Miao et al. (2020) estimated that between 1982 to 2015, the annual precipitation level in Mongolia during the growing season decreased by 18 mm every 10 years, highlighting that precipitation plays a more dominant role in grassland greenness as opposed to the grazing effect of livestock. Upon studying the drought conditions in Mongolia from 2001-2013, Kimura and Moriyama (2021) emphasized that with enough increase in the annual precipitation (including the winter season), Mongolia will approach climatically stable conditions, and drought occurrences will be less frequent.

The Cause of Land Degradation

While there are many causes for land degradation, almost all researchers point to livestock overgrazing as the leading cause of land degradation in Mongolia. But the effect of overgrazing could vary depending on the environmental features. Jamsranjav et al. (2018) distinguished that "livestock effects were strongest in the steppe zone, moderate in the desert steppe, and limited in the mountain/forest and eastern steppes." Moreover, the food habits of the livestock in the same zones might differ by the type of species. Especially the food habits of sheep and goats differ from, for example, horses but are somewhat similar to cattle (Takatsuku and Morinaga, 2020).

2.3. Contribution of the Study to the Existing Literature

While many researchers found that overgrazing is the leading cause of land degradation in Mongolia, there is a lack of research that identifies the land degradation effect by livestock species type. These distinctions could play a crucial role not only in raising public awareness but also in the effectiveness of government policy interventions against land degradation and land use regulations.

Moreover, based on the existing literature review, the impact of land degradation on livestock production appears to be another understudied topic in the literature. This aspect is equally important since the livestock sector production makes up about 90 percent of Mongolia's entire agricultural sector's production. Therefore, this study adds to the literature by focusing on livestock species types and their impact on land degradation, as well as determining the potential impacts of land degradation on the livestock sector.

3. Data

The data that were used for the analysis (Table 3) were obtained from two main sources. Data on precipitation level, livestock, and population-related variables were obtained from the Mongolian National Statistics Office (NSO) website (www.1212.mn). All of the land-related data were obtained from the Mongolian Environmental Information Center's (EIC) website (www.eic.mn/land).

Table 3. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Province (21 provinces)	210	11	6.07	1	21
Year (10 years)	210	5.5	2.879	1	10
Average precipitation (mm)	210	240.443	103.853	67.6	558.8
Total land (ha)	210	7,425,768.2	4,225,850	84,400.14	16,538,047
Pastoral land (ha)	210	5,249,345.6	3,136,907.3	39,308.23	11,458,007
Non-degraded pastoral land (ha)	210	2,871,277.4	1,836,842.1	12,121.707	6,987,142.7
Degraded pastoral land (ha)	210	2,378,068.2	1,475,158.7	15,332.21	7,857,823.6
Horse (thousand heads)	210	166.495	109.374	9.127	425.937
Cattle (thousand heads)	210	186.853	146.596	5.606	722.169
Camel (thousand heads)	210	19.224	30.415	.021	166.8
Sheep (thousand heads)	210	1,269.887	781.125	47.489	3,321.255
Goat (thousand heads)	210	1,165.067	645.485	37.983	2,733.7
Herder population	210	13,944.195	8,017.86	931	32,810
Livestock population (thousand head)	210	2,807.525	1,503.846	114.35	6,167.036
Livestock production (million tugriks)	210	15,0792.19	87,651.965	7,746.906	46,0221.97

Source: National Statistics Office of Mongolia (2023); Environmental Information Center of Mongolia (2023)

For the analysis, due to data availability, I used province-level data from all 21 provinces of Mongolia for 10 years (from 2010 through 2021). In the following figures, I show the breakdown of the data in Table 3 (at the country level), by comparing these to other relevant statistics.

Figure 5 illustrates the total number of livestock and land degradation trends from 2010-2021, at the country level. When it is shown by livestock species type (Figure 6), sheep and goats have the highest and continuous rise during 2012-2017. The number of sheep somewhat stabilized in 2017 with a slight rise in 2019 and 2021, while the number of goats seems to start declining in 2020 and continued to decline in 2021.

Figure 5. Total Livestock & Pastoral Land Degradation Trend

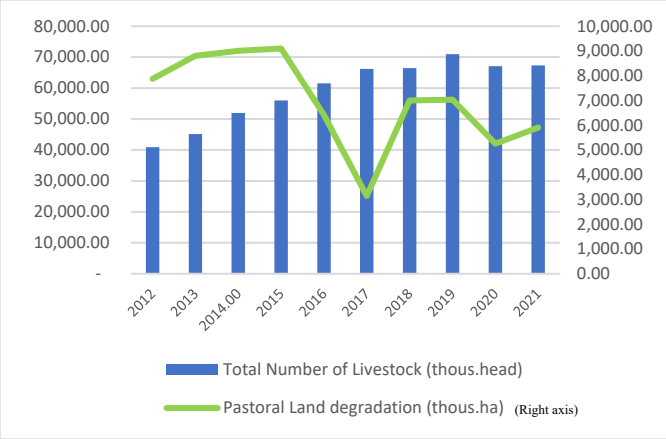
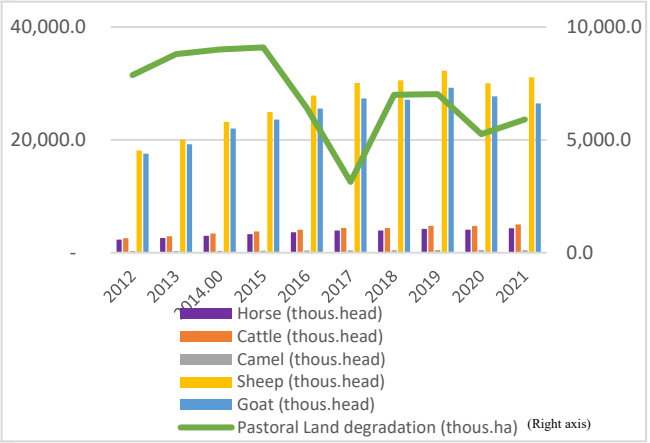


Figure 6. Total Livestock by Species Type and Pastoral Land Degradation



Source: National Statistics Office of Mongolia (2023)

Around 73 percent of the land in Mongolia is classified as agricultural land (EIC, 2023) and just about 0.2 percent is classified as mining land (although, the damages caused by mining activities to the land are incomparable). Within the agricultural land, about 96 percent is used as pastoral land (Figure 7). However, as shown in Figure 8, pastoral land area has been continuously decreasing since 2012, while land degradation fluctuates. As of 2021, pastoral land has decreased by 2 percent compared to the 2012 level (Figure 8).

Figure 7. Land by Classification (thous. ha)

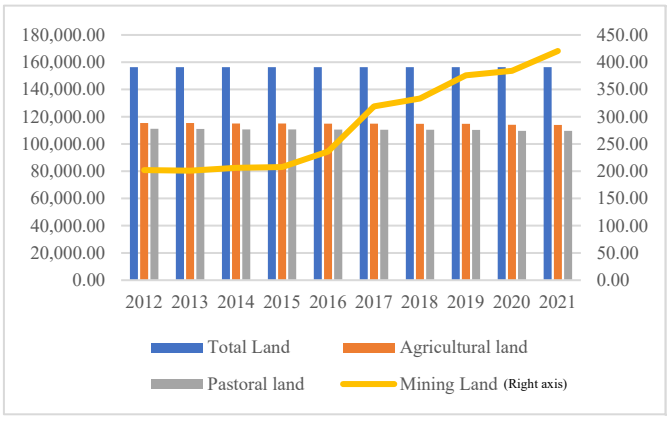
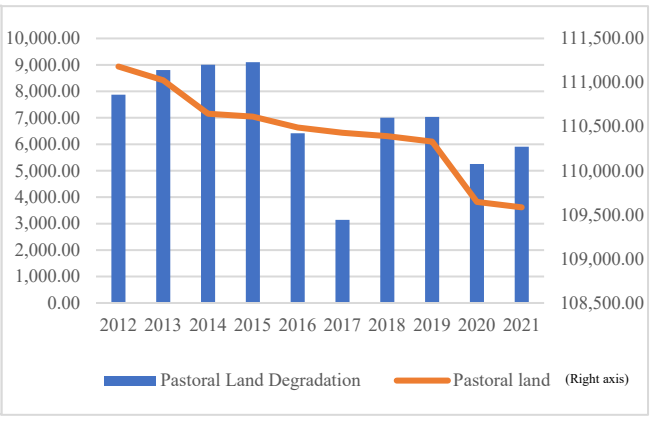


Figure 8. Pastoral Land & Degradation (thous. ha)



Source: National Statistics Office of Mongolia (2023)

Similar to the global trend, the average temperature in Mongolia during 2012-2021 continuously increased, except for the 2016 and 2018 declines (Figure 9). The average temperature was the lowest in 2012 (-0.13 degrees Celsius), and highest in 2021 (2.23 degrees Celsius).

Figure 9. Pastoral Land Degradation & Average Temperature

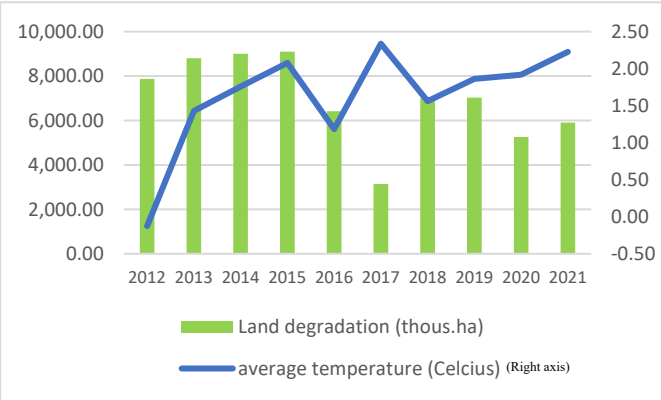
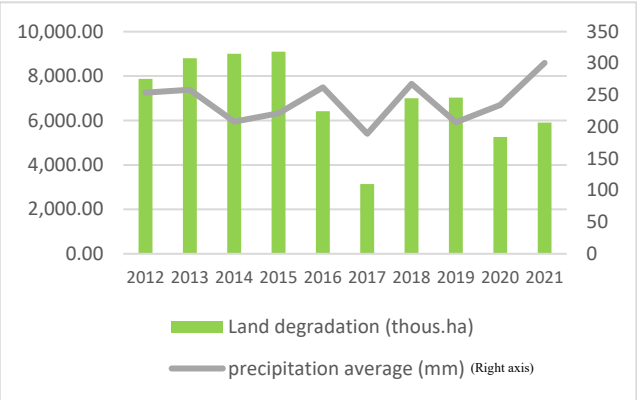


Figure 10. Pastoral Land Degradation & Average Precipitation



Source: National Statistics Office of Mongolia (2023)

As for the average precipitation levels, it appears that during the years with the highest land degradation, precipitation levels were relatively lower, with the exception of 2017 (Figure 10). From 2012 to 2021, the lowest annual average precipitation level was 189 mm in 2017, and the highest annual average level was around 300 mm in 2021.

Figure 11. Total Population vs. Total Herdsmen

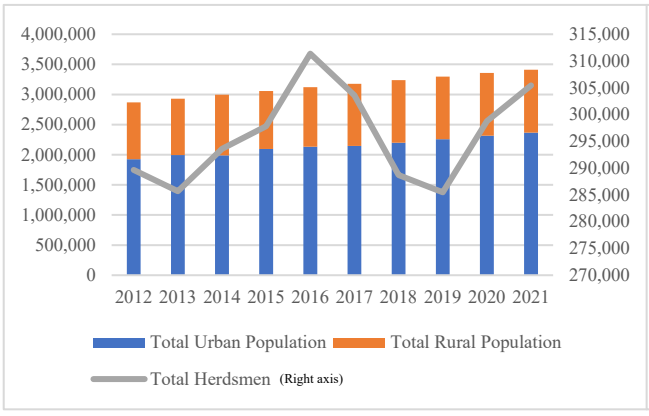
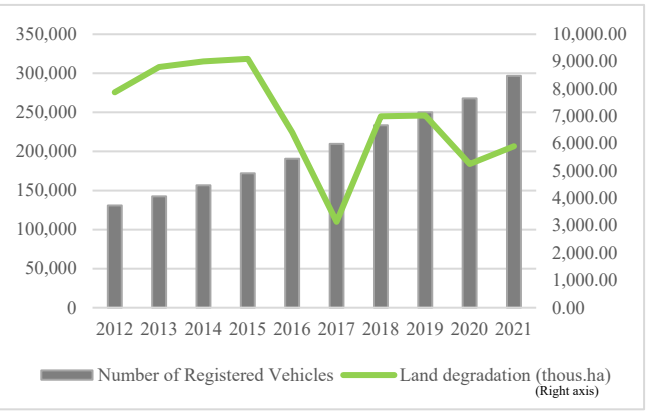


Figure 12. Number of Registered Vehicles vs. Pastoral Land Degradation



Source: National Statistics Office of Mongolia

Over the past decade (2012-2021), Mongolia's population has continued to grow steadily, by about 2% annually on average (Figure 11). Around 2/3 of the population is urban (the majority of them live in the capital city of Ulaanbaatar), and the remaining 1/3 (a little over one million people) live in the provinces. On average, about 30% of the rural population are herdsmen.

In addition to the livestock population increase, the number of vehicles in Mongolia in both urban and rural areas has been continuously increasing. As shown in Figure 12, in 2021, the

number of registered vehicles in the rural area increased by 227% relative to the 2012 level. While the effect of vehicles on pastoral land degradation is beyond the scope of this study, it is another important aspect that could be positively contributing to land degradation.

Figure 13. Total GDP & Livestock Production (mln. tugriks)

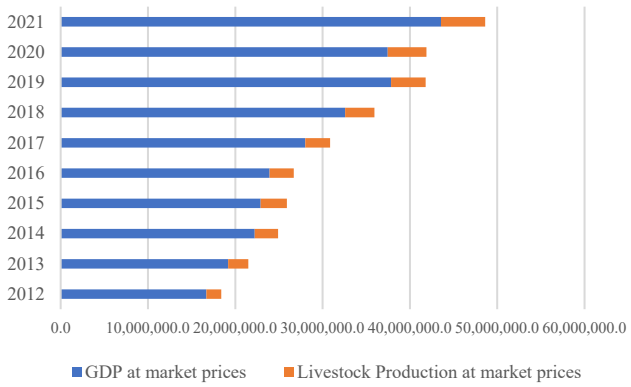
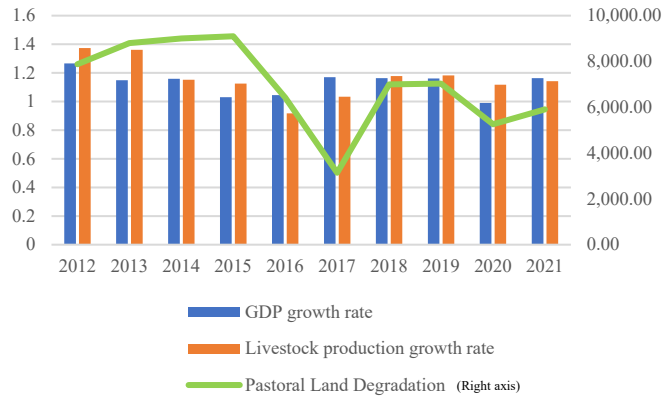


Figure 14. GDP and Livestock Production Growth Rates & Pastoral Land Degradation



Source: National Statistics Office of Mongolia (2023)

In 2021, Mongolia's GDP at market prices was 43.5 trillion tugriks, out of which 5 billion came from livestock production (Figure 13). This ratio has relatively been stable during 2012-2021. On average, livestock production makes up about 11-12 percent of the GDP annually. When comparing growth rates, livestock production growth rates appear to be either at a similar level or higher than GDP growth rates, with the exception of 2016 and 2017 (Figure 14).

4. Research Design

4.1. Research Question

Through conducting this study, I attempt to give empirical answers to the following two questions:

1. Which type of livestock species have significant impacts on pastoral land degradation in Mongolia?
2. What is the potential impact of pastoral land degradation on livestock production?

Based on these questions, I made the following hypotheses.

Livestock Effect on Land Degradation:

$H1_0$: Livestock species (horse, cattle, camel, sheep, and goats) do not affect pastoral land degradation

$H1_1$: Livestock species (horse, cattle, camel, sheep, and goats) affect pastoral land degradation.

Land Degradation Effect on the Livestock Production:

$H2_0$: Pastoral land degradation does not affect livestock production

$H2_1$: Pastoral land degradation affects livestock production.

Answering these research questions can help herders and the general public to raise awareness of the consequences of the uncontrolled rise of livestock and the impact of each type of livestock species on pastoral land degradation. Moreover, the answers to these questions will help the Mongolian policymakers to develop targeted policy measurements towards livestock population and pastoral land management, which would then help to improve the efficiency and effectiveness of the policy implementations.

4.2. Estimation

4.2.1. Estimation of Livestock Effect on Land Degradation by Species Type

To obtain a consistent and unbiased estimate of the land degradation effect of different livestock species, I use a Ridge regression technique on the fixed effects model. The fixed effect model was suitable for the panel data since there is a need to account for time and province-level unobserved factors. However, due to the high correlations between the livestock species, the fixed effect model alone is not sufficient to mitigate the issue of multicollinearity. Therefore, incorporating the Ridge regression technique into the fixed effect model was appropriate for this analysis as it helps mitigate multicollinearity and enhances the stability of the regression model through the introduction of a penalty term (regularization).[2] Moreover, to facilitate the analysis and reduce the influence of extreme values, the variables in the model were expressed in per-unit terms (per hectare of non-degraded pastoral land) and log-normalized.

$$ln(Degraded\ Land\ _{it}) = \beta_0 + \beta_1 * ln(LIVESTOCK_{it}) + \beta_2 * ln(Herders_{it}) + \delta_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where:

i – subscript refers to each province. There are in total 21 provinces.

t – subscript refers to the time period of observations. In the analysis, I used panel data from 2012 to 2021.

$Degraded\ Land_{\text{it}}$ – degraded land per ha of non-degraded land, in province i in time t measured by a hectare (ha). **(Dependent Variable).**

β_0 – constant

β_1 – the percentage change (elasticity) in the amount of pastoral land degradation in response to a one percent change in livestock population.

[2] The penalty term in ridge regression is a mathematical adjustment that helps prevent overfitting and reduces the impact of multicollinearity. It encourages the model to find a balance between accurately fitting the data and keeping the coefficients small. By shrinking the coefficients towards zero, the penalty term helps improve the stability and reliability of the regression model.

$LIVESTOCK_{it}$ – livestock population in province *i* in time *t* by species type, measured by thousand heads. There are five types of livestock species, sheep, goat, horse, cattle, and camel **(Variable of Interest).**

β_2 – the percentage change (elasticity) in the amount of pastoral land degradation in response to a one percent change in herders' population (provinces).

$Herders_{it}$ – the number of herders in province *i* in time *t*. **(Independent Variable).**

δ_i – province-specific effect of unobserved heterogeneity of the provinces that is constant across time (e.g., extreme weather events such as dzud, soil quality, and other cultural and social factors).
γ_t – time-specific effect of unobserved heterogeneity across time that is constant across provinces (e.g., policy changes, seasonal variations).

ε_{it} - idiosyncratic error, specific to province and time period.

4.2.2. Estimation of Pastoral Land Degradation Effect on Livestock Production

To answer the question of whether pastoral land degradation affects livestock production, I use a similar technique, as was used in the 4.2.1 section. Due to the gradual nature of land degradation, which is estimated on an annual basis, it was necessary to introduce a lag of one period to the variable of interest (degraded pastoral land) in order to observe its impact on livestock production. In addition, to reduce the influence of extreme values, the variables have been log-normalized.

$$ln(Livestock\ Production_{\ it}) = \gamma_0 + \gamma_1 * \ln(Degraded\ Pastoral\ Land_{it-1}) +$$

$$\gamma_2 * ln(Livestock_{it}) + \gamma_3 * ln(Herders_{it}) + \gamma_4 * ln(Precipitation_{it}) + \mu_i + \varphi_t + u_{it} \quad (2)$$

where:

γ_0 – constant

γ_1 – the percentage change (elasticity) in the amount of livestock production in response to a one percent change in pastoral land degradation.

$Livestock\ Production_{\ it}$ – livestock production in province *i* in time *t.* **(Dependent Variable).**

$Degraded\ Pastoral\ Land_{it-1}$ – degraded pastoral land in province *i* in time t-1. Time is lagged by one period since the effects of land degradation on livestock may not be immediate and there may be a time delay before the impact becomes apparent. **(Variable of Interest).**

γ_2 – the percentage change (elasticity) in the amount of livestock production in response to a one percent change in livestock population.

$Livestock_{it}$ – livestock population in province *i* in time *t.* **(Independent Variable).**

γ_3 – the percentage change (elasticity) in the amount of livestock production in response to a one percent change in herders' population.

$Herders_{it}$ – the number of herders in province *i* in time *t.* **(Independent Variable).**

γ_4 – the percentage change (elasticity) in the amount of livestock production in response to a one percent change in precipitation levels.

$Precipitation_{it}$ – the level of precipitation in province *i* in time *t.* **(Independent Variable).**

μ_i – province-specific effect of unobserved heterogeneity of the provinces that is constant across time (e.g., extreme weather events such as dzud, soil quality, and other cultural and social factors)

φ_t – time-specific effect of unobserved heterogeneity across time that is constant across provinces (e.g., policy changes, seasonal variations).

u_{it} – idiosyncratic error, specific to province and time period.

5. Results and Discussion

5.1. Livestock Effect on Pastoral Land Degradation by Species Type

Prior to running a regression, I set the province and year fixed effects, each absorbing province, and time-specific variables that have not been observed and could have an impact on land degradation. After running a Ridge regression on panel data using the aforementioned fixed-effects model (1), I obtained the following results (Table 4).

Table 4. Summary of the Results: Livestock Effect on Land Degradation by Species Type

VARIABLES	(1) Log(Degraded land per ha non-degraded pastoral land)
Log(Horse per ha of non-degraded pastoral land)	0.0513*** (0.00705)
Log(Cattle per ha of non-degraded pastoral land)	0.0202*** (0.00363)
Log(Camel per ha of non-degraded pastoral land)	0.063*** (0.00673)
Log(Sheep per ha non-degraded pastoral land)	0.0599*** (0.006804)
Log(Goat per ha of non-degraded pastoral land)	0.1159*** (0.01124)
Log(Herder population per ha non-degraded pastoral land)	0.0875*** (0.00582)
Observations	210
Province FE	YES
Year FE	YES
R-squared	0.6165

Robust Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To deal with the serial correlation issue of panel data, I used clustered standard errors, by grouping observations at the province level.

a. The Effect of Sheeps on Pastoral Land Degradation

The result in Table 4 suggests that a one percent increase in the sheep population per hectare of non-degraded pastoral land would lead to about a 0.06 percent increase in pastoral land

degradation, all else being equal. The p-value of the result is below 0.01, indicating that the null hypothesis of sheep having no degradation effect on land can be rejected with 99 percent confidence. Although the sheep population is the highest among the livestock species group, its effect on pastoral land degradation is not significantly higher than the others. This could imply that sheep cause less harm to biodiversity and controlling the number of sheep could potentially mitigate their damaging effects.

b. The Effect of Goats on Pastoral Land Degradation

According to the results reported in Table 4, the goat has the highest significant impact on pastoral land degradation. It is estimated that a one percent increase in goat population per hectare of non-degraded pastoral land leads to a 0.12 percent increase in pastoral land degradation, all else being equal. The result is significant at a 99 percent confidence level. This result is supported by the findings of the previous literature, which identified that overgrazing by goats may have more severe effects on biodiversity than other livestock species since the ecosystems in marginal environments frequently grazed by goats are found to be particularly susceptible to vegetation removal (Anderson and Gugerty, 2011).

c. The Effect of Cattle on Pastoral Land Degradation

According to the estimated results in Table 4, a one percent increase in the cattle population per hectare of non-degraded pastoral land leads to a 0.02 percent increase in pastoral land degradation, while controlling for the other variables. This result is significant at a 99 percent confidence level. The effect of cattle population on pastoral land degradation is the smallest among the livestock species group. One interesting finding about cattle's effect on land degradation is that while they tend to consume large amounts of vegetation which then leads to loss of vegetative cover, cattle can contribute to nutrient and resource cycling in farming systems (Anderson and Gugerty, 2011).

d. The Effect of Camels on Pastoral Land Degradation

Results in Table 4 suggest that a one percent increase in the camel population per hectare of non-degraded pastoral land leads to a 0.06 percent increase in pastoral land degradation, all else being equal. This result is significant at a 99 percent confidence level. Even though the total population of camel heads in Mongolia is just about one percent of the sheep population (31 million sheep heads vs. 454 thousand camel heads as of 2021, NSO) its effect on pastoral land degradation is almost equivalent to the effects of sheep. One explanation could be related to the relatively large body mass of camels compared to sheep and exerting higher static pressure on the soil.

e. The Effect of Horses on Pastoral Land Degradation

The estimated results of Table 4, suggest that a one percent increase in the horse population per hectare of non-degraded pastoral land leads to a 0.05 percent increase in pastoral land degradation (ceteris paribus), which is slightly less than the camel and sheep effects. The result is significant at a 99 percent confidence level. Similar to camels, horses also have relatively large body mass. Thus, they most likely are consuming large amounts of vegetation and contributing to the loss of vegetative cover. However, unlike camels, horses are the most frequently used transportation method among herders and are lighter in weight. Thus, they may not be exerting as much static pressure on the soil as camels.

f. The Effect of Herder Population on Pastoral Land Degradation

While the most damage to the pastoral land is caused by livestock, it is important to distinguish the contribution of the herder's population to the pastoral land degradation since they reside along with their livestock, usually moving around twice a year, switching their summer and winter residences depending on the vegetation levels of the area. The estimated results in Table 4 suggest that a one percent increase in the herder population per hectare of non-degraded pastoral land leads to a 0.09 percent increase in pastoral land degradation, all else being equal

(the result is significant at a 99 percent confidence level). This shows that the herder's population has the second-highest positive effect on pastoral land degradation. This implies that livestock is not the sole contributor to the issue and that addressing land degradation requires considering not only livestock management but also the practices and behaviors of herders.

5.2. The Effect of Pastoral Land Degradation on Livestock Production

The estimated results of the second regression model (2) are shown in Table 5.

Table 5. Summary of the Results: The Effect of Pastoral Land Degradation on Livestock Production

VARIABLES	(1) Log(Livestock Production)
Log(Degraded Pastoral Land: lagged one period)	-0.925** (0.455)
Log(Livestock Population)	8.226*** (0.661)
Log(Herders Population)	-0.254** (0.128)
Log(Average Precipitation)	0.167** (0.0662)
Observations	209
Number of provinces	21
Province FE	YES
Year FE	YES
R-squared	0.9212

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Similar to the first regression model (2), the standard errors were clustered at the province level since the variation in the dependent variable is mainly explained by differences between provinces.

a. The Effect of Degraded Pastoral Land on Livestock Production

Table 5 illustrates the estimation of pastoral land degradation effect on livestock production, holding herders (labor), livestock, and weather variables constant. The estimated coefficient illustrates that a one percent increase in pastoral land degradation in the previous year leads to a 0.9 percent decrease in livestock production in the current year, implying that pastoral land

degradation has a significant and detrimental impact on livestock production. In other words, pastoral land degradation negatively affects the availability and quality of grazing resources, which, in turn, hinders the productivity and health of livestock. A reduced vegetation cover, depletion of nutrient-rich soil, and decreased availability of suitable forage for livestock due to pastoral land degradation can result in reduced weight gain, decreased reproduction rates, and overall lower productivity of livestock. Thus, this estimated result is an indicator of the importance of implementing effective land management practices and strategies to mitigate land degradation and preserve or restore the quality of grazing areas for livestock.

b. The Effect of Livestock Population on Livestock Production

As for the livestock population, not surprisingly, the increase in the livestock population leads to a significant increase in the livestock production amount. According to the estimates in Table 5, a one percent increase in livestock population leads to an 8 percent increase in livestock production, holding other variables constant. The result is significant at a 99 percent confidence interval. While it is intuitive to expect that the livestock population drives livestock production, the resources that are available for sustaining a large amount of livestock are limited. Thus, for sustainable livestock production, it is important to focus on quality rather than quantity.

c. The Effect of Precipitation on Livestock Production

Precipitation is another factor that affects livestock production. The estimated results in Table 5 suggest that a one percent increase in average precipitation levels leads to a 0.17 percent increase in livestock production, all else being equal. While the magnitude of the coefficient is small, the result is statistically significant (at a 95 percent confidence level). The result suggests that higher levels of precipitation can contribute to improved forage availability, water resources, and overall environmental conditions that support livestock growth and health. The positive relationship between precipitation and livestock production aligns with the findings of Kimura and Moriyama (2021), which emphasized that with enough increase in the annual

precipitation (including the winter season), Mongolia will approach climatically stable conditions, and drought occurrences will be less frequent.[3]

d. The Effect of Herders Population on Livestock Production

Conversely, when the herders' population is included as one of the variables in the model, the results show that a one percent increase in herder population is associated with a 0.2 percent decrease in livestock production, holding other factors constant. This suggests that as the herder population grows, there may be factors or dynamics at play that negatively impact livestock production. One possible interpretation is that an increase in herder population may lead to increased competition for grazing resources and available pastureland. This heightened competition could result in overgrazing or insufficient grazing opportunities for livestock, leading to reduced livestock productivity. Moreover, a larger herder population might put additional pressure on land management practices, such as rotational grazing or sustainable land-use practices. Insufficient land management, as a result of increased population, could contribute to land degradation, further compromising the availability of suitable grazing areas for livestock and subsequently impacting production.

5.3. The Limitations of the Study

While this study provides valuable insights into the relationship between livestock species, pastoral land degradation, and livestock production in Mongolia, it is important to acknowledge certain limitations. Firstly, the generalizability of the findings may be limited to the specific context of the 21 provinces of Mongolia, and caution should be exercised when applying the results to other countries or regions. Secondly, the analysis relies on panel data collected over 10 years, and it is possible that a longer time series and/or village-level data would provide a more comprehensive understanding of the dynamics between livestock, pastoral land

[3] However, in this context, it is important to separate the precipitation levels that are not threatening the well-being of livestock from the extreme weather events due to excessive precipitation that leads to millions of loss of animals.

degradation, and livestock production. Additionally, the study focuses on the direct effects and does not account for potential indirect or mediated relationships. Furthermore, other factors such as climate change, socioeconomic factors, and policy interventions, which could influence the outcomes, were not included in the analysis. Lastly, while efforts were made to control for confounding factors, there may still be unobserved variables that could impact the results. By acknowledging these limitations and understanding their implications, this study contributes to the ongoing discussion and encourages further advancements in this field of research.

6. Conclusion

Most of the previous literature has focused on determining the negative impact of livestock overgrazing on land degradation. However, considering the variety of livestock species that are raised in Mongolia's rangeland along with the unique and traditional herding practices, studying the effect of livestock on pastoral land degradation by species type is of particular interest to policymakers. Moreover, degraded pastoral land due to overgrazing, would in turn, potentially impact livestock production. Given that livestock production makes up about 90 percent of the total agricultural sector in Mongolia, studying the effect of degraded pastoral land on livestock production is of utmost importance for the country's economic policy. Hence, this study adds to the literature by focusing on the effect of livestock on pastoral land degradation by their species type and the pastoral land degradation effect on livestock production.

The estimated results of this study suggest that all five types of livestock species have a positive impact on pastoral land degradation. However, among the livestock species group, goats have the highest effect on land degradation. A one percent increase in goat population per hectare of non-degraded pastoral land leads to a 0.12 percent increase in pastoral land degradation. This result is supported by findings of the previous literature, which identified that overgrazing by goats may have more severe effects on biodiversity than other livestock species since the ecosystems in marginal environments frequently grazed by goats are found to be particularly susceptible to vegetation removal (Anderson and Gugerty, 2011).

As for the estimates of the degraded pastoral land's effect on livestock production, the study results suggest that a one percent increase in pastoral land degradation in the previous year leads to a 0.9 percent decrease in livestock production in the current year, implying that pastoral land degradation has a significant and detrimental impact on livestock production. In other

words, pastoral land degradation negatively affects the availability and quality of grazing resources, which, in turn, hinders the productivity and health of livestock. Thus, this estimated result is an indicator of the importance of implementing effective land management practices and strategies to mitigate land degradation and preserve or restore the quality of grazing areas for livestock.

7. Recommendation

Overall, from the study results, it is evident that there is a crucial need for developing and implementing a sustainable livestock population control policy, with a specific target on the goats to prevent overpopulation. However, controlling the livestock population alone may not effectively prevent overgrazing issues. Therefore, the implementation of sustainable grazing policies and practices is another utmost priority for policymakers. One way of implementing sustainable grazing practices is via the introduction of Precision Livestock Farming technology, such as "grazing cow" (Figure 15). This is designed to prevent overgrazing, by allowing the herders/farmers to monitor their livestock's whereabouts and grazing intensities in real time.

Figure 15. Grazing Cow Monitor

Source: Internet of Food and Farm (2020)

By leveraging technology and data-driven approaches, precision livestock farming offers opportunities for improved animal welfare, optimized resource utilization, and better decision-making in livestock farming practices, as well as providing an infrastructure for effective policy implementation to correct market inefficiencies.

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