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Research Article

Integrating Forest Conservation and Sustainable Tourism: Mitigating Desertification in Mongolia through Localized Strategies

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Abstract
The degradation of Mongolia's forests and the expansion of desertification are critical environmental challenges, exacerbated by a combination of human activities and climate change. Analysis of yearly time series data, without accounting for regional variations, initially suggests that human activities, such as overgrazing, deforestation, and land mismanagement, are the primary drivers of desertification. However, when region-specific factors and sub-categories of land degradation are considered, the relative importance of climate change becomes more pronounced, highlighting the intricate relationship between environmental degradation and socio-economic factors. This complexity underscores the need for localized strategies to mitigate forest loss and desertification. As regional dynamics play a significant role, effective forest conservation efforts in Mongolia must address both human-induced pressures and climate resilience. The paper explores integrating sustainable tourism into the forest conservation strategies.
Keywords: PCA (Principal Component Analysis), Mongolian Desertification, Number of Livestock, Climate Change, Time Series Data.

1. Driving Factors of Desertification in Mongolia

Desertification, a process that transforms fertile land into deserts, has become a critical issue in Mongolia, exacerbating both environmental and socio-economic challenges. Mongolia is particularly vulnerable due to its unique geographical location and ecological conditions. Yellow dust storms, originating from the vast desertified regions, have intensified in recent years, causing severe health problems and economic damage in Mongolia and neighboring countries such as China, South Korea, and Japan. These storms carry fine particulate matter across large distances, negatively impacting air quality, agriculture, and public health. The worsening of these storms highlights the ongoing degradation of land in Mongolia and the growing threat of desertification in Asia as a whole (Source: Xinhua, 2023).

Forests in Mongolia occupy only about 8 percent of the total land area, a relatively small proportion compared to other countries. According to recent data from the Ministry of Environment and Tourism (2023), approximately 77 percent of Mongolia’s land has already been damaged by desertification and land degradation. This alarming figure underscores the scale of the environmental crisis. The scarcity of forested areas, combined with the advancing desertification, puts significant pressure on the country’s ecosystems, biodiversity, and rural livelihoods (Source: Xinhua, 2023).

The drivers of desertification in Mongolia are multifaceted and stem from both natural and anthropogenic (human-driven) factors. On the natural side, Mongolia’s harsh climate, characterized by extreme temperature fluctuations, low rainfall, and high winds, creates an environment susceptible to land degradation. Climate change has further aggravated these conditions, leading to prolonged droughts, more intense weather events, and increased variability in precipitation patterns. Such climatic changes exacerbate soil erosion, reduce vegetation cover, and increase the risk of desertification (Source: Xinhua, 2023).

Human activities, however, play an equally significant, if not more critical, role in accelerating desertification. Overgrazing, deforestation, and unsustainable agricultural practices are major contributors to land degradation. Livestock herding, a cornerstone of Mongolia’s economy and traditional nomadic lifestyle, has expanded dramatically in recent decades. This has led to overgrazing, particularly in areas where the carrying capacity of the land is insufficient to support large herds. The removal of vegetation by livestock destabilizes the soil, making it more prone to erosion and desertification. Additionally, deforestation for fuelwood, mining activities, and infrastructure development have reduced forest cover, further diminishing the natural barriers against land degradation (Source: Xinhua, 2023).

The combination of these human and natural factors has resulted in a complex and worsening desertification scenario. As Batjargal (1997) notes, desertification in Mongolia is the cumulative effect of these intertwined forces, and addressing the problem requires an integrated approach that accounts for both environmental and socio-economic drivers. Sustainable land management practices, reforestation efforts, and policies aimed at balancing economic growth with environmental preservation are essential to combatting desertification in Mongolia. Given the vastness of the problem, solutions must also involve local communities and indigenous knowledge systems, as well as international cooperation, especially in light of the transboundary effects of desertification, such as dust storms. Sustainable tourism, which promotes eco-friendly travel and conservation efforts, could be a valuable tool in addressing these challenges. By promoting the preservation of Mongolia's unique natural landscapes and involving local communities in conservation efforts, sustainable tourism can provide alternative livelihoods and reduce pressure on the land, helping to mitigate the driving factors of desertification.

1.1. Climate Change

Climate change plays a pivotal role in the worsening environmental conditions in Mongolia, contributing significantly to the increasing frequency and severity of yellow dust storms. These storms, which originate in Mongolia and spread to neighboring countries such as China, South Korea, and Japan are a visible symptom of the larger issue of desertification driven by climate change. As the country's soil continues to degrade year by year, the environmental, economic, and health impacts of this phenomenon become more pronounced. According to the Ministry of Environment and Tourism (2023), the number of yellow dust storms has been steadily increasing, a clear indicator of the serious degradation of Mongolia's soil (Source: Xinhua, 2023). One of the most alarming indicators of climate change's impact on Mongolia is the significant rise in average temperatures. Over the past 80 years, Mongolia's average temperature has increased by 2.25 degrees Celsius, which is nearly triple the global average temperature rise during the same period. This dramatic increase in temperature has altered the region's ecosystem, exacerbating the processes of land degradation and desertification. As temperatures rise, soil moisture decreases, vegetation cover is reduced, and the land becomes more susceptible to erosion, further intensifying the spread of desertification (Source: Xinhua, 2023).

Simultaneously, there has been a notable decline in precipitation levels across Mongolia, contributing to the worsening desertification problem. Over the past 80 years, annual precipitation has decreased by approximately 7 percent, with a particularly significant drop in rainfall during the warm season. This is especially concerning because warm-season rainfall is crucial for sustaining Mongolia's vegetation, which in turn helps to stabilize the soil and prevent erosion. Without sufficient rainfall, the country's grasslands and forests are unable to regenerate, leading to further degradation of the land. The southern and central regions of Mongolia have been particularly hard hit by the decline in precipitation. Studies, such as those conducted by Liu *et al.,* (2018), have shown that these areas have experienced the sharpest decreases in rainfall, which has led to more rapid desertification. As vegetation in these regions dies off due to lack of water, the exposed soil becomes more vulnerable to wind erosion, increasing the likelihood of yellow dust storms. The frequent dust storms not only affect Mongolia but also have significant transboundary consequences. Winds carry the dust across borders, affecting air quality and public health in other countries like China, South Korea, and Japan, further demonstrating the regional impact of Mongolia's desertification crisis (Source: Xinhua, 2023).

The changing climate has also led to an increase in the frequency of natural disasters in Mongolia, such as droughts, floods, and extreme temperature fluctuations. These disasters are compounding the effects of desertification and further straining Mongolia's already fragile ecosystems. As the frequency and intensity of these events grow, so too does the urgency for coordinated regional and global responses. Dealing with the environmental issues arising from climate change and desertification in Mongolia is not something that can be managed by the country alone. It requires concerted efforts and joint actions from all countries in the region, particularly those affected by the dust storms and other transboundary environmental impacts (Source: Xinhua, 2023).

Yellow dust storms originating from Mongolia pose a serious threat to the health and economies of nearby nations. In China, for example, these storms contribute to respiratory problems and cause significant economic losses by damaging crops and infrastructure. In South Korea and Japan, similar issues arise as the dust reduces air quality and increases public health risks, particularly for those with pre-existing respiratory conditions. These impacts highlight the importance of international collaboration in addressing the root causes of desertification in Mongolia, particularly climate change (Source: Xinhua, 2023).

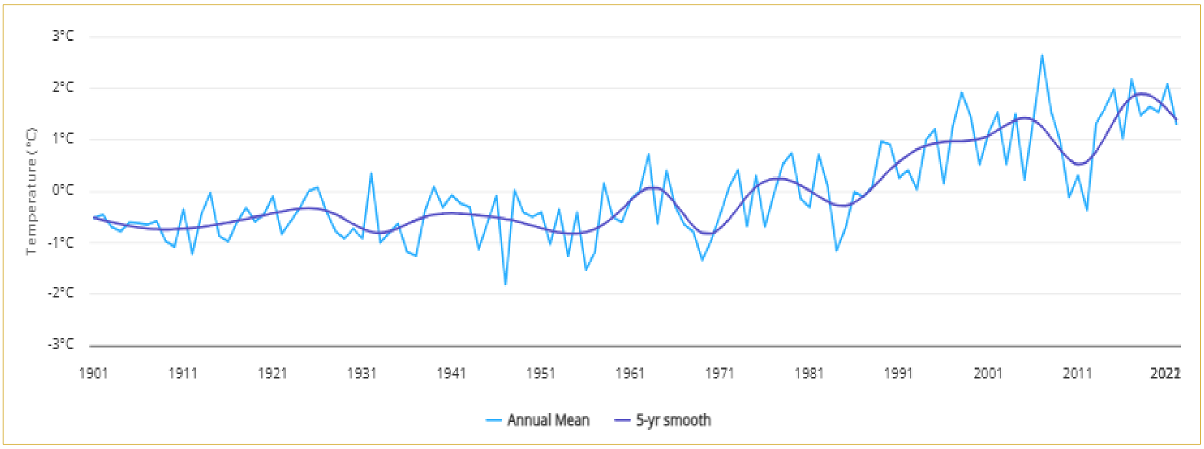

Figure 1. Annual average mean surface air temperature in Mongolia (Source: Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/mongolia/climate-data-historical).

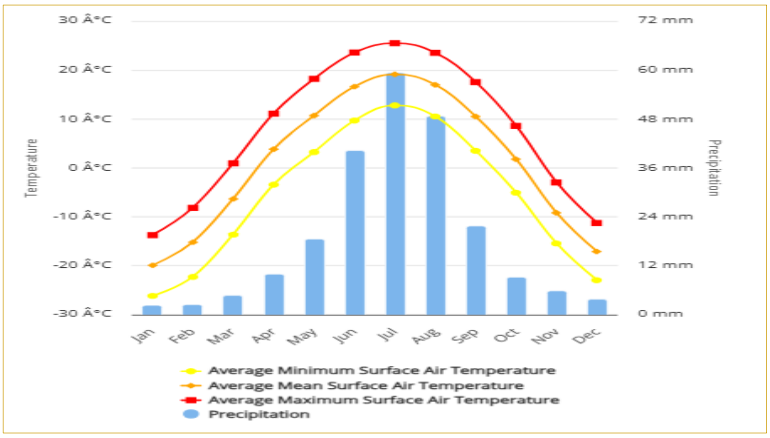

Figure 2. Maximum, minimum, average air temperature and precipitation along a year (Source: Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/mongolia/climate-data-historical).

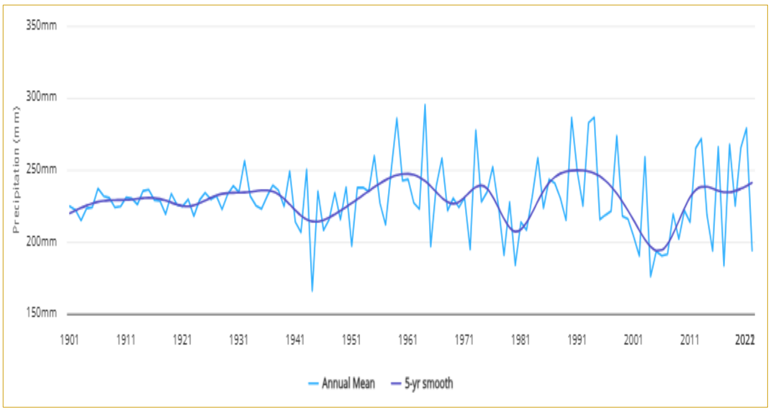

Figure 3. Average yearly precipitation (Source: Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/mongolia/climate-data-historical).

1.2. Human Activities

Human activities, particularly overgrazing, mining, and the construction of unpaved rural roads, are major contributors to the worsening desertification and land degradation in Mongolia. The country's traditional nomadic lifestyle, which revolves around livestock herding, has increasingly come into conflict with the fragile ecosystem. As one of the last remaining nomadic countries in the world, Mongolia's dependence on livestock is significant. By the end of 2022, the country had reached a historic high, with 71.1 million head of livestock-a record since animal census records began in 1918 (Source: Xinhua, 2023). This sharp increase in livestock numbers, especially goats and sheep, has led to overgrazing, particularly in the more arid regions of the country. The animals, particularly goats, feed on grassland vegetation, often uprooting it completely, which leaves the soil exposed to erosion. Without sufficient time for the land to regenerate, the natural vegetation is unable to recover, exacerbating the process of desertification. As herders seek to maintain their livelihoods, the pressure on the land grows, further straining the ecosystem (Source: Xinhua, 2023).

1.2.1. Overgrazing

Mongolian government has tried to diversify the inland country's mining-dominant economy by promoting livestock husbandry. Especially, in the early 1990s, Mongolia reformed its economic system and implemented the 'privatization of livestock' (Buren, 2011; Wang *et al.,* 2020). Moreover, every year Mongolian government gives awards and certificates to families with at least a thousand head of livestock. For example, a total of 191 herder families in the eastern Sukhbaartar province were received this honor in 2022.

Mongolian herders, therefore, have been paying more attention to increasing the number of their livestock than improving the quality of livestock husbandry. Consequently, overgrazing has become one of the driving factors that worsen the desertification because reduced grass could hold less soil in land in turn. To fatten their livestock, herders always move to other regions with rich grass. In other words, Mongolia's grazing system was concentrated on the seasonal and fixed-point grazing, hindering rotational grazing system. As a result, there was not enough recovery time for grassland vegetation, resulting in an unbalanced relationship between diversity in grassland plant and diversity in livestock structure (Su, 2015; Liu, 2018).

Figure 4. Total number of livestock from 2003~2023 (Source: National Statistics Office of Mongolia: https://www.1212.mn/en/statistic/statcate/573054/table-view/DT_NSO_1001_021V1).

1.2.2. Mining

In addition to overgrazing, indiscriminate mining operations are a significant contributor to desertification in Mongolia. The country is rich in natural resources, and as a result, the mining sector plays a central role in its economic growth, accounting for more than 20 percent of the nation's gross domestic product (GDP) (Ministry of Mining and Heavy Industry, 2023). The allure of resource extraction has led to rapid expansion in the industry, driven by the demand for minerals such as copper, coal, and gold, which are crucial to both domestic and international markets (Source: Xinhua, 2023).

However, the fast and often unregulated growth of the mining sector has come at a severe environmental cost. Many mining operations are situated near the headwaters of Mongolia's major river systems, causing widespread disruption to the country's water resources. In 2022 alone, over 360 rivers, streams, lakes, and springs were reported to have dried up, largely due to the diversion and depletion of water for mining purposes. This depletion not only exacerbates land degradation but also threatens biodiversity and the livelihoods of local communities that rely on these water sources. The unchecked expansion of mining thus poses a significant challenge to sustainable development and environmental conservation in Mongolia (Source: Xinhua, 2023).

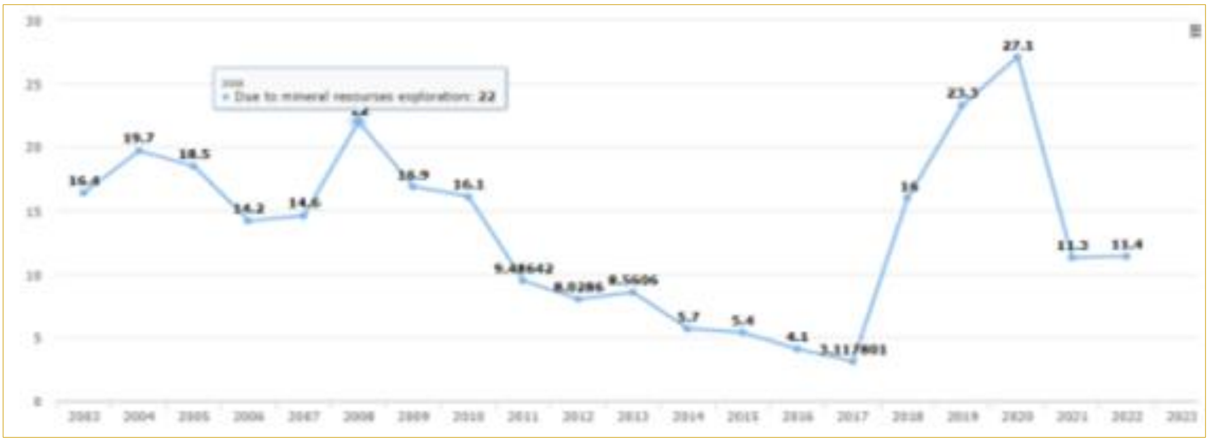

Figure 5. Land degradation due to mineral resources exploitation (Source: National Statistics Office of Mongolia: https://www.1212.mn/en/statistic/statcate/573072/table-view/DT_NSO_2400_009V1).

1.2.3. Unpaved Rural Roads

Unpaved rural roads have also emerged as a significant factor contributing to desertification and land degradation in Mongolia. According to data from the Ministry of Road and Transport Development, Mongolia's state road network spans over 112,400 kilometers, yet only 7,830 kilometers of these roads are paved. The paved sections were primarily completed through the Millennium Road project in 2022, which aimed to connect the nation's 21 provinces with the capital, Ulaanbaatar. However, the vast majority of Mongolia's roads remain unpaved, creating a situation where drivers, particularly in rural areas, frequently forge new paths across the landscape. This practice leads to severe soil degradation as repeated driving compacts the soil and strips it of vegetation, accelerating desertification (Source: Xinhua, 2023).

Additionally, changing lifestyle practices among Mongolian herders have contributed to the problem. Traditionally, herders used horses to care for their livestock, which had a relatively lower environmental impact. However, modern herders now increasingly rely on motorcycles to traverse pastures, further exacerbating soil degradation. The constant use of these motorized vehicles over fragile pastureland has not only intensified land erosion but also contributed to the degradation of the delicate grasslands that are crucial to the ecosystem. These factors combined make unpaved roads and the increased use of motorized transport significant contributors to Mongolia's ongoing desertification crisis (Source: Xinhua, 2023).

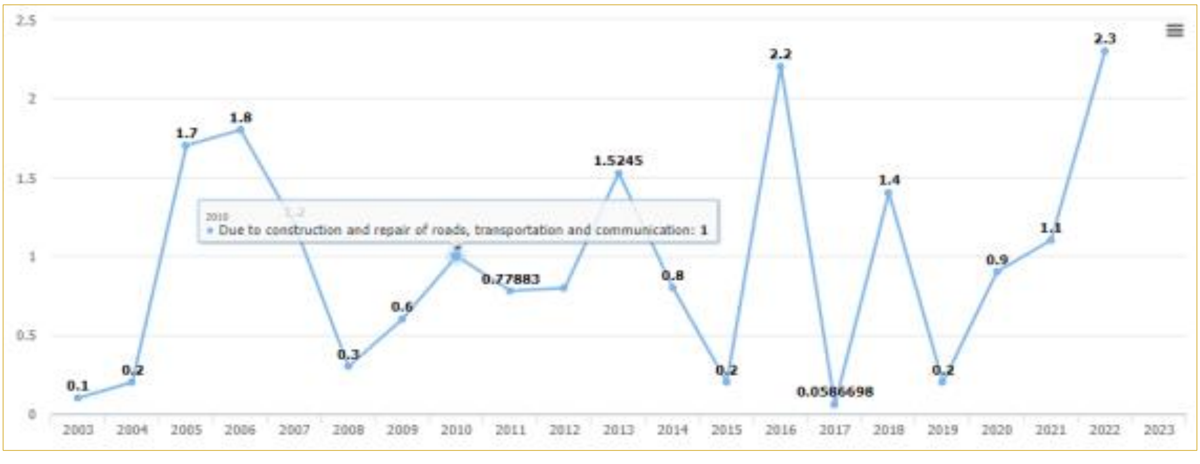

Figure 6. Land degradation due to construction and repair of roads, transportation and communication (Source: National Statistics Office of Mongolia: https://www.1212.mn/en/statistic/statcate/573072/table-view/DT_NSO_2400_009V1).

2. Previous Studies

2.1. Importance of Regions

The relative contributions of influencing factors of desertification vary across regions. For example, Sukbaatar Province is windy, which implies wind velocity is one of the main factors of desertification (Su, 2015; Liu *et al.,* 2018). But in forest areas, fire destroys vegetation coverage and increases desertification, one of the important natural driving factors (Filei *et al.,* 2018). On the steppe, overgrazing is an important human driving factor. In the mining area of southern Mongolia, mineral mining and road erosion are two human factors of desertification (Batjargal, 1997; Batkhishig, 2011). In the arable land, soil erosion caused by agricultural production is the leading human factor (Batkhishig, 2011).

2.2. Relative Contributions

Filei *et al.,* (2018) investigated the impact of natural and human factors on land degradation in Mongolia from 1982 to 2016. They evaluated that the decrease in precipitation and increase in temperature were the dominant factors for the land degradation; in particular, precipitation during the vegetation growth period was found to be the key factor (Filei *et al.,* 2018). On the other hand, Tian et al. studied samples from lakes in central Mongolia and concluded that the transition to a market economy since the 1990s has resulted in severe land degradation (Tian *et al.,* 2014).

The above contradictory findings on the contribution of natural and human factors may be attributed to the difference in research scales (Liang *et al.,* 2021).

3. Statistical Model

Instead of evaluating the significance of the explanatory variables related with the desertification of Mongolia merely based on the aggregate time series data without regional classification, this study tries to look into the hidden structure governing the aggregate data by utilizing Principal Component Analysis (PCA). Figure 7 shows the total land degradation measured by hectare from 2003 to 2023.

Figure 7. Total land degradation (Source: National Statistics Office of Mongolia: https://www.1212.mn/en/statistic/statcate/573072/table-view/DT_NSO_2400_009V1).

The variables used in the PCA are listed below. All variables are yearly time series from 2003 to 2023 obtained from National Statistics Office of Mongolia, Ministry of Environment and Tourism, and Climate Change Portal.

Degrad: Total land degradation measured by hectare in year t; Preci: Total amount of precipitation measured in millimeter in year t; Temper: Average air temperature measured in Celsius in year t; T.Horse: Total number of horses in year t; T.Cattle: Total number of cattle in year t; T.Camel: Total number of camels in year t; T.Sheep: Total number of sheep in year t; T.Goat: Total number of goats in year t.

Descriptive statistics of the above 8 variables are given below.

Table 1. Descriptive statistics.

	N	Mean	Std Dev	Skewness	S.E. Skew	Range	Minimum	Maximum
Degrad	21	9047.03	2872.76	-.01	.50	10617.90	3458.70	14076.60
Preci	21	226.20	34.59	.18	.50	103.05	175.93	278.98
Temper	21	1.25	.77	-.56	.50	3.01	-.37	2.64
T.HORSE	21	3039.96	1036.48	.47	.50	2909.39	1920.30	4829.69
T.Cattle	21	3367.61	1255.93	.35	.50	3720.04	1792.80	5512.84
T.Camel	21	350.39	90.32	.32	.50	220.35	253.50	473.85
T.Sheep	21	22160.29	7531.83	.03	.50	21991.28	10756.40	32747.68
T.Goat	21	20831.26	5834.88	-.19	.50	18608.76	10652.90	29261.66
Valid N (listwise)	21							
Missing N (listwise)	0							

Table 2. Pearson's correlation matrix of 8 variables.

		Degrad	Preci	Temper	T.HORSE	T.Cattle	T.Camel	T.Sheep	T.Goat
Degrad	Pearson Correlation	1.000	-.297	-.055	-.744	-.767	-.795	-.783	-.734
	Sig. (2-tailed)		.191	.812	.000	.000	.000	.000	.000
	N	21	21	21	21	21	21	21	21
Preci	Pearson Correlation	-.297	1.000	-.182	.308	.318	.385	.312	.265
	Sig. (2-tailed)	.191		.431	.174	.160	.085	.168	.245
	N	21	21	21	21	21	21	21	21
Temper	Pearson Correlation	-.055	-.182	1.000	.467	.465	.411	.491	.544
	Sig. (2-tailed)	.812	.431		.033	.034	.064	.024	.011
	N	21	21	21	21	21	21	21	21
T.HORSE	Pearson Correlation	-.744	.308	.467	1.000	.994	.981	.958	.906
	Sig. (2-tailed)	.000	.174	.033		.000	.000	.000	.000
	N	21	21	21	21	21	21	21	21
T.Cattle	Pearson Correlation	-.767	.318	.465	.994	1.000	.979	.976	.933
	Sig. (2-tailed)	.000	.160	.034	.000		.000	.000	.000
	N	21	21	21	21	21	21	21	21
T.Camel	Pearson Correlation	-.795	.385	.411	.981	.979	1.000	.969	.924
	Sig. (2-tailed)	.000	.085	.064	.000	.000		.000	.000
	N	21	21	21	21	21	21	21	21
T.Sheep	Pearson Correlation	-.783	.312	.491	.958	.976	.969	1.000	.985
	Sig. (2-tailed)	.000	.168	.024	.000	.000	.000		.000
	N	21	21	21	21	21	21	21	21
T.Goat	Pearson Correlation	-.734	.265	.544	.906	.933	.924	.985	1.000
	Sig. (2-tailed)	.000	.245	.011	.000	.000	.000	.000	
	N	21	21	21	21	21	21	21	21

Table 2 shows the correlation matrix of the above 8 variables. On the aggregate yearly time series level, the number of 5 types of livestock is negatively correlated with the level of land degradation. Both the amount of precipitation and average air temperature are negatively correlated with land degradation level. But these two effects of precipitation and temperature are insignificant. By proceeding to find eigenvalues and eigenvectors from the above correlation matrix with a selection rule of eigenvalue greater than 1, two principal components are found as in the Table 3 of component characteristics and Figure 8 of scree plot below.

Table 3. Component characteristics by PCA.

Component Characteristics ▼

	Unrotated solution			Rotated solution		
	Eigenvalue	Proportion var.	Cumulative	SumSq. Loadings	Proportion var.	Cumulative
Component 1	5.818	0.727	0.727	5.818	0.727	0.727
Component 2	1.258	0.157	0.885	1.259	0.157	0.885

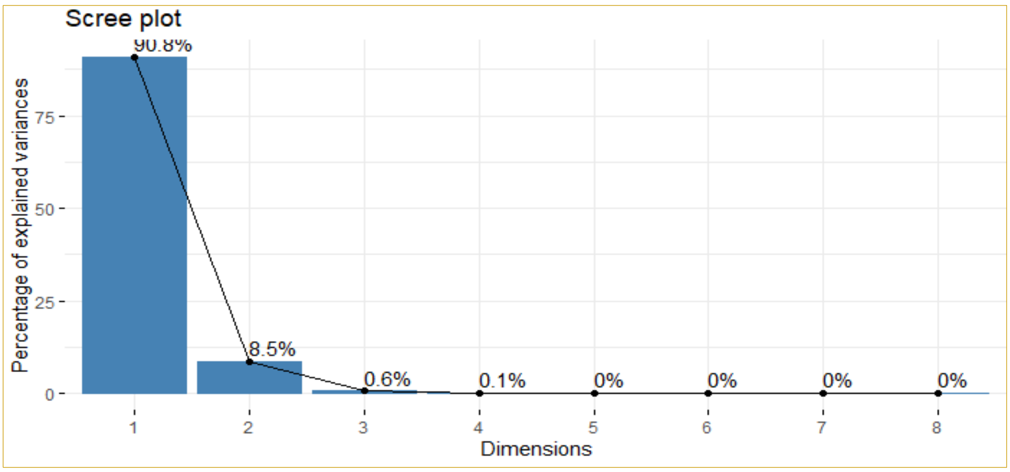

Figure 8. Scree plot of PCA.

About 90 percent of variances of these 8 variables are captured by these two factors. Outcomes are slightly different when different rotation or transformation methods are adopted.

Following Table 4 reveals that, in terms of the first principal component, land degradation level and each number of livestock types have heavy factor loadings.

On the other hand, the amount of precipitation and average temperature have heavy factor loadings in terms of the second component. The level of land degradation, temperature and precipitation exhibit relatively high uniqueness values, which implies that many outside variables can cause the variability of these variables. Overall relationship is summarized in the Figure 9 of path diagram with different relative strengths and directions of correlation.

Table 4. Component loadings of PCA.

Chi-squared Test

	Value	df	p
Model	83.261	13	< .001

Component Loadings

	PC1	PC2	Uniqueness
T.Sheep	0.992	0.033	0.014
T.Cattle	0.987	0.013	0.025
T.Camel	0.985	−0.069	0.024
T.HORSE	0.977	0.022	0.046
T.Goat	0.964	0.106	0.059
Degrad	−0.804	0.303	0.262
Temper	0.486	0.765	0.179
Preci	0.350	−0.751	0.314

Note. Applied rotation method is varimax.

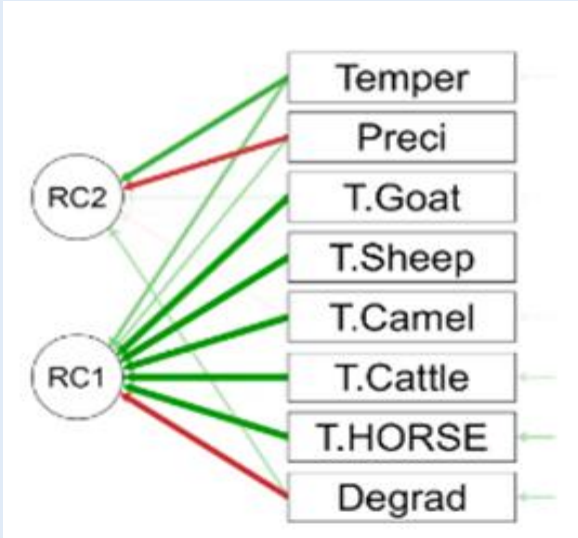

Figure 9. Path diagram: red line implies negative correlation.

To more closely look at the relationship, cosine measures of representation and contributions of 8 variables on each principal component are attached in Appendix. Most of information is captured in the below Biplot.

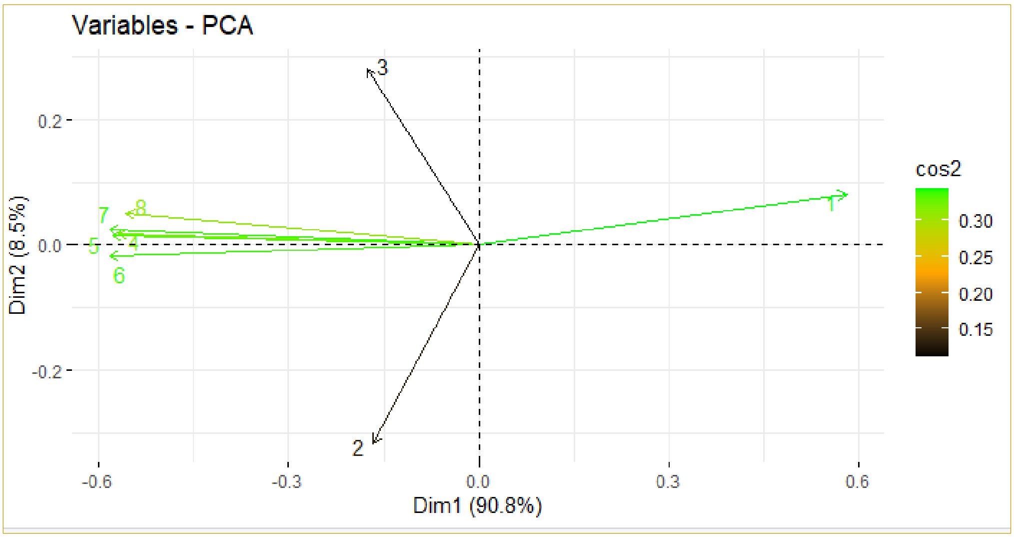

Figure 10. Biplot of PCA.

1: Land degradation, 2: Precipitation, 3: Temperature, 4: Horse, 5: Cattle, 6: Camel, 7: Sheep, 8: Goat.

Biplot of Figure 10 demonstrates:

1) Land degradation itself is basically intermingled with the number of livestock, instead of precipitation and temperature in terms of the first principal component.

2) Each number of livestock is highly correlated.
3) Each number of livestock is strongly negatively correlated with the level of land degradation, while it is positively correlated, although correlation is very weak, with air temperature and the amount of precipitation.
4) The level of land degradation is negatively correlated with average temperature, the amount of precipitation and the number of livestock.
5) The first principal component explains about 90 percent of variation of 8 variables while the second explain only 8 percent.
6) The amount of precipitation and temperature contribute the second component, while they are negatively correlated with each other.
7) The differences between land degradation and each number of livestock in terms of factor 1 is more decisive than those of precipitation and temperature in terms of factor 2.

4. Model Extension

National Statistics office of Mongolia provides yearly land degradation data from 2003 to 2023 classified by land types such as pasture and wood land, water source land, or by degradation factors such as mining and construction. Since several values of sub-group data are missing in 2023, years from 2003 to 2022 are included in the following PCA. Figure 11 exhibits most of land degradation coincides with the pasture and wood land degradation. Scree plot is in Appendix (Figure 18).

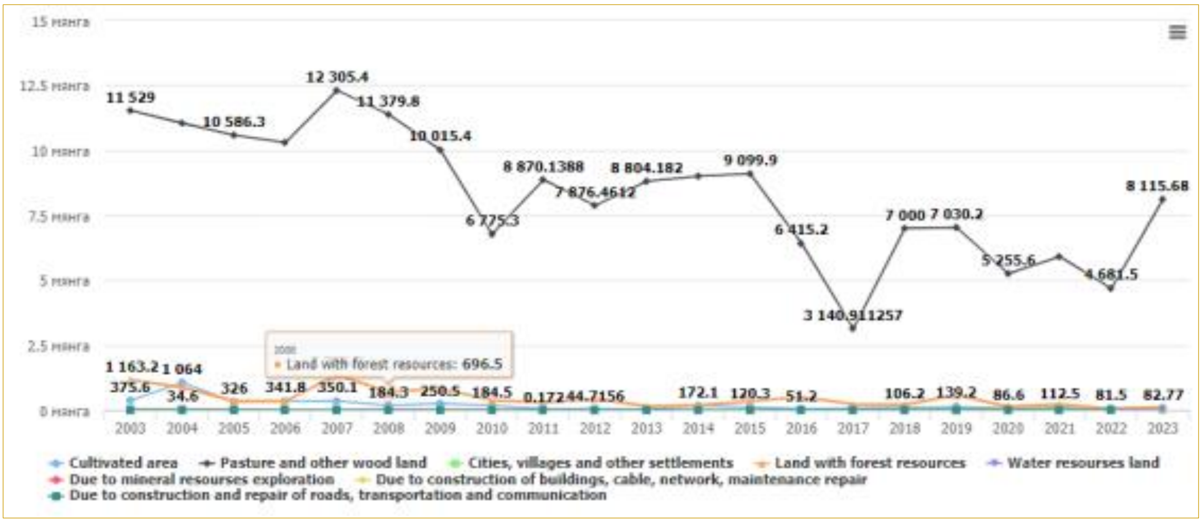

Figure 11. Land degradation classified (Source: National Statistics Office of Mongolia: https://www.1212.mn/en/statistic/statcate/573072/table-view/DT_NSO_2400_009V1).

When each category of land degradation is included instead of total land degradation, five principal components are selected with the same standard of eigenvalue greater than 1. Contributions of variables are given in Figure 12 and 13 below. Component loadings are shown in Table 5. Biplot is given in Figure 14.

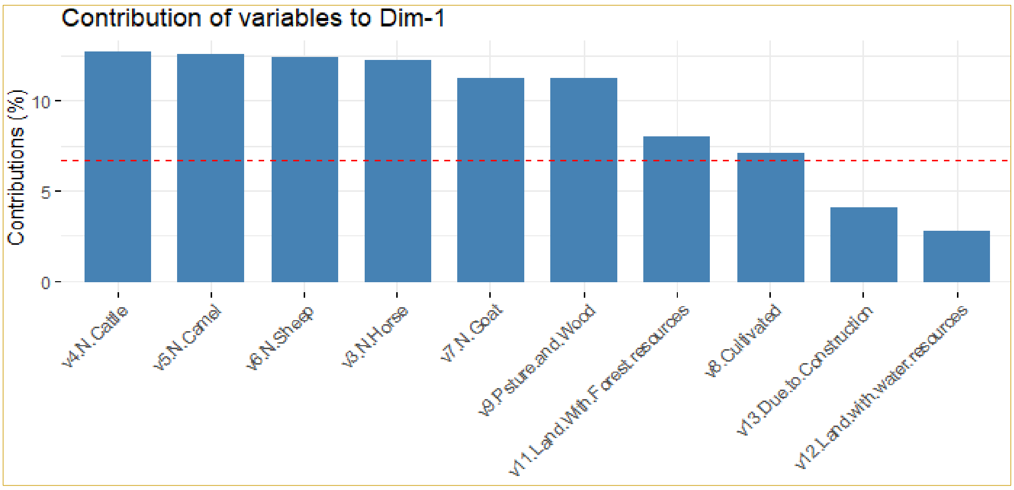

Figure 12. Contribution of variables to the first principal component, land degradation classified.

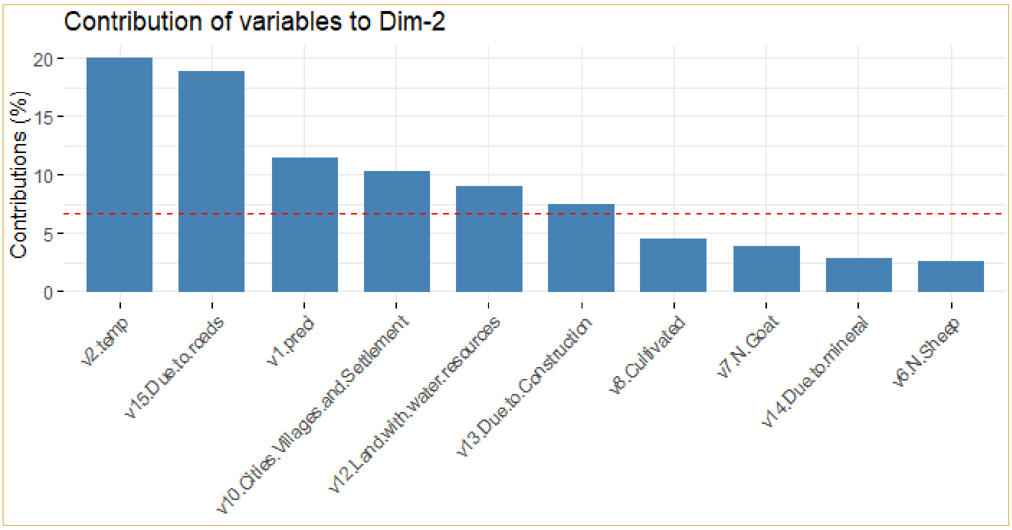

Figure 13. Contribution of variables to the second principal component, land degradation classified.

Table 5. Factor loadings of 5 principal components.

Variables	Component 1	Component 2	Component 3	Component 4	Component 5
Precipitation	0.154954267	0.33833714	0.359783021	0.507000973	0.12543241
Temperature	0.089200982	-0.44786505	-0.223265110	0.056603307	-0.38603697
N. Horse	0.349450746	-0.15442810	0.018984096	-0.071222302	-0.08211469
N. Cattle	0.356092239	-0.14507804	0.018984096	-0.039818532	-0.04591686
N. Camel	0.354323355	-0.14068670	0.086191819	0.007277825	-0.01940824
N. Sheep	0.352064948	-0.16195464	-0.041786740	0.044601133	0.01850483
N. Goat	0.335218319	-0.19802559	-0.073640882	0.097446513	0.03224829
Cultivated	-0.265964007	-0.21093372	0.127417972	-0.341321592	-0.37718073
Pasture and wood	-0.335192484	0.02667324	0.029046977	0.112950025	-0.26125461
Cities, villages and settlement	-0.002940383	-0.32119834	0.559219942	-0.100542602	-0.03269829
Land with forest resources	-0.282782411	-0.15670877	-0.010574277	0.281710182	0.01519569
Land with water resources	-0.166036887	-0.29984088	-0.273141377	-0.272104874	0.71501774
Due to construction	-0.202230764	-0.27374001	-0.219661436	0.413933227	-0.14029016
Due to mineral	-0.111461916	-0.16812818	0.572285867	-0.205937622	0.12738441
Due to roads	0.115299972	0.43448507	-0.159545818	-0.463713527	-0.25623052

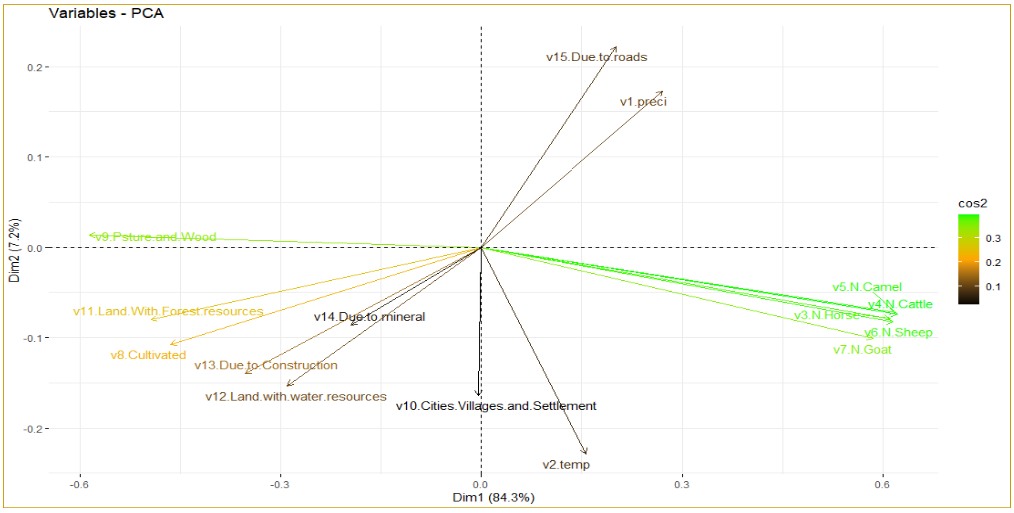

Figure 14. Biplot of PCA, land degradation classified.

In addition to the above figures, Scree plot and Cos2 representation are attached in Appendix (Figure 18 and 19).

Above component loadings and biplot indicate that:
1) Each number of livestock is strongly positively correlated, as is before.
2) The negative correlation between each number of livestock and pasture and wood land degradation contributes the most in explaining variations of all variables.
3) Each number of livestock is negatively correlated with almost all types of land degradation except for land degradation due to construction of roads.
4) Not only the nature aspects but also the human activities related characteristics are mixed in the second component, which is quite different from the previous result.
5) The desertification causes cannot be clearly partitioned into human activities and climate changes since both aspects coexist in the first two components.
6) The role of precipitation and temperature is diffused across from the second to fifth component, although the sum of these four components is only about 9 percent in explaining variations of variables.
7) The relative importance of precipitation and temperature has increased in the first component, compared to the previous outcomes.

5. Conclusion

Empirical interpretation of the principal components related to land degradation in Mongolia reveals certain limitations. Principal component analysis (PCA) is a mathematical tool used to reduce dimensionality and simplify complex datasets by transforming them into principal components. However, PCA itself does not directly interpret the nature of the underlying factors contributing to the data. In the case of Mongolian desertification, PCA has identified that land degradation is predominantly associated with factor 1, which is primarily influenced by human activities. This factor encompasses a range of anthropogenic activities such as overgrazing, mining, and the construction of unpaved roads. Conversely, factor 2, which reflects climatic variables such as precipitation and temperature, is more directly related to climate change impacts rather than human activities.

At the aggregate time series level, the data suggests that human-induced factors are the primary drivers of desertification in Mongolia. However, this conclusion may be oversimplified. When analyzing land degradation by specific sources, the distinction between human and climatic factors becomes less clear. The impact of climate change, while initially appearing less significant, becomes more pronounced when considering regional variations and specific degradation sources.

Regional differences in climate patterns and land use practices further complicate the assessment of desertification drivers. Variations in precipitation and temperature across different areas of Mongolia can alter the perceived significance of climatic versus anthropogenic factors. Therefore, a more nuanced understanding of desertification requires detailed regional studies that incorporate both human and climatic influences.

Given the complexity of the factors driving desertification in Mongolia, addressing the issue effectively necessitates a multifaceted approach. In addition to implementing policies aimed at mitigating human activities, such as stricter regulations on overgrazing and mining, promoting sustainable tourism can play a crucial role in conservation efforts. Sustainable tourism offers an opportunity to enhance environmental awareness and provide economic incentives for preserving natural landscapes. By encouraging responsible travel practices and supporting local communities in maintaining and restoring degraded areas, sustainable tourism can help mitigate the adverse effects of desertification. Thus, integrating sustainable tourism into broader land management strategies could provide a valuable complement to existing conservation efforts, fostering both environmental preservation and economic development.

Declarations

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References

1. Batjargal, Z. 1997. Desertification in Mongolia. RALA Report, 200: 107–113.
2. Batkhishig, O. 2011. Report of a synthesis workshop on dryland ecosystems in East Asia: Land dynamics amid social and climate change. Human Impact and Land Degradation of Mongolia, The Higher Education Press: Beijing, China.
3. Buren, G.W. 2011. A study on desertification status, causes and prospect of grassland animal husbandry in Mongolia. Inner Mongolia University: Hohhot, China.
4. Filei, A.A., Slesarenko, L.A., Boroditskaya, A.V. and Mishigdorj, O. 2018. Analysis of desertification in Mongolia. Russian Meteorology and Hydrology, 43(9): 599-606.
5. Liang, X., Li, P., Wang, J., Shun Chan, F.K., Togtokh, C., Ochir, A. and Davaasuren, D. 2021. Research progress of desertification and its prevention in Mongolia. Sustainability, 13(12): 6861.
6. Liu, H.J., Liu, S.J., Liu, K.L., Li, J.J., Wan, X., et al. 2018. Comparison of causes of desertification between Xilingol League of Inner Mongolia and Sukhbator Province of Mongolia. Inner Mongolia Science Technology and Economy, 24: 57-58.
7. Liu, S.J., Liu, H.J., Liu, K.L., Li, J.J., et al. 2018. Desertification survey for Sukhbaatar and Kent provinces of Mongolia. Western Resources, 4: 183-186.
8. Su, R.S.G. 2015. Study on desertification status and countermeasures of Sukhbato province, Mongolia. Inner Mongolia University: Hohhot, China.
9. Tian, F., Herzschuh, U., Mischke, S. and Schlütz, F. 2014. What drives the recent intensified vegetation degradation in Mongolia–climate change or human activity?. Holocene, 24(10): 1206–1215.
10. Wang, J., Wei, H., Cheng, K., Ochir, A., et al. 2020. Spatio-temporal pattern of land degradation from 1990 to 2015 in Mongolia. Environmental Development, 34: 100497.
11. Xinhua. 2023. Explainer: Why large parts of Mongolia are affected by desertification. Retrieved from https://english.news.cn/20230510/0286878b2b04421780ff49cb4f36a4a1/c.html

Appendix

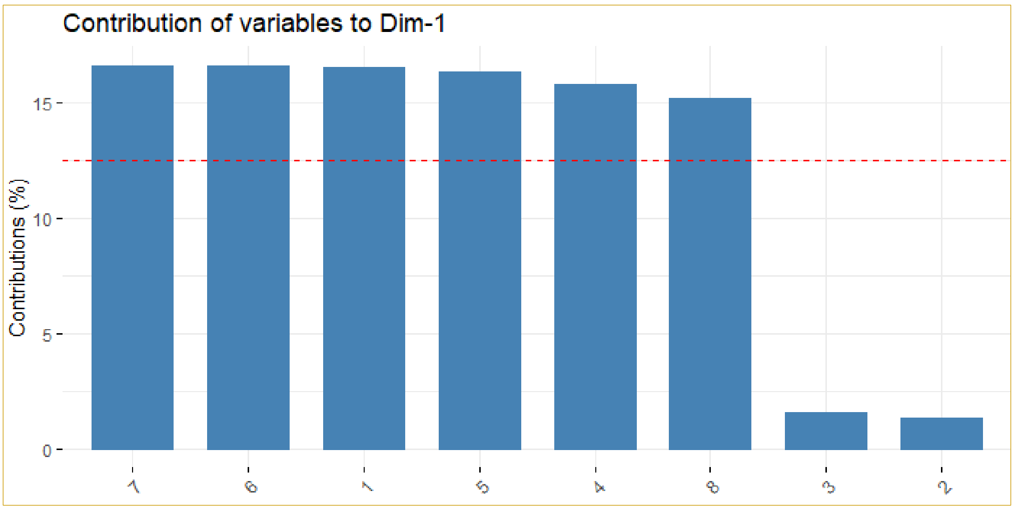

Figure 15. Contribution of variables to the first principal component.

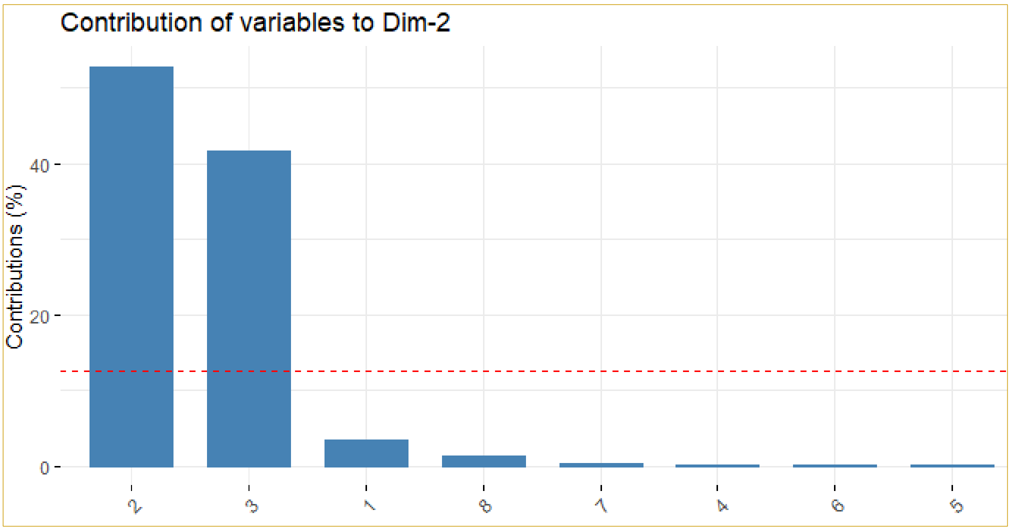

Figure 16. Contribution of variables to the second principal component.

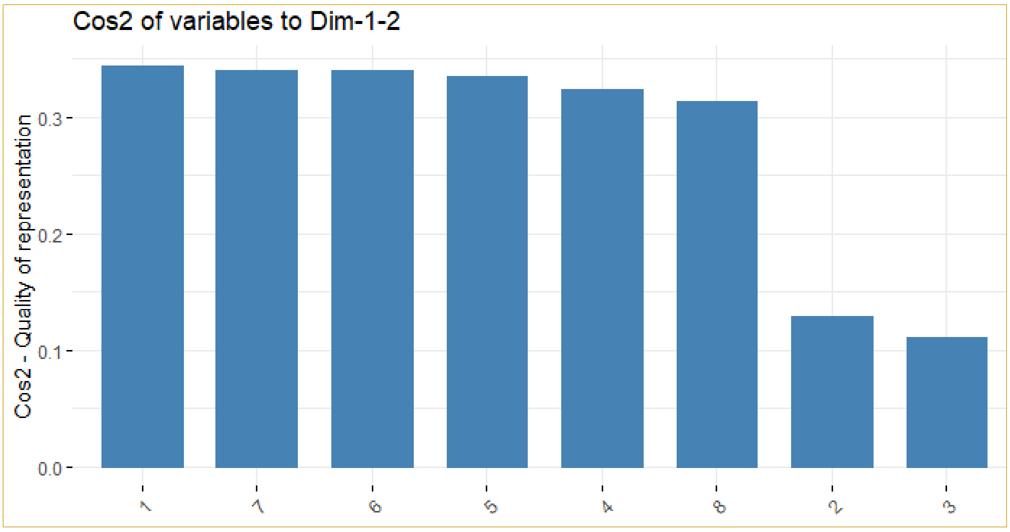

Figure 17. Cos2–quality of representation.

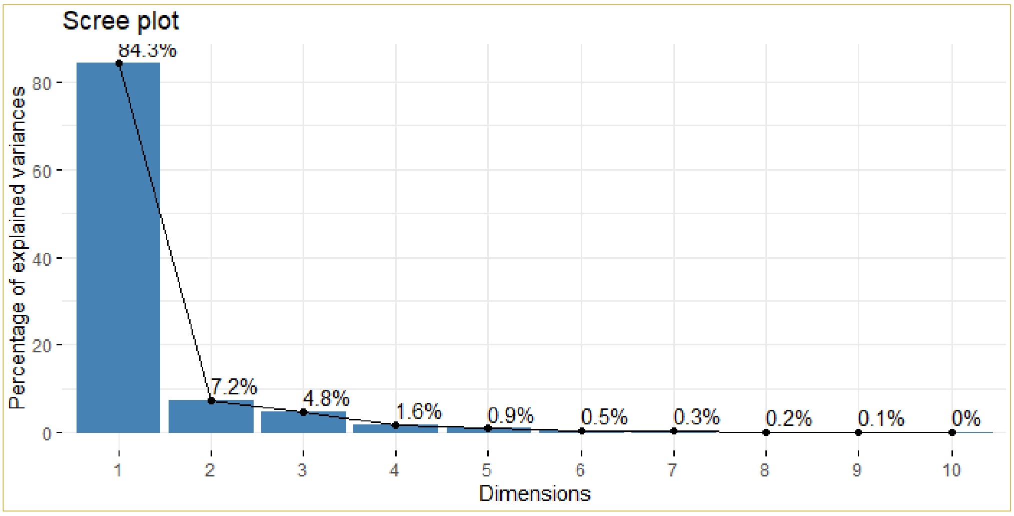

Figure 18. Scree plot, land degradation classified.

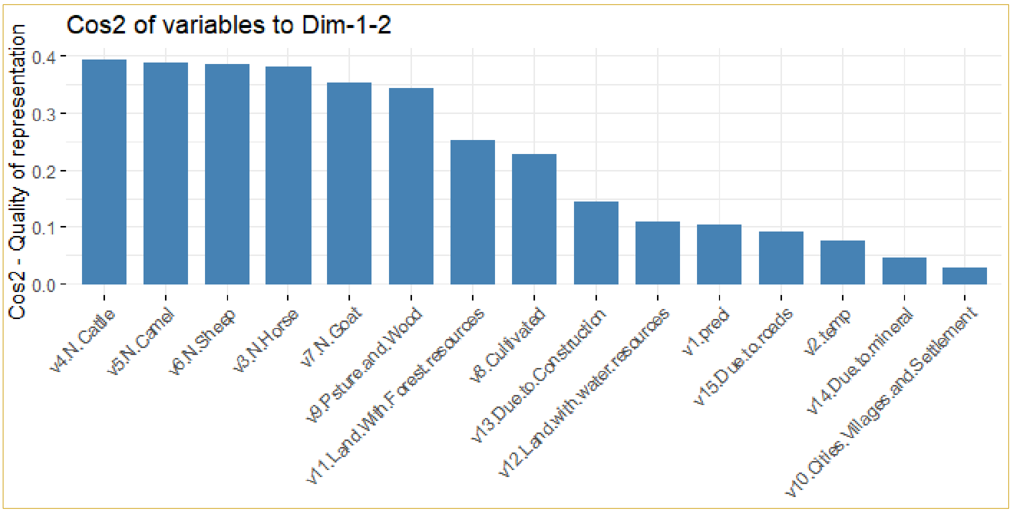

Figure 19. Cos2–quality of representation, land degradation classified.