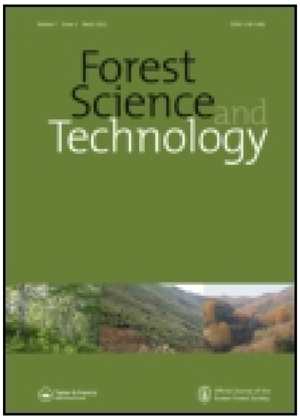

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Analyzing causes of desertification in Bayankhangai soum, Tuv province, central Mongolia

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Analyzing causes of desertification in Bayankhangai soum, Tuv province, central Mongolia

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The aim of this paper was to develop a simple assessment for precisely appraising the status and trends of desertification in Bayankhangai soum. The Bayankhangai soum is in central Mongolia, which is a part of the Hustai National Park, and this soum (administrative subdivision) belongs to the Orhon and Tuul river basins of the Khangai mountain region, encompassing 100,733 ha, and 7170 ha that is specially protected. The current study is more focused on methods for assessing climate change, pastureland change by herders and land degradation assessment. The degradation of pastureland has occurred rapidly as a consequence of herding controls being replaced by open access during the transition from socialism to a market economy. Therefore, range carrying capacity status which includes available herb biomass and predicted livestock consumption. In recent years land degradation, as measured by the decline of soil fertility and desertification as grasslands decrease, has increased with more grassland becoming sandy.

Keywords: assessment; climate change; desertification; Mongolia

Introduction

Mongolia has been struggling with desertification and land degradation for the last 30 years and, hence, desertification is becoming a national security issue. Mongolia, through its geographical location, climate, variety of land surface and ecological structure, is in an extremely susceptible and dry area with low humidity. Therefore, it is always affected by drought and desertification. Bayankhangai soum was chosen as a study area because of its current problems of land degradation and desertification (Figure 1).

The Bayankhangai soum is bounded by 47°40′ N, 48°00′ N and 105°30′ E, and covers an area of 100,733 ha; 81.6% of the total land is pasture and it is included in the dry steppe region. The surface is covered with proluvial-diluvial and proluvial deposits that have eroded and accumulated into forms. The area lies at a relatively low elevation. Generally, Bayankhangai soum is located relatively close to Ulaanbaatar. This condition has a negative influence on wildlife, and hence climate and pasture indicators were the most important factors affecting the desertification process in the study area.

Desertification assessment

Desertification studies in Mongolia began in the 1980s with the first nationwide assessment conducted jointly with the Turkmen Institute of Arid Land Studies and the Institute of Geography, Mongolia. As part of this joint research entitled “Desertification process study and elaborating the action plan for atonal use and protection of dryland ecosystem”, the natural boundaries of the drylands were defined, the influence of natural and human factors were differentiated, and a comprehensive methodology for assessment was developed.

According to the UNEP climatic classification (Dregne 1983), more than 90% of the total area is dry or semi-dry and 44.7% of this land, which is equal to 700,000 km^2, has been affected by desertification. Moreover, over a period of 30 years, 46.5% of agricultural areas have suffered from wind and water erosion; forest cover has been reduced by 1.4 million hectares, 400 rivers and lakes have dried out, and degradation has increased by 8–10% over the last 10 years (Adyasuren 2000). Vegetation yields, especially in dry regions such as the desert steppe and steppe, have decreased six times (Ministry of Nature and Environment 2002). The decline in the growing-season rainfall has been suggested as the major cause of desertification in Mongolia (Bayasgalan and Dash 2002). Dust and sand storms frequently occur in association with strong winds and exposed soil conditions (Natsagdorj et al. 2003). Severe droughts and long-term shifts in the magnitude of precipitation are typical, and droughts occur as often as once every two or three years (Adyasuren 2000). The northern part of Mongolia, Selenge, was analyzed by GIS (Badarch et al. 2011), and a similar study was conducted monitoring desertification of Mongolia using Landsat TM satellite imagery (Cui et al. 2011).

The aim of this study was to assess desertification based on pasture degradation, climate change, human-induced changes of land use and land cover, and socio-economic factors and to assess their impact using a defined set of indicators within the selected soum.

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Figure 1. Location of the Bayankhangai soum, Tuv province, Mongolia.

Materials and methods

Data source

Landsat data including two scenes (12 September 1994 path/row 132/27, and 27 September 2000 path/row 132/27) of Landsat ETM (Enhanced Thematic Mapper plus, ETM+) in 2000 covering all of Bayankhangai soum were used for monitoring desertification from 1994 to 2000. Both spectral data were collected in autumn, mainly in September. Meteorological data including monthly average temperature, precipitation of two meteorological stations (Ulaanbaatar and Erdenesant stations) and near the Bayankhangai were collected from Central Mongolia Meteorological. Social–economic census data of Bayankhangai soum were collected from local statistical yearbooks.

Methods

Climate assessment

Long-term temperature and precipitation changes, as well as evaporation, were analyzed to assess the impact of climate change. Climatic stress can be measured as a function of changes in the Standardized Precipitation Index (SPI) and Pedi index by deviations of temperature and precipitation from the long-term pattern (Bayasgalan and Dash 2002). There is no measuring station in Bayankhangai soum. However, long term meteorological data was taken from the nearest stations, Ulaanbaatar and Erdenesant (Hydrometeorology Institute), to assess the change of temperature and precipitation for the period 1960–2005.

Land degradation assessment

Vegetation cover and sand dunes accumulation images were used for this assessment, which were derived from Landsat ETM+ imagery using the Normalized Difference Vegetaton Index (NDVI) and the Normalized Differential Sand Dune Index (NDSDI) algorithms, respectively. A high value of the Land Degradation Index (LDI) indicates a more severe level of land degradation. It is calculated using the following formula:

$$\text{LDI} = \sum_{i=1}^{n} PC_i^{-q}$$

where LDI ($0 \leq \text{LDI} \leq 1$) represents the risk of the land degradation in the county; C_i is the rank at which the land in an assessment unit has been degraded; P refers to the areal percentage of the land having a rank I, n stands for the number of indicator classes; and q denotes the exponent of rank. In order to study the temporal dynamics, the LDI was calculated for each county for 1994 and 2000.

Results and discussion

Climate condition

The mean annual temperature in Bayankhangai soum center is 0.6 °C, the annual temperature of the coldest month (January) is −23.2 °C and that of the warmest month (July) is 20.4 °C. Due to the inversion factor, the temperature during the cold season rises by 0.5–0.6 °C as elevation increases by 100 m, and during the warm seasons the temperature falls by 0.3–0.4 °C with increase of elevation by 100 m. Weather records show that the warmest temperature of Bayankhangai was 40.5 °C and the coldest temperature was −39.6 °C. Winter monthly average soil surface temperature was 1–2 °C warmer than the air temperature and this difference increases to 3–6 °C in the warm season. Surface temperature falls to −41 to −36 °C in winter and reaches 52–56 °C in summer.

The seasonal changes of air temperature show that all seasons have warmed, with the mean annual temperature having increased by 2.0 °C, summer temperature by 2.6 °C, winter temperature by 2.3 °C, and spring and autumn temperatures by 1.5–1.9 °C. Since 1970 the number of days warmed above 30.0 °C to 33.0 °C has increased by 5–6 days.

The total evaporation during 1961–2004 increased by 132 mm, whereas precipitation during this period decreased by almost 88 mm (Figure 4). Annual rainfall as recorded in the *Climate reference book of the aimag* equals 130.4 mm, which seems to be low at least 100 mm too low. The neighboring settlement areas Erdenesant, Ugtaal, and Ulaanbaatar receive 256.5 mm, 267.4 mm and 230.5 mm precipitation, respectively; thus Bayankhangai soum should receive around 204.0 mm of precipitation.

Herders and livestock

Livestock production is the major source of income of pastoral households, and about 35% of the total population in Bayankhangai soum or 495 people rely on herding for their livelihood (Mongolian Society for Range Management 2009). The herders' economic well-being has generally improved with increased livestock number.

From 1991-2005, the number of livestock of the Bayankhangai soum has increased by 2.6, and the rate of the increase reached its peak during 1991–2005. The number of livestock per hectare varies from 0.57 sheep unit. It is expected that, in the last six years, the number of livestock

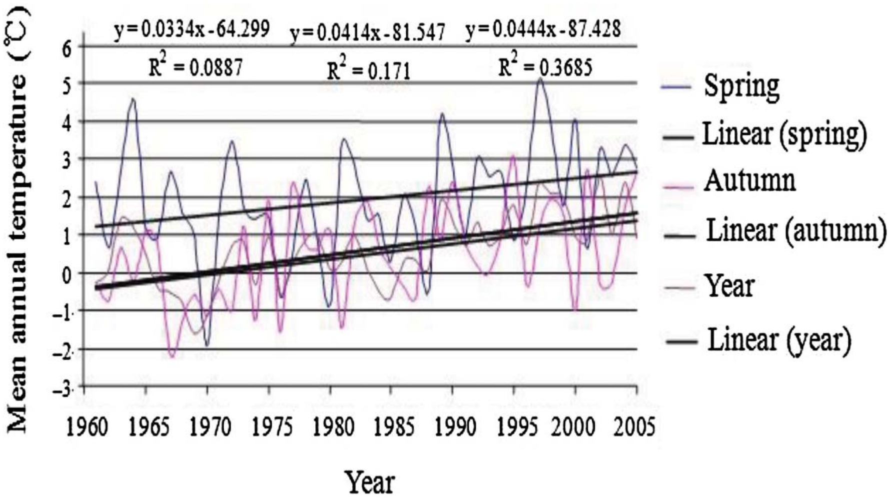

Figure 2. Changes in mean annual temperature of spring and autumn, for 1960–2005.

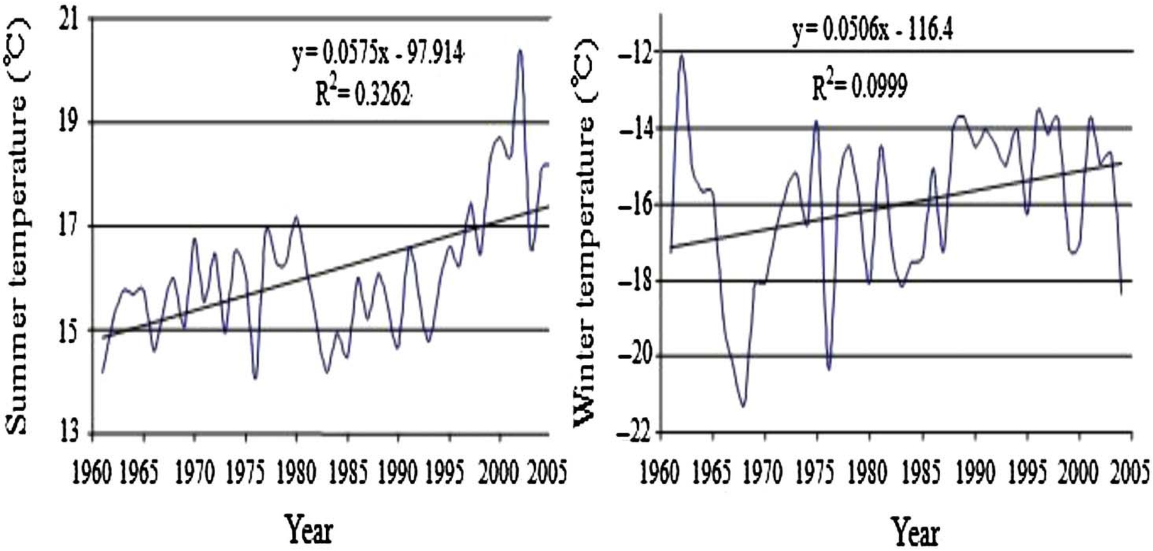

Figure 3. Long-term trend of the summer and winter temperature of Bayankhangai soum for 1960–2005.

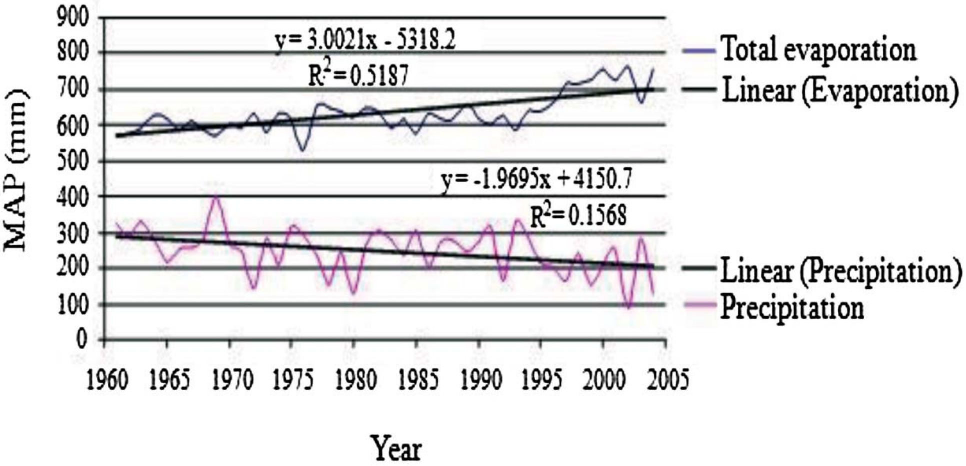

Figure 4. Long-term trend of the open surface evaporation and precipitation (MAP) amount that occurred when temperature is above 0.0 °C.

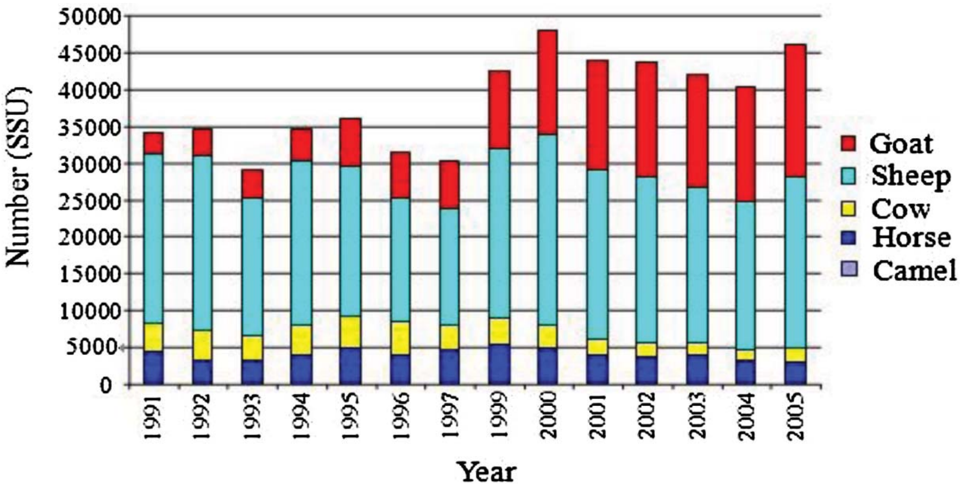

Figure 5. Herd structure and dynamic livestock number of Bayankhangai soum, for 1991–2005 (Statistic Yearbook of Tuv aimag, 2008 in Population Year Book (2008)).

will have increased by almost 10,000, which poses a serious threat to the land carrying capacity for the coming years.

Pasture degradation

Plant species composition is shifting towards a decreasing number of edible plant species. This decrease also affects wildlife diversity, as an increase of livestock number during the last two decades has decreased the grazing area gazelles. Regarding pasture plant species, Bayankhangai soum was reported to have 17–19 plant species in 1980–1981; this was reduced to 10–16 in 2005–2006 (Figure 6). The pasture investigation of 2005–2006 shows that species such as *Stipa mongolica*, *Allium polyrrhizum* and *Leymus* sp. are rarely found in the pasture.

Land degradation status

Land cover of Bayankhangai soum is dominated by rangeland including grasslands, steppe and dry steppe. Changes in land use over the centuries have been defined by the physical climate and pastoral patterns of herding strategies (Chuluun and Ojima 2002). Land cover change over the area was assessed using Landsat images obtained in 1994 and 2000. Land cover and its changes are shown with three maps showing land cover divided into nine classes: forest, water bodies, steppe (grassland 1), mountain steppe (grassland 2), dry steppe (grassland 3), sand, bare ground, roads, and crop land. The area of each category was estimated and is shown in Table 1 and Figure 7. This assessment showed that in 1994 weather patterns were considered normal, whereas in 2000 the country experienced drought. A small part of the Bayankhangai soum is illustrated in green.

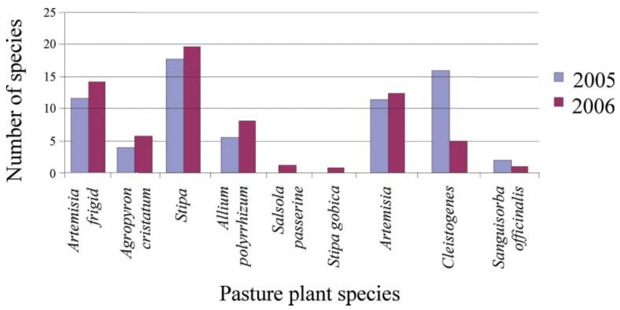

Figure 6. Loss of major pasture plant of Bayankhangai soum for 2005–2006.

Table 1. Land cover changes of Bayankhangai soum for 1994–2000.

Land cover classes	Area (km^2) 1994	Area (km^2) 2000	Change (km^2)
Forested area	12.02	5.82	6.2
Water bodies	1.39	0.31	1.08
Grassland 1 (steppe, mountain and meadow)	435.0	112.33	322.67
Grassland 2 (mountain ranges)	325.6	613.4	−287.74
Grassland 3 (dry steppe)	32.54	113.21	−80.67
Sand	0.03	0.28	−0.26
Barren land	7.56	0.01	1.54
Roads	5.96	6.95	−0.99
Cultivated area	184.6	145.49	38.10
Total	998.7	–	–

According to the land cover change survey, the above-mentioned classes have been changed significantly. The forested area of the Bayankhangai soum has decreased by 14,400 ha between 1994 and 2000. The area occupied by water bodies decreased by 42,500 ha, and the area of roads has increased by 3300 ha during this period. The satellite image analysis is not suitable to classify land cover especially for classifying different grassland types. Secondly, grassland of Mongolia depends greatly on climate variability. For instance, the year 1994 had a good summer while 2000 had droughts.

The degradation was found to occur in soum as well; normal or slightly degraded areas comprise the largest class at 43.4% or 43,718 ha. Moderately degraded areas make up the second largest class at 32.5% or 32,738 ha,

Table 2. Land degradation level of Bayankhangai soum.

Total area (ha)	Desertification rate					
	Normal or weak (ha)	%	Moderate (ha)	%	Heavy (ha)	%
100,733	43,718	43.4	32,738	32.5	24,276	24.1

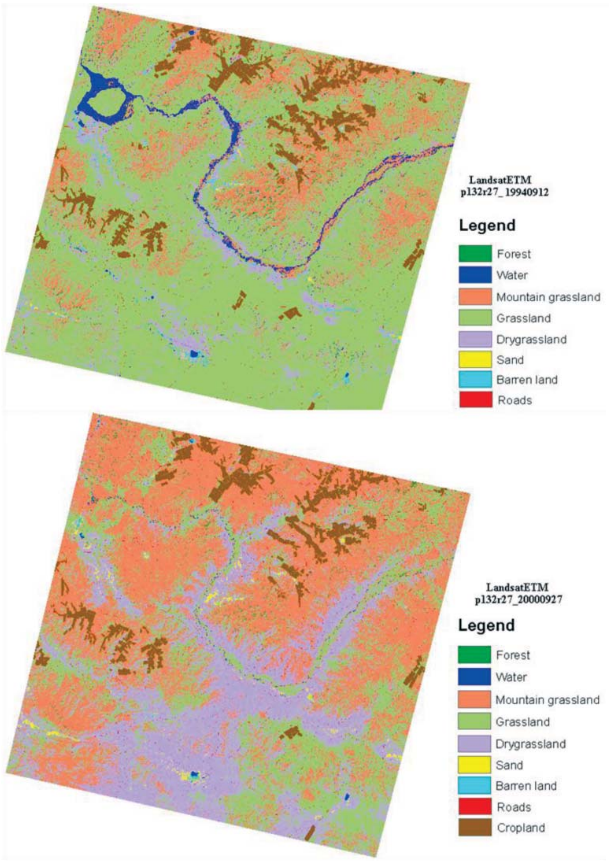

Figure 7. Land cover changes of Bayankahngai soum. Landsat data of (a) 12 September 1994 path/row 132/27 and (b) 27 September 2000 path/row 132/27.

and heavily degraded areas constitute 24.1% or 24,276 ha (Table 2). The heavily desertified land tended to increase such as at Bayankhangai soum, which can be explained by increasing pressure on pastureland as well as drought and water erosion, especially along the roads and dried river bed.

Conclusion and recommendations

Firstly, the increased influence of climate change increases the risk of land degradation, and through all ecosystems this risk is increased through inappropriate land use management. Average annual temperature increased by 1.5–1.9 °C in spring and autumn, in winter by 2.3 °C, in summer by 2.6 °C, and by 2.0 °C across the year. The last 45 years' average rainfall information showed that today rainfall is decreasing by 2.2 mm/year. Since 1961, mean annual precipitation decreased by 37%. Also summer rainfall decreased by 70 mm.

Secondly, the direct influence of land degradation and desertification on pastureland, as well as on rural livelihoods, has considerably increased. The livestock numbers increased from 18,4000 in 1985 to 86,700 in 2008. In the last 20 years, pastureland increased by 1727 ha, hay field increased by 2250 ha, and non-arable land increased by 14,455 ha. Pasture yield in 1980–1981 was 4100 kg/ha, which decreased to 3600 kg/ha in 2006. The possible recommendation for a particular case can be made from results on livestock herding as a basis of traditional methods. In this respect, the practice of leaving degraded pasture for 4–5 years to promote natural regeneration is suitable.

During 1980–2006 vegetation cover decreased by 10%. Today, pasture vegetation cover is about 30–35% and capacity exceeds by >2 times. Agricultural land decreased by 6930 ha and abandoned land increased by 14,455 ha. During 30 years of cultivation, the highest yield was collected during the first decade (1300 kg/ha), while in the second decade the yield gradually decreased and during 1990–2000 was 250–750 kg/ha. The possible recommendation for rehabilitating in deserts can be suggested from results on vegetation changes; more traditional plantation of perennials may be useful to experiment with in certain areas.

Finally, results of changes of land use and land cover over the Bayankhangai soum during a six-year period (1994–2000) provide some insight into the socio-economic causes of land degradation and desertification. For instance, land degradation was measured using remotely sensed Landsat images for 1994 and 2000 and it has provided more evidence of degradation. The land degradation map shows that 43.4% of the territory degraded weakly, 32.5% degraded moderately and 24.41% degraded heavily due to climate change and overgrazing, irrigation and vehicle-induced degradation, degradation of vegetation cover, loss of soil nutrients and fertility in arable land, and increases of deforested and denuded land.

Acknowledgement

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