2005

The Effects of Anthropogenic Impact on Plant and Soil Cover in Mongolia

Werner Hilbig
Petershausen, Germany

Christian Opp
Philipps-University Marburg, opp@staff.uni-marburg.de

In: Proceedings of the symposium "Ecosystem Research in the Arid Environments of Central Asia:
Results, Challenges, and Perspectives," Ulaanbaatar, Mongolia, June 23-24, 2004.
Erforschung biologischer Ressourcen der Mongolei (2005) 5.

Erforsch. biol. Ress. Mongolei (Halle/Saale) 2005 (9): 163–177

The effects of anthropogenic impact on plant and soil cover in Mongolia[1]

W. Hilbig & C. Opp

Abstract

Under the prevailing variable natural conditions nomadic pastoralism was the most suitable form of land use in Mongolia and the neighboring countries in the past. Furthermore, small areas were used for agriculture in some regions. Therefore, anthropogenic influence was present throughout history. In the forest steppe zone this led to the disappearance of forest sites which then gave way to meadow steppe.

The severe impact on the natural pastures by continuous increase of livestock herding and other human activities was perceptible during the socialist period. But since the 1990s, after the transition to market economy, this impact has increased greatly and a great number of degradation features and irreversible damages in the plant and soil cover can be observed now. Especially in the vicinity of the Mongolian capital Ulaanbaatar, along the north-south road corridor from Russia to the Chinese border, but also in some western regions of the country herders concentrate their livestock in search for better marketing opportunities. Especially there, the vegetation in vast areas is overgrazed by biting and trampling to such an extent that its regeneration is endangered. Degraded and devastated pasture types with a decrease of valuable forage plants and a high increase of ruderal elements can be found in these grasslands. Characteristic sequences of pasture degradation are presented here.

The degradation effects steppes and desert steppes as well as reed, mire, and meadow vegetation in the river valleys and lowlands. In the desert regions saxaul vegetation is especially threatened. In some cases after degradation of the plant cover these degradation processes effect soil cover, too.

Impacts on soil cover caused by ploughing of virgin land, by ploughing of long term used arable land, and by irrigation are the main reasons for soil degradation. Also recreational activities in the vicinity of settlement centers and traffic along the tracks lead to detrimental vegetation and soil cover changes. Unsystematic forest clearing goes on at a high level and often results in irreversible soil degradation.

Keywords anthropogenic impact, Mongolia, overgrazing, vegetation, soil degradation

Introduction

In Mongolia and the neighboring countries nomadic pastoralism was the most suitable form of land use under the prevailing natural conditions for hundreds and thousands of years. Anthropogenic influence was ubiquitous with the exception of some high mountain regions and the most extreme arid deserts in the Gobi. As a consequence forested areas in the zone of forest steppe were replaced by meadow steppes. Also in the past small areas were used for agriculture. The influence of livestock herding reaches from the taiga forests in the North to the deserts in the South, from the river valleys and basins to the alpine belt in the mountain regions. The effects of man's activity are much more visible in present times than they were in the past because pasture use was liable to especially pronounced fluctuations in the last decades of the Mongolian history.

[1] Results of the Mongolian-German Biological Expedition since 1962, No. 248.

During the socialist period intensive livestock breeding in cooperatives and state farms became the norm. Private ownership of pasture land did not exist. Private livestock of the herders was allowed only in little numbers for subsistence. After the livestock increase in the 1930s till 26 Mill. in 1940 and the following retrogression the number of domestic animals increased again in the 1960s and 1970s. In the 1980s livestock numbers hovered around 22–25 Mill., 60 % of which were sheep (Anonymous, 1991).

This was the onset of the severe impact on nature, which resulted in the degradation of plant and soil cover. However, as the socialistic management included pasturing restrictions to certain administrative territories, truck transportation facilities for livestock 'migration' over long distances, and winter forage reserves, pastures could regenerate, at least partly (Opp & Hilbig, 2003).

As a consequence of the transformation from socialism to market economy, at the beginning of the 1990s, all formerly state-owned livestock became privatized. However, all pasture remains state property, so the privately owned livestock feeds on pastures in state ownership. Subsequently livestock numbers increased continuously reaching its peak with more than 33 Mill. in 1999. The proportion of goats, which especially impair the vegetation, increased from 1990 till 1994 by 40 % (Müller & Bold, 1996; Müller & Janzen, 1997; Opp, 1996, 1997). Janzen & Bazargur (2003) compared the livestock numbers of 1989 and 1999 and gave an impressive map, which shows these changes for all Aymags (provinces) of the country. In this process not only the number of domestic animals increased, but also the number of their owners. People, who had a different education and jobs and therefore did not have experience in livestock herding, became herders after the tremendous economic changes following 1990. Today herders concentrate their livestock because of better market chances especially in the vicinity of the Mongolian capital, at both sides of the north-south transit road, from Russia to China, but also in some western regions. This is possible as all pasture land is still in national ownership and access to pasture is free (Opp, 1996). This causes reduced pasture migration (Janzen & Bazargur, 2003). The vegetation there is under such intensive pressure, caused by biting and trampling, that its regeneration is endangered. Effects of the pasture impact to plant and soil covers are intensified by drought effects. Soil stress caused by evaporation sometimes is even higher than that caused by trampling of livestock (Opp, 1997). Avadorj explained in a lecture in 2004, that 80 % of the whole pasture ground of Mongolia is regarded as degraded. Batkhishig & Lehmkuhl (2003) emphasize that 22 % of the pasture land are heavily degraded and 20 % of that is destroyed by road erosion, caused by increasing private traffic, especially after 1990. This is about as much land as is under cultivation in Mongolia. Only 1.7 % of all pastures are considered to be without any signs of degradation.

Degradation of plant and soil cover is a very complex process, and does not operate identically in different parts of the country due to different natural conditions, various soil types, and floristic species combinations. At the beginning of the process the first changes are often visible only in the modification of the proportions of some plant species. In later stages originally not present species groups appear and finally new plant communities are developing. Beside soil stress caused by trampling of grazing animals, there are also direct impacts to soil cover caused by ploughing of virgin land, by ploughing of arable land and by irrigation (Opp & Barsch, 1993).

Methods

This paper is based on countless phytosociological vegetation relevés made during numerous expeditions to Mongolia. The names of the plant species follow Gubanov (1996), the names of the vegetation units, especially of the plant associations, follow Hilbig (1995, 2000a).

In addition to usual methods of analyzing vegetation and soil cover (Barsch et al., 2000), soil samples were taken from disturbed and undisturbed areas and soil standard data (grain size distribution, humus content, etc.) determined. Furthermore, soil density, total pore volume,

Figure 1: Destruction of larch forest in the Western Tannu-Ola (Tuva). Photo by W. Hilbig.

pore size distribution and saturated vertical water conductivity were assessed, which qualify survey data by quantitative values, and allow statements about natural and man-made soil degradation. Soils were surveyed and described following both, AG Boden (1994), including proposals made by Haase (1983) and WRB (1994, 1998). This became necessary, because soil units after WRB classification do not correspond well with diversity and diagnostic features of the studied soils.

Results

Effects of anthropogenic impact on main vegetation types

The effects of anthropogenic impact of the last decades can be observed in all vegetation zones, altitudinal belts and vegetation types.

In the forest steppe zone intensive grazing in combination with logging leads to a disrupted forest distribution which is characteristic for today's landscape. Nowadays the forests are restricted to the more favorable sites while they are replaced by secondary steppes at all other sites.

The process of forest destruction is still ongoing in present times (figure 1). Irregular wood cutting in combination with free pasture may lead to the complete destruction of the forest vegetation in a few years. Especially relic stands and forest patches at the border of the forest distribution may disappear completely in a short time (figure 2, see also Hilbig, 2000b). Furthermore, irreversible soil erosion at steep slopes makes new forest development impossible.

The elm (*Ulmus pumila*) is especially endangered as it exists very often only in degraded relic stands. Strongly browsed elm bushes in the steppe surroundings (figure 3) show, that the originally existing elm bush forest cannot regenerate without protection from grazing. Also the

Figure 2: Destruction of larch forest and soil erosion at a steep northern slope in the Tsast-uul (Mongolian Altay, Bayan-Ölgiy Aymag). Photo by W. Hilbig.

young exemplars of the larch (*Larix sibirica*) are intensively browsed. Exemplars with a height of 0.5 m can be 10–20 years old. Also the Mongolian flood plains are heavily affected by grazing. Dense riverine poplar forests with shrubs and tall forbs remain only on river islands and at other places, that are difficult to reach for humans and livestock. The remaining poplar forests often remind one of parks without any regrowth or shrub layer but with a short grass cover. In the last years river valley forests still were cleared completely (figure 4). Even willow shrubbery as a last remnant of former wooden vegetation is destroyed by overgrazing (figure 5) and cutting for timber or fuel.

Also in the desert and semi desert (desert steppe) zone grazing and browsing contributes to the reduction of woody vegetation. The extended duration of stay of the herders in the little oases and valleys with increasing numbers of livestock leads to the destruction of wooden plants and the extinction of regrowth. Often also the herb layer of the little stands of *Populus diversifolia* has been changed to a high degree, and is replaced by poisonous and some annual ruderal plants (figure 6). At this point it has to be emphasized, that ecosystems of arid areas are especially sensitive to anthropogenic impact because of their low productivity and difficult conditions for regeneration.

Also the saxaul stands (*Haloxylon ammodendron*) which serve as the primary forage basis in the desert regions are often heavily grazed. Some individuals die off due to heavy browsing and subsequently the stems are used for fuel. In the northern part of its distribution the saxaul has already been reduced to a high degree. Mongolian botanists such as Gal and from German side Helmecke have pointed to the harmful influence of overgrazing for the existence of the saxaul stands and their continuous use as livestock forage (Gal, 1968, Helmecke & Schamsran, 1979).

The high level of anthropogenic impact is evident in the grass dominated vegetation, from different types of steppe communities to the meadows and pastures in the valleys and basins. Steppe areas, which due to the missing water supply are only used for winter pasture, show the

Figure 3: Strongly browsed elm bush and *Caragana* shrubs in the south of Dashinchilen (Arkhangay Aymag). Photo by W. Hilbig.

lowest anthropogenic impact. Intensive grazing pressure in most steppe sites leads to increasing proportions of poisonous, strongly aromatic, hairy and spiny-prickly species, because animals avoid these kinds of plants.

In his book 'Forage plants of Mongolia' Yunatov (1954) evaluated the forage value of many species and also listed the plants scorned by the animals (table 1). These plants, which often have beautiful flowers, can luxuriously develop and dominate in overgrazed steppes and meadows. They include species from the genera *Artemisia, Heteropappus* and *Peganum*, as well as *Hypecoum erectum, Leontopodium ochroleucum, Stellera chamaejasme* (figure 7), and *Iris lactea* (figure 8).

Also weeds, low stoloniferous and rosette plants (*Halerpestes salsuginosa, Potentilla anserina, Plantago depressa, Taraxacum leucanthum*) are promoted by grazing as they cannot be grazed to such an extend as other plants and are less sensitive to trampling due to their low growth. Higher growing, trampling sensitive grasses diminish. Originally dominant steppe species like *Stipa krylovii, Koeleria cristata* and *Agropyron cristatum* are replaced by other species like *Cleistogenes squarrosa, Leymus chinensis, Carex duriuscula, Artemisia frigida* and *Potentilla acaulis*. The high proportion of the low-growing *Carex duriuscula* is characteristic for strongly degraded steppe vegetation (see tables 2 & 3). Also annual ruderal species are increasing. Due to overgrazing the species composition of the steppe communities on deep, well developed soil profiles is very similar to that on flat, low developed stony soil profiles. In the mountainous regions slopes are covered with livestock tracks of the domestic animals, which indicate high pasture intensity (figure 9).

Within the manifold steppe communities, described by Russian authors, steppe communities with varying grazing impact can be distinguished by the dominance of grass species with different

Figure 4: Riverine poplar forest devastation in the Tesijn-gol flood plain near Erzin (Tuva). Photo by W. Hilbig.

pasture sensitivity. The *Stipa krylovii-Leymus chinensis*-steppe, the *Stipa krylovii-Artemisia frigida*-steppe and the *Stipa krylovii-Carex duriuscula*-steppe are grazing facies of the otherwise in their species composition uniform steppe association of the *Cymbario-Stipetum krylovii*.

Especially near settlements and jurt camps the steppe vegetation looses their typical and valuable species completely. Instead, ruderal, mostly annual species flourish, which have their optimal habitat in dry streams (sairs) with open soil surface, such as *Setaria viridis, Ceratocarpus arenarius, Salsola tragus, Chenopodium-, Lappula-* and *Axyris*-species. Three relevés from the vicinity of a jurt camp in the region of Darkhan show the changes in plant cover, the decrease in valuable forage grasses and the increase of ruderal species as a result of increasing grazing and trampling influence towards the jurt place (table 4). Another degraded plant stand from the Arkhangay Aymag (Hilbig, 1990, p. 53), which can only hardly be termed as steppe vegetation, is composed of the following species: *Artemisia adamsii* 3, *Carex duriuscula* 1, *Leymus chinensis* 2, *Potentilla bifurca* +, *Axyris prostrata* 2, and *Lepidium densiflorum* +.

Table 3: Decreasing and increasing species of the mountain steppe association *Hedysaro inundati-Stipetum krylovii* (after the constancy table in Hilbig, 1990). Column 1– *Astragalus inopinatus* subassociation, column 2 – *Carex duriuscula* facies.

Species	**1**	**2**
Stipa krylovii	V	III
Festuca lenensis	V	II
Poa attenuata	IV	II
Koeleria cristata	V	II
Carex pediformis	III	.
Carex duriuscula	III	V
Potentilla bifurca	III	IV

Also along dirt-track roads and on old tracks steppe species are replaced by less palatable

Figure 5: Overgrazing of willow shrubbery by camels in the Khovd-gol flood plain near Khovd (Khovd Aymag). Photo by W. Hilbig.

Table 1: Plant species, scorned by livestock (after Yunatov, 1954).

Plant species, scorned by livestock	
Artemisia adamsii	*Neopallasia pectinata*
A. macrocephala	*Oxytropis myriophylla*
A. mongolica	*O. trichophysa*
A. palustris	*Pedicularis longiflora*
A. sieversiana	*Pedicularis* spp.
Dracocephalum foetidum	*Peganum harmala*
Gentiana decumbens	*P. nigellastrum*
Heteropappus, several species	*Potentilla fruticosa*
Hypecoum erectum	*Stellera chamaejasme*
Iris lactea	*Thalictrum foetidum*
Leontopodium campestre	*Veronica incana*
Lophanthus chinensis	

Figure 6: Degraded *Populus diversifolia* stand in the little oasis Züün-mod in the South of Shine-jinst (Trans-Altay-Gobi, Bayankhongor Aymag). Photo by W. Hilbig.

Figure 7: Crowds of *Stellera chamaejasme* in the meadow steppe (Töv Aymag). Photo by W. Hilbig.

Figure 8: Mass development of *Iris lactea* in the Khovd-gol flood plain near Khovd (Khovd Aymag). Photo by W. Hilbig.

Table 2: Decreasing and increasing species of the steppe association *Cymbario-Stipetum krylovii* (after the constancy table in Hilbig, 1990). Column 1 – typical subassociation, column 2 – *Caragana microphylla* facies, column 3 – *Carex duriuscula* facies.

a)	**1**	**2**	**3**
Stipa krylovii	V	V	IV
Cleistogenes squarrosa	V	V	IV
Koeleria cristata	IV	IV	I
Agropyron cristatum	V	V	III
Poa attenuata	III	IV	I

b)	**1**	**2**	**3**
Carex duriuscula	III	IV	V
Chenopodium aristatum	s	III	.
Chenopodium album	s	III	II
Chenopodium acuminatum	.	II	.
Salsola tragus	s	III	II
Sibbaldianthe adpressa	II	III	III
Potentilla bifurca	IV	IV	V
Rheum undulatum	I	I	II

Figure 9: Livestock tracks in the Türgen-uul (Uvs Aymag). Photo by W. Hilbig.

plants. Typically, *Salsola tragus* stands, which are especially poor in species, grow on such sites. The regeneration of the original steppe vegetation needs a long time. Especially in the desert steppe the continuous presence of livestock in the surrounding area of jurt camps and near wells often leads to complete bareness of vegetation. The *Stipa glareosa-Anabasis brevifolia* association, typical for vast areas in the semi desert zone, degrades to a *Peganum nigellastrum* facies and finally to species poor *Peganum nigellastrum* stands, which also form the typical vegetation found in the sum centers in southern Mongolia.

Also the reed vegetation is grazed. Reed and sedge marshland is severely and continuously disturbed by livestock. The young shoots are grazed already in spring. Intensive trampling damages soil structure and plant cover. When heavily grazed reed beds remain of low height plants from the annual mud bank of the Bidentetea group like *Bidens tripartita, Chenopodium glaucum,* and *Persicaria lapathifolia* benefit from the gaps in the vegetation cover and dwarf rushes (*Juncus bufonius, Cyperus fuscus*) invade.

During socialist times seemingly suitable sites of the forest steppe and steppe zone were taken

Table 4: Steppe degradation stages near Darkhan along a gradient away from a jurt camp (after Hilbig, 1990). Relevé 1 is furthest away from the jurt, site 3 nearest. Moreover in relevé 1: *Allium bidentatum* 1, *Allium senescens* +, *Bupleurum bicaule* +, *Dianthus versicolor* +, *Koeleria cristata* 1, *Orostachys malacophylla* +, *Veronica incana* +; in relevé 3: *Urtica cannabina* +.

Species	**1**	**2**	**3**
Stipa krylovii	3	2	1
Caragana microphylla	1	1	1
Kochia prostrata	2	2	1
Artemisia frigida	1	+	+
Cleistogenes squarrosa	2	1	1
Agropyron cristatum	1	1	+
Allium ramosum	+	+	+
Dontostemon integrifolius	+	+	+
Carex duriuscula	2	2	2
Potentilla bifurca	+	+	.
Stipa sibirica	2	.	+
Chenopodium acuminatum	1	3	3
Chenopodium aristatum	1	1	+
Chenopodium album	+	1	1
Salsola tragus	+	1	+
Artemisia scoparia	.	+	+
Elymus chinensis	.	+	+

under agricultural use with varying success (Barsch et al., 1994, Hilbig & Bumžaa, 1985), most of them in dry farming, in the semi desert zone with irrigation. A large proportion of these fields were used for fodder production in addition to the forage from the pastures. However following the political changes in the last years most of these fields were abandoned. Now they are fallows, covered with dense and high ruderal stands of low forage value and it is expected that long time is needed for the redevelopment of steppe vegetation.

Effects of anthropogenic impact on soil cover

The response of soils to anthropogenic impacts was studied partly at the same sites, as the vegetation studies, but partly also at other sites. In general, soils were analyzed both within the zonal belts of soil formation (in the northern, central and southern part of Mongolia) and along typical altitudinal gradients between mountain slopes and intra-mountainous basins (Opp, 1994; Opp et al., 2000).

Ploughing of virgin land under the natural conditions of Mongolia with soil profiles of light granulometric composition, strong winters with little snow, strong winds, and a long dry season is the main factor of degradation, sharply enhancing the processes of wind and water erosion (Opp, 1998). Ploughing of large areas significantly reduces the areas of pastures and meadows. Therefore, it indirectly increases the grazing impact on the remaining pastures. Ploughing of virgin land also causes exhaustion of soils. This implies mainly a decrease of humus and nutrients, or at least a transformation of humus content in the top layer of the soils, due to erosion and intensive mineralization of organic matter and deterioration of physical properties of the soils, such as decomposition and compaction.

Degradation of Mongolia's soils can also be observed on irrigated lands. Irrigation is practised in two ways: sprinkler or top-irrigation and subsequent submersion. Either way of irrigation causes changes in physical properties (degradation of fabrics, crustification and slitization of

soil surfaces and of the upper horizons), in humus composition and soil fertility, and leads to salinization of the irrigated soils.

Within the northern part of Mongolia, within the sub-alpine and taiga mountain belts land use impacts on soils are rare. However, the more taiga is cleared, the more soil erosion can be observed. The corresponding accumulated sediments can be found in hollows or at bottom sites of the mountain slopes. Meadow steppes have their greatest extension within the northern part of Mongolia. Due to their fertile Chernozem and Dark Castanozem (Chestnut) soils, they are intensively used. However, their effective use as arable land depends on the availability of irrigation water, because precipitation alone is not always sufficient for farming. On the margin of sprinkler plots the irrigation splash causes a differentiation in texture, especially a shift of silt particles. The resulting little elasticity of the upper soil horizons causes an enormous soil strength due to physical stress. Areas which had not been irrigated for some time and tracks made by wheels of the sprinklers often showed crustifications and salinization of the upper soil horizons. Vegetation cover is accordingly thin and accompanied by halophilous species. Although Mongolian arable land is not as compacted by agricultural technique as similar land in Central Europe (Opp, 1995), superficial crustifications, caused by not-functioning sprinklers or by wrong irrigation times are wide spread phenomena. The same effects of salinization can also be observed in the central and southern parts of Mongolia, whenever surface water occurs.

In the central part of Mongolia in the forest steppe and steppe zone, the areas of meadow steppe and dry steppe show typical signs of overgrazing, such as decreasing vegetation cover, crusting, and stress from desiccation as a consequence of trampling by livestock. Although the intensity of livestock grazing is much higher in the steppe than in the mountain steppe and dry steppe, soil degradation is lower at the former and higher at the later. The analyzed average values of bulk density at the meadow steppe sites show a lower level of degradation in comparison to the mountain steppe sites. The highest values of bulk density were measured at dry steppe sites. This is not only a result of anthropogenic land use but also an effect of the lower level of precipitation and therefore regeneration ability of the vegetation on the one hand and the higher level of evapotranspiration on the other hand. The total pore volume of the top soil layer of such sites under evaporation stress even under good conditions is not higher than 32 %. The corresponding values of macro-pore volume vary between 3 and 8 % (Opp et al., 2000).

In the southern part of Mongolia, the regions of desert steppe and deserts, the highest proportional increase in goat numbers of all livestock was observed after the political and economic transformation. Although the natural forage basis there is lower than in the central or northern parts of the country, forage was not a problem during the 1990s because annual precipitation levels were relatively high. Therefore, soil degradation and degradation of the vegetation cover did not increase parallel to the increasing livestock numbers. However, only some dry years at the end of the 1990s lead to an enormous loss on vegetation and animals. An increasing warming and a decreasing of precipitation at the same period lead to a higher evaporation and impoverishment of the vegetation cover in extreme continental areas, as it was already the case during the 1970s and 1980s in Mongolia (Opp, 1994). The higher sensitivity of extreme continental areas to climatic changes often causes a lower carrying capacity, an increasing deflation, erosion, compaction of the fabrics, scab formation and salinization of the soils (Opp & Khakimov, 2003).

During the investigations special attention was paid to the degradation of the humic soil layers, as these are the basis for vegetation growth and soil fertility. The obvious degradation of the humic layers measured during the field survey could not be confirmed by the data for organic matter and dissolved organic carbon (DOC). Comparing visually degraded sites with more natural ones in the same Dark Castanozem soil region, which do not show considerably lower contents of C_{org} and DOC, only the ratio of humic and fulvic acids shows differences – the former contain less than 25 % of humic acids, whereas the latter contain 34 %. 'Colluvial' accumulated soil profiles of steppe sites show low contents of humic and fulvic acids ($< 15\,\%$ – $< 18\,\%$) although they are the result of relocated humus-enriched Castanozem material (Opp & Haase, 2001).

Conclusion

The anthropogenic impact on plant and soil cover can be found in all zones and altitudinal belts and all different soil and vegetation types of Mongolia. Ploughing, livestock grazing, and logging exert the highest influence on the pasture land.

The level of degradation of plant communities respectively their replacement by restitutional communities depends on a high degree on the grazing intensity which in turn depends on the accessibility for livestock and the distance to settlements, but also on their forage value, regeneration ability, and on the level of precipitation.

The strongest form of soil degradation in Mongolia is caused by ploughing. Deformation and compaction of the top soil by livestock is the most frequent form of degradation. These processes lead to a blocking-up of the macro-pore system at the soil surface. The current state of soil degradation is the higher the dryer the site conditions are. Therefore, in Mongolia precipitation can be regarded as an important natural factor limiting any form of land use (Opp & Khakimov, 2003). To prevent soil degradation of irrigated soils it is necessary to determine the optimal content of humus of the top soil in accordance to changed hydrothermal conditions. This can be either achieved by organic fertilizing or by crop rotation.

Investigations of the humic layers showed that although total contents of organic matter (C_{org}) and DOC do not indicate a degradation of the upper horizons, the change of the proportions of humic and fulvic acids suggests a chemical degradation of the soils. As most of the degraded sites currently are used as pastures it must be supposed that grazing not only influences soil stability, but also its fertility and chemical characteristics. However, the effect of degradation and accumulation of humic substances for soil functionality, soil fauna, and vegetation cover should be an issue of further investigations.

Measurements to minimize degradation of vegetation and soil include the limitation of livestock with regard to the natural conditions and better consideration of the different pasture types for seasonal grazing (Janzen & Bazargur, 2003; Kloss & Succow, 1974, 1977). Furthermore, the development of better traffic roads and infrastructure is necessary to preserve the nature for future use.

References

AG Boden (1994): Bodenkundliche Kartieranleitung (4th Edition). Hannover, Germany.

Anonymous (1991): National Economy of the MPR for 70 years. Ulaanbaatar, Mongolia.

Barsch, H., Billwitz, K. & Bork, H.-R. (2000): Arbeitsmethoden in Physiogeographie und Geoökologie. Klett-Gotha.

Barsch, H., Opp, C. & Steinhardt, U. (1994): Geoökologische Probleme in der Waldsteppe der nördlichen Mongolei (2nd Edition). Potsdamer Geographische Forschungen 3.

Batkhishig, O. & Lehmkuhl, F. (2003): Degradation und Desertifikation in der Mongolei. Petermanns Geographische Mitteilungen 147(5): 48–49.

Gal, J. (1968): The actual regeneration perspectives of the saxaul forests in Mongolia. Mong. Orny gazarz. Asuudal 1968(8): 90–110. [In Mongolian with Russian abstract]

Gubanov, I.A. (1996): Conspectus of flora of Outer Mongolia, vascular plants. Valang, Moscow. [In Russian]

Haase, G. (1983): Beiträge zur Bodengeographie der Mongolischen Volksrepublik. Studia Geographica 34: 231–367.

Helmecke, K. & Schamsran, Z. (1979): Ergebnisse ökologischer Untersuchungen in der Gobi

der Mongolischen Volksrepublik: 2. Untersuchungen über die osmotischen Verhältnisse ausgewählter Pflanzenarten. Archiv für Naturschutz und Landschaftsforschung 19: 81–85.

Hilbig, W., (1990): Pflanzengesellschaften der Mongolei. Erforschung biologischer Ressourcen der MVR 8, Halle: 3–146.

Hilbig, W. (1995): The vegetation of Mongolia. SPB Academic Publishing, Amsterdam.

Hilbig, W. (2000a): Kommentierte Übersicht über die Pflanzengesellschaften und ihre höheren Syntaxa in der Mongolei. Feddes Repertorium 111: 75–120.

Hilbig, W. (2000b): Forest Distribution and Retreat in the Forest Steppe Ecotone of Mongolia. In. *Environmental Changes in High Asia.* Edited by: Miehe, G. & Zhang, Y., Marburger Geographische Schriften 135: 171–187.

Hilbig, W. & Bumžaa, D. (1985): Die Ackerunkrautvegetation der Mongolischen Volksrepublik. Archiv für Naturschutz und Landschaftsplanung 25: 19–32.

Janzen, J. & Bazargur, D. (2003): Wandel und Kontinuität in der mobilen Tierhaltung der Mongolei. Petermanns geographische Mitteilungen 147(5): 50–57.

Kloss, K. & Succow, M. (1974): Standortkundliche Grundlagen und praktische Empfehlungen für die Intensivierung der landwirtschaftlichen Produktion des Staatsgutes 'Ernst Thälmann' Bornuur, Mongolischen Volksrepublik. Forsch.-Ber., Ms., Berlin.

Kloss, K. & Succow, M. (1977): Grassland site types of the North Mongolian forest steppe zone and possibilities of intensification. In: *Proceedings of the 13th International Grassland Congress.* Leipzig & Berlin: 611–613.

Müller, F.-V. & Bold, B.-O. (1996): Zur Relevanz neuer Regelungen für die Weidelandnutzung in der Mongolei. Die Erde 127: 63–82.

Müller, F.-V. & Janzen, J. (1997): Die ländliche Mongolei heute; Mobile Tierhaltung von der Kollektiv- zur Privatwirtschaft. Geographische Rundschau 49: 272–278.

Opp, C. (1994): Böden und Bodenprozesse in der Mongolei, Zeugen des Klima- und Nutzungswandels in Zentralasien. Geowissenschaften 12(9): 267–273.

Opp, C. (1995): Diagnosis of changes in agro-ecosystems caused by natural disturbances and anthropogenic impacts. Examples from Central Europe and Central Asia. In: *Global Environmental Change – Perspectives of Remote Sensing and Geographic Information Systems.* Edited by: Singh, R.B. New Delhi & Calcutta: 171–184.

Opp, C. (1996): Die Mongolische Republik - Natur- und Lebensräume im Wandel. Journal Heidelberger Geographische Gesellschaft 10. 13–28.

Opp, C. (1997): Socio-economic and climate change in Mongolia – effects on grassland ecosystems. Proceedings of the 18th International Grassland Congress, Winnipeg, Saskatoon, Canada 1997, Volume 2: 27.9–27.10.

Opp, C. (1998): Geographische Beiträge zur Analyse von Bodendegradationen und ihrer Diagnose in der Landschaft. Leipziger Geowissenschaften 8: 189.

Opp, C. & Barsch, H. (1993): Geomorphological and geoecological processes in the Mountain Forest Steppe of Northern Mongolia. Zeitschrift für Geomorphologie N.F., Supplement-Band 92. 145–157.

Opp, C., Haase, D. & Khakimov F.I. (2000): Soils and soil processes in the Tyvinian part of the Uvs-Noor Basin. Polish Journal of Soil Science XXXIII(2): 71–80.

Opp, C. & Haase, D. (2001): Entwicklung und Degradation von Humusdecken unter kontinentalem Klima – Beispiele aus dem Uvs-Nuur-Becken (Mongolei/Tywa). Mitteilungen der Deutschen Bodenkundlichen Gesellschaft 96(2): 539–540.

Opp, C. & Hilbig, W. (2003): The impact of overgrazing on natural pastures in Mongolia and Tyva. Berliner paläobiologische Abhandlungen 2: 96–98.

Opp, C. & Khakimov, F.I. (2003): The response of soils to climatic and environmental changes in Central Asia. Berliner Paläobiologische Abhandlungen 2: 98–100.

Yunatov, A.A. (1954): Forage plants of pastures and meadows of the MPR. USSR Academy of Sciences Publishing House, Moscow, Leningrad. [In Russian]

WRB (1994): World Reference Base for Soil Resources, Draft. Wageningen, Rome.

WRB (1998): World Reference Base for Soil Resources, Atlas. Leuven.

Werner Hilbig
Münchner Str. 8
D-85238 Petershausen, Germany

Christian Opp
Philipps-University Marburg
Department of Geography
Deutschhausstr. 10
D-35032 Marburg, Germany
opp@staff.uni-marburg.de