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Mapping Khulan Habitats: A GIS-Based Approach

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Mapping Khulan habitats - a GIS-based approach[1]

H. von Wehrden & K. Wesche

Abstract

This paper focuses on the contribution that a combination of public domain GIS data with extensive habitat data can make to Khulan conservation in southern Mongolia. We describe a dataset taken in the Great Gobi 'A' Strictly Protected Area which represents the driest region within the overall Khulan distribution range. Potential habitats were classified following a phyto-sociological approach based on vegetation samples collected in the field. These data are combined with an open source climate model that allowed assessment of the influences of mean precipitation and temperature regime on habitat conditions. The results are put into a Gobi-wide context providing an overview of an ongoing comprehensive habitat analysis of all main Khulan habitats in southern Mongolia.

Keywords: Khulan, Gobi, Habitat mapping, Mongolia

Introduction

Much of the remaining herds of the Mongolian wild ass (also known as Khulan - *Equus hemionus hemionus*) live in southern Mongolia. Five national parks and protected areas have been established since the 1960's to preserve this region's fragile arid ecosystems (fig. 1, BANZRAGCH 1998). Several animal species that are internationally listed as endangered (www.redlist.org) are found in these protected areas, yet only one large wild herbivore - the Khulan - roams in all of them. It occurs in all zonal vegetation types in the region including dry mountain steppes, semi-deserts as well as true deserts. Unfortunately, detailed data on habitat conditions have only started to become available. Over the last three years vegetation maps have been compiled for two protected areas in southern Mongolia, namely the Gobi Gurvan Saykhan National Park and the Great Gobi B Strictly Protected Area (von WEHRDEN et al. 2006b, von WEHRDEN & TUNGALAG 2004).

In this paper we present initial data for the Great Gobi 'A' Strictly Protected Area (henceforth called GG'A' SPA), where the number of Khulans is comparably low (ULIKPAN 2004); probably as a consequence of poor habitat conditions there. We will focus on the contribution spatially explicit vegetation data can make to an enhanced understanding of the Khulan's habitat requirements and distribution. Spatial data are compiled in a GIS-system that also incorporates a climate model and a topographical dataset. The underlying questions ask whether and how these datasets can contribute to successful conservation of wild ass in southern Mongolia. Therefore, the results presented here are briefly compared to data for other protected areas in the Mongolian Gobi.

Study area – the general context

The southern Mongolian protected areas represent part of the Gobi desert, which belongs to the eastern part of the old-world's desert belt. Mean annual precipitation is generally below 200 mm/a, even at the highest mountain peaks. The lower pediments and depressions receive less than 120 mm/a. Precipitation originates mainly from two directions. Western disturbances pass the Turanic highlands and reach as far as western Mongolia. In contrast, the climate of the larger central and eastern part of the country is related to the East-Asian monsoon. These disturbances originate in

[1] Results of the Mongolian-German Biological Expeditions since 1962, No. 282.

the south-east, yet due to cyclonal rotation the rain passes into southern Mongolia from northern to north-eastern directions. Cold winters and hot summers characterize this continental-arid environment (WEISCHET & ENDLICHER 2000). Winter precipitation is low or absent, and strong storms are common especially during springtime (BARTHEL 1990, BARTHEL et al. 1983).

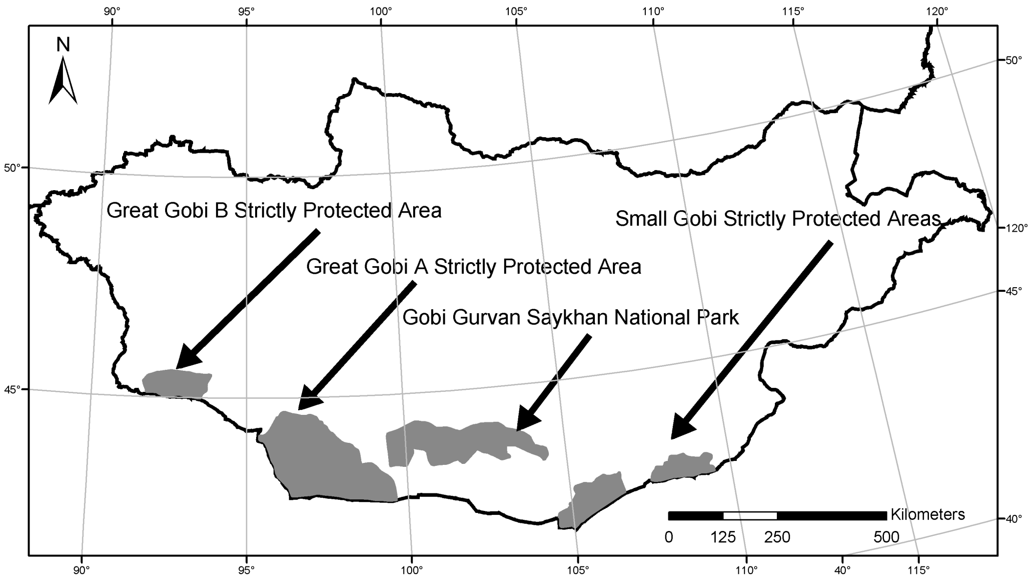

Fig. 1: Overview map of the protected areas in southern Mongolia.

The south-easternmost ranges of the Altay reach far into the Gobi. Related to the alpine faulting of the Himalaya, these mountains were relatively recently lifted and are now being constantly eroded in the harsh climate. Deflation and physical erosion shape the surfaces. The mountain ranges are surrounded by vast pediments composed of their own debris. These are successively dissected by an endorheic drainage system typical for arid environments.

Altitudinal climatic gradients are characteristic for the area. Mountains generally receive more precipitation than the lowlands and form islands of green mountain steppes surrounded by (semi-) desert vegetation. Locally, sands and geological faults offer water surplus sites on the otherwise dry pediments. In some depressions enough water accumulates to form oases.

The flora of southern Mongolia is dominated by Central Asian elements; the Dzungarian Gobi contains more Turranic elements, whereas the eastern parts of the Gobi comprise several eastern Asian species. Accordingly, GUBANOV (1996) divided the Mongolian Gobi into four sub-zones, namely the Dzungarian Gobi, the Transaltay Gobi, the Gobi-Altay and the Alashan Gobi. Each region is represented by one protected area. The GG'A' SPA represents the Transaltay Gobi, and Central Asian elements dominate the vegetation. The overall number of plants is relatively low (GUBANOV 1996, see tab. 1) which indicates relatively drier conditions compared to the other three subzones.

The general terminology on vegetation types in Central Asia is somewhat confusing (ZEMMRICH, 2005). In the context of the Transaltay Gobi, we regard all stands containing perennial grasses as desert steppes. They are semi-desert communities as are shrub-dominated stands without grasses. Yet, if the cover of shrubs is sparse (e.g. lower than 2 %) we call these stands true deserts. The Transaltay hardly receives any precipitation from the West and is also screened from the Monsoon system by the Mongolian and Gobi Altay as well as the mountain ranges south of the main chain. Not surprisingly, large parts of the Transaltay Gobi are true deserts with huge vegetation-free depressions.

Table 1: Overview of the protected areas in the southern Mongolian Gobi. Columns 2-6 refer to rainfall estimates derived from the GIS (HIJMANS et al. 2005); column 7 indicates the number of higher plant species found in each region. However, these numbers are based on the ecozonal division proposed by Gubanov (1996), which differs from that of the borders of the protected areas.

Protected Area	**Precipitation (mm)**					**Plant species**
	min	**max**	**range**	**mean**	**s.d.**	**richness**
Great Gobi 'B' SPA	69	177	108	96	17	717
Great Gobi 'A' SPA	33	124	91	54	11	340
Gobi Gurvan Saykhan NP	39	222	183	103	35	752
Small Gobi 'A'	63	115	52	84	8	223
Small Gobi 'B'	113	173	60	139	14	~223

Methods

In line with TURNER (1989) we consider landscapes as spatially heterogeneous areas which comprise mosaics of habitat patches. The sum of all patches represents the landscape as a whole. To assess the habitats within all 5 protected areas in the southern Mongolian Gobi we combined traditional methods of vegetation description and analysis with a GIS-approach. Based on a modified Braun-Blanquet-system, vegetation samples were taken in all nature reserves. Plots were chosen deliberately, but site selection was based on visual inspection of unsupervised classifications (40 classes) and red-green-blue pictures derived from Landsat ETM+ (= enhanced thematic mapper) datasets. Vegetation cover was directly estimated in percentage. Environmental data such as exposure, inclination and soil conditions were also recorded for each plot. Plants were identified in the field with standard flora guides (e.g. GRUBOV 2000, and subsequent volumes, GRUBOV 2001, GUBANOV 1996). Names were cross-checked at the Herbarium of the University of Halle-Wittenberg; taxonomically difficult groups were inspected by specialists (see acknowledgements). Vegetation samples were then classified using phytoscio-logical table work; available classification schemes served as a starting point (e.g. HILBIG 1990, 1995, 2000; von WEHRDEN & TUNGALAG 2004, WESCHE et al. 2005; KÜRSCHNER 2004). Basic characteristics of sites were summarised with descriptive statistics (e.g. Boxplots and simple regressions) using the “R” software (www.r-project.org). To that end field data were supplemented by publicly available information extracted from the “Diva-GIS” (www.diva-gis.org, HIJMANS et al. 2005) and from a digital elevation model (e.g. SRTM-data, http://seamless.usgs.gov/).

Appropriate methods of remote sensing analysis had already been established and tested for the Great Gobi 'B' SPA and the Gobi Gurvan Saykhan NP. The classified vegetation samples served as ground truth data for supervised classifications of the Landsat datasets. To satisfy statistical needs plots were enlarged individually. This was done manually based on unsupervised classifications plus Tasselled Cap and NDVI transformations (CAMPBELL 1996). Details on the application of this method are published elsewhere (von WEHRDEN et al. 2006b). Classifications were carried out using a maximum-likelihood algorithm with a 7 x 7 nearest neighbour filter. The classifications were stratified using a digital elevation model derived from SRTM datasets. The SRTM tiles were merged and corrected using Blackart (www.terrainmap.com) and the 3DEM software. The final classifications were compiled in Arc Map 9.0. An error matrix was calculated using an independent dataset that was also taken in the field. Kappa statistics were additionally analysed; an indirect check within the overlapping regions of the various employed satellite scenes served as a third mode of accuracy assessment. Scenes giving NDVI, TNDVI, TC, RGB (CAMPBELL 1996) and other transformations of the Landsat data are also included in the final GIS, since they offer information about the ecology of the region as well. Information on slope and aspect (based on the topographical data 1:25000), and the available climate data (www.diva-gis.org) were also made available within ArcMap 9.0.

Results and Discussion

Abiotic conditions

Figures 2-5 provide examples of basic topographic and climate characteristics of the region. The available topographic data (fig. 2) was used to perform regression analysis to check whether the climatic model merely depicts rainfall and temperature as a function of the altitude or offers independent information. This analysis proved that both annual precipitation (fig. 3) and the July maximum temperature (fig. 4) are strongly correlated with altitude. Elevation shows a strong negative correlation with modelled July temperature ($r^2 = 0.89$), but a strong positive correlation with precipitation ($r^2 = 0.88$). The two prominent mountain ranges in the southern part of the protected area receive an estimated 110 mm/a (fig. 3), while the depression in the western part of the park gets hardly any rainfall (annual mean down to 33 mm). These areas do not offer habitats for the Khulan at all. They are dry, devoid of vegetation and isolate the mountains to the North of the Transaltay Gobi. Taken together, July maximum temperature and precipitation offer an explanation as to why Khulans are mainly found in the mountain and hill regions of the GG'A' SP and are hardly seen at lower elevations.

However, the low correlation between the January minimum temperature and altitude ($r^2 = 0.41$) indicates a different pattern not directly related to elevation (fig. 5). The model assumes that cold air from northern Mongolia flows into the northern parts of the GG'A' SPA in winter. The central depressions are not affected resulting in higher temperatures there. Moreover, modelled winter precipitation is higher in the northern parts of the Transaltay region compared to the southern lowlands (data not shown). Taken together, coldness and moisture should make winter conditions in the northern part of the GG'A' SPA extremely harsh. This may affect migration patterns of Khulans in winter.

The vegetation data

281 vegetation checks were available for the compilation of the vegetation map (see fig. 2 for the route of our survey). Accuracy of the supervised classification of the satellite imagery was assessed using a set of 365 "fast plots" independently taken *en route*. A detailed classification of the principal communities has been published (von Wehrden et al. 2006a); here we provide only short descriptions (see tab. 2). Certain communities were rare and/or rarely sampled; these were merged with others to obtain units that could be mapped with reasonable accuracy.

Table 2: Overview table of the communities discussed in the text

Vegetation type	abbreviation	mean species richness
Caragana leucophloea - Stipa glareosa community	St-Ca	8.0
Stipa glareosa - Allium mongolicum community	St-Al	6.0
Stipa glareosa - Anabasis brevifolia community	St-An	6.7
Ephedra przewalskii - Zygophyllum xanthoxylon community	Ep-Zy	4.8
Haloxylon ammodendron community	Ha	3.3
Reaumuria soongorica - Haloxylon ammodendron community	Ha-Re	3.1
Reaumuria soongorica community	Re	2.9
Iljinia regelii community	Ilji	2.9
Vegetationless	No	1.0

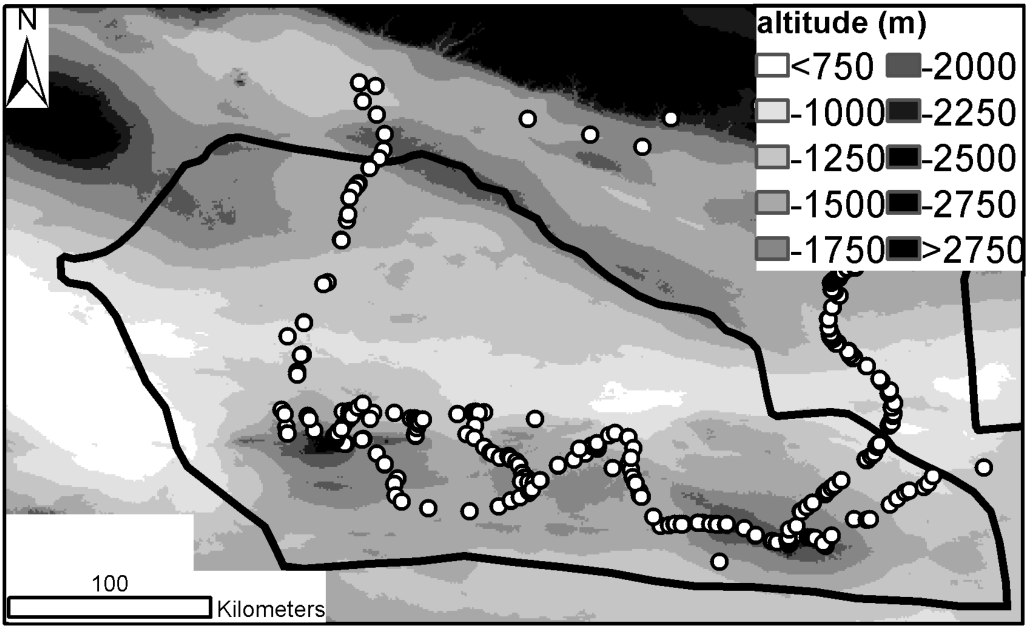

Fig. 2: Topographical map of the working area. The route of our survey is indicated by the white dots.

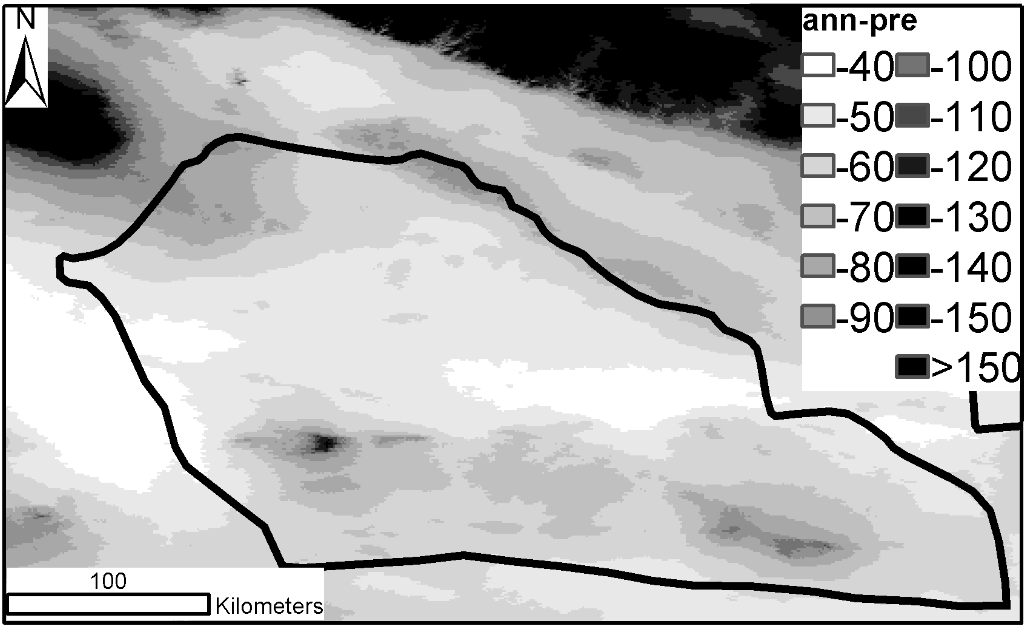

Fig. 3: Map showing the modeled annual precipitation within the working area (data from HIJMANS et al. 2005).

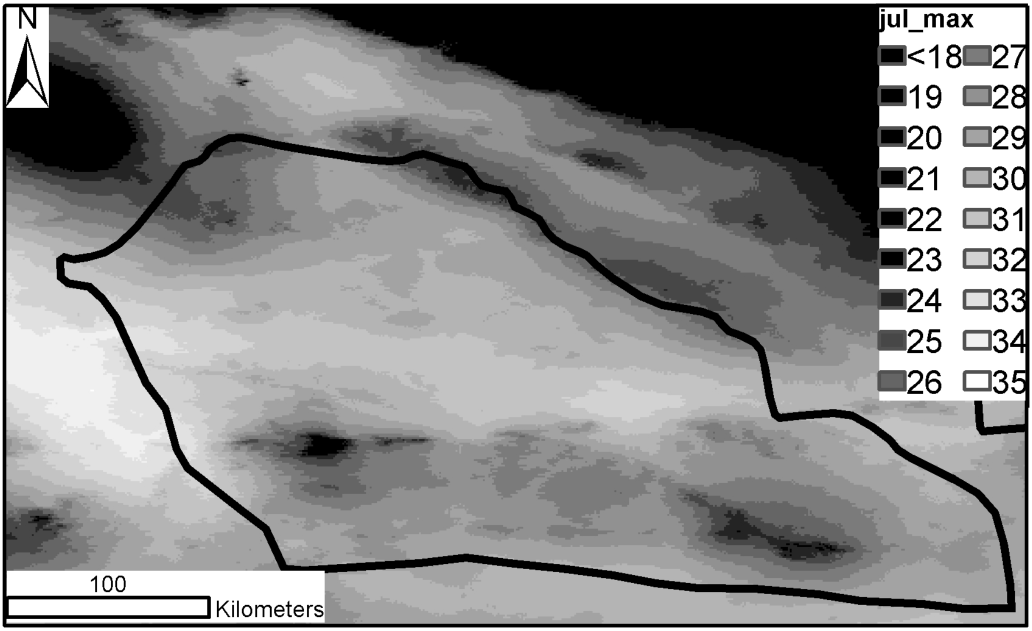

Fig. 4: Map showing the modeled July maximum temperature.

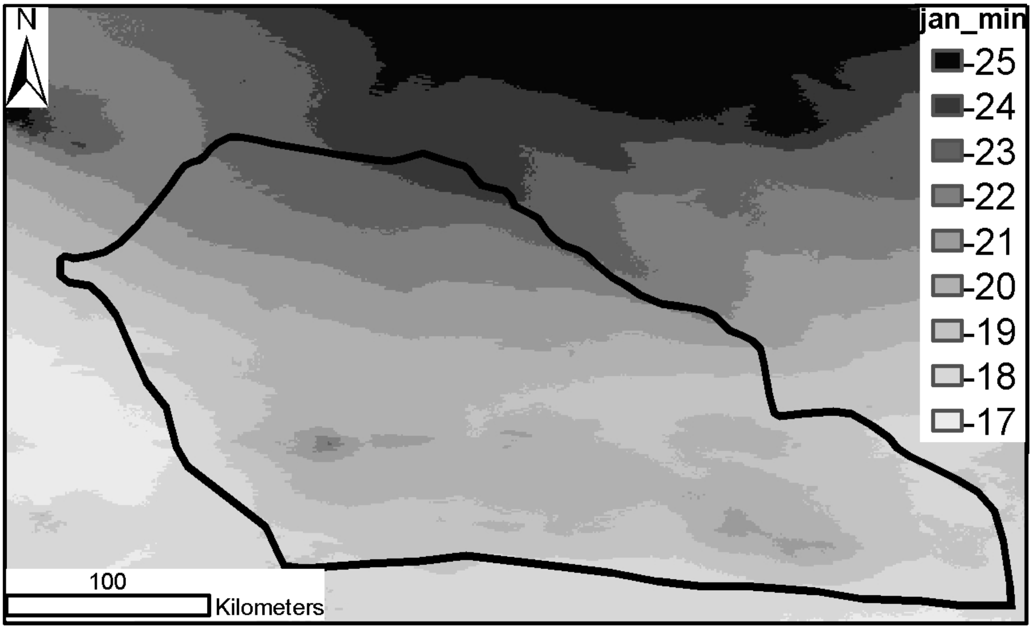

Fig. 5: Map showing the modeled January minimum temperature.

Stipa glareosa desert steppes

Three different *Stipa glareosa* communities were included in the map. All grow on stony and shallow soils and are restricted to mountain sites, higher hills or wetter slopes. They belong to the context of low-shrub semi deserts within HILBIG's (1995) community system.

The *Caragana leucophloea - Stipa glareosa* community shows the highest plant diversity of all communities (see fig. 6e, tab. 2). They grow on the higher flanks of mountain ranges, but can be found within some hilly regions as well. Sandy and stony soils are typical for this community, which is found on similar soils in the Great Gobi 'B' SPA (von WEHRDEN & TUNGALAG 2004). There, *Caragana leucophloea - Stipa glareosa* steppes are grazed by Takhi (*Equus przewalskii*). In the north-eastern part of the area just west of the Gobi-Gurvan Saykhan National Park this community becomes more common, which indicates the gradually moister conditions towards the Gobi-Altay. This mapping unit is characterised by a comparatively high cover of grasses (see fig. 6c) as well as by a shrub layer growing up to 50 centimetres in height (see fig. 6a). Stands receive the highest rainfall of all mapped vegetation types at around 80 mm/a on average (fig. 6f). The presence of a few shrubs which are common in more dense desert-steppes in the Gobi-Altay underlines the importance of this habitat as grazing ground. Both the Atas Bogd and the Tsagaan Bogd host this plant community. However, both ranges show a pronounced small-scale heterogeneity, so several sub-communities were included in the *Caragana leucophloea* unit. A *Stipa orientalis* community was also sampled in the mountains, but stands were extremely small and highly scattered around the summit regions.

The *Stipa glareosa - Allium mongolicum* community occurs on some pediments. The absence of *Anabasis brevifolia* differentiates it from the next mapping unit. Figure 6f demonstrates that both units receive approximately similar levels of precipitation. This is surprising as *Stipa - Allium* desert steppes in other protected areas tend to occur under somewhat moister conditions (WESCHE et al. 2005; von WEHRDEN & TUNGALAG 2004).

Much more widespread in the area is the *Stipa glareosa - Anabasis brevifolia* community. It is typically found on hills and mountain sites, as well as on the upper pediments. The inclination of the stands is comparatively high at an average of 5° (see fig. 6d), and is even higher over metamorphic rock. Hence deflation and strong physical erosion characterise the sites; soils are therefore stony and shallow. Since the vegetation comprises numerous herbs as well as grasses (see fig. 6c), stands of this unit can also be regarded as important grazing grounds. In moist years, the cover of annuals may increase. However, even the moistest zonal stands in the Transaltay are drier than those in the neighbouring protected areas, e.g. the GG'B' SPA and the GGS NP (see also WESCHE et al. 2005, and von WEHRDEN & TUNGALAG 2004).

The general dryness of the Transaltay Gobi is also exemplified by the widespread occurrence of *Sympegma regelii*, which is almost consistently found in all zonal plant communities. This shrubby *Chenopodiaceae* has a Central Asian distribution (KÜRSCHNER 2004) and is drought-resistant (BOBROVSKAJA 1985; see HELMECKE & SCHAMSRAN 1979 and HELMECKE & SCHAMSRAN 1985 for other species).

Ephedra przewalskii - Zygophyllum xanthoxylon community

Lower down towards the depressions the cover of shrubs increases on the pediments, whereas the abundance and diversity of herbaceous species declines fig. 6c). Sayrs form extensive drainage systems, which are now rarely flooded, though floods may have been more common in the past (LEHMKUHL 2000). Sediments' grain-sizes indicate that these floods can be quite powerful and transport larger stones. Such sites are covered by high-shrub semi-deserts, of which the *Ephedra przewalskii - Zygophyllum xanthoxylon* stands are the most common type. The community mediates between the desert steppe vegetation found at higher elevations, and the semi-deserts and true desert vegetation of the lowlands. The mean species richness is lower than in the *Stipa glareosa* communities (see fig. 6e). The cover of shrubs is slightly higher, but still lower than in the *Haloxylon* stands (see fig. 6b). Mean precipitation for the *Ephedra - Zygophyllum* stands is estimated to be around 60 mm/a. The spatial variation is quite high, which reflects the huge altitudinal gradient occupied by this mapping unit. Wide areas on the pediments and along drainage lines, as well as wider gorges and intramontane basins, are covered by this mapping unit. However, this community is almost never found on steeper slopes, and inclination is generally well below 5° (see fig. 6d).

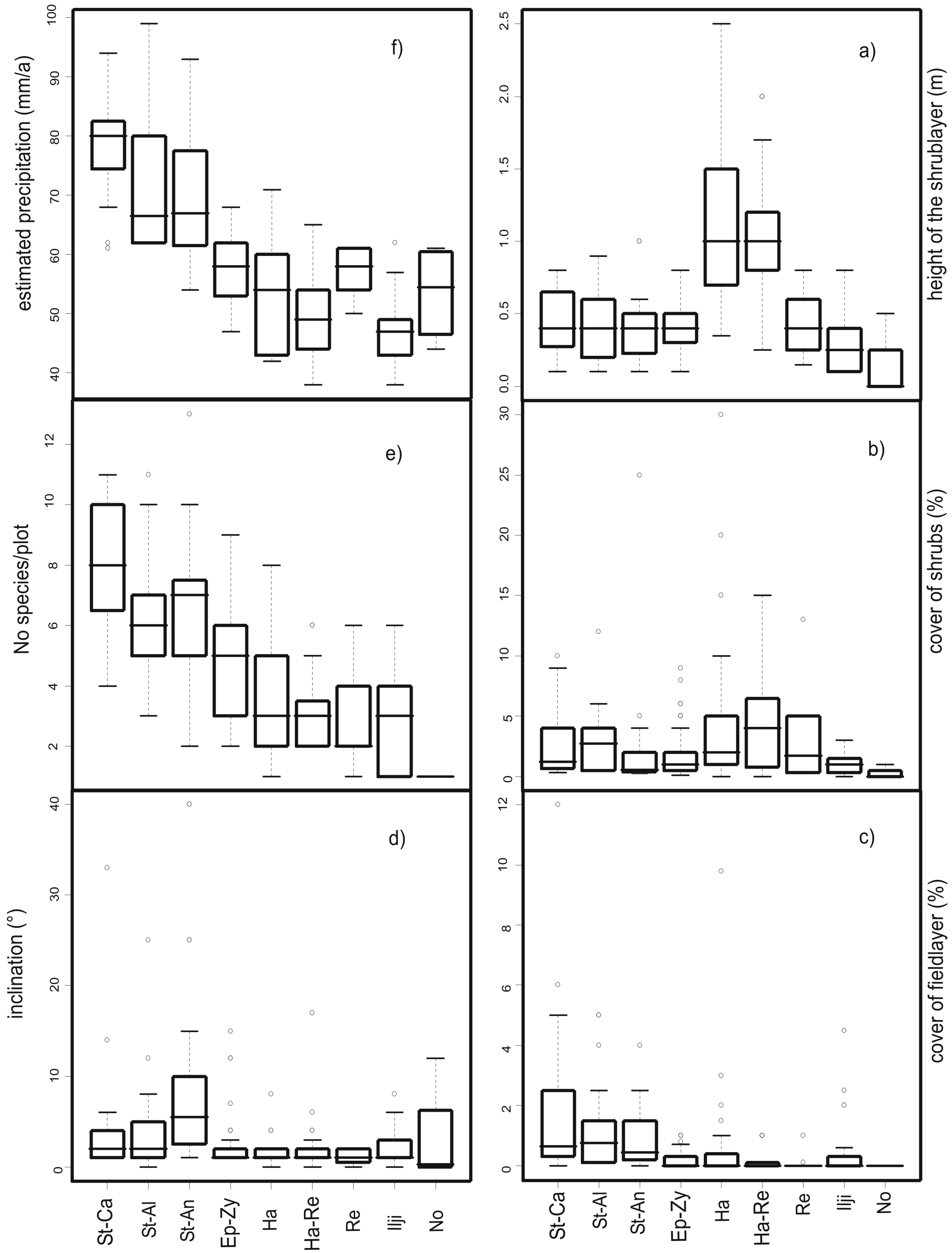

Fig. 6: Boxplots summarizing the habitat characteristics for the discussed plant communities. The individual box plots show (starting top right clockwise): the height of the shrub layer in meters; the cover of the shrub layer in percentage; the cover of the field layer in %; the slope in degrees; the number of species per plot; the precipitation in millimeters per year. The abbreviations labeling the horizontal axes are described in tab. 2.

Haloxylon ammodendron community

The Saxaul, *Haloxylon ammodendron*, is a character tree of Central Asia. It is one of the few tree-forming species in the goosefoot family (Chenopodiaceae). However, most specimens in the study area are shrubby, possibly as a result of permanent grazing (HELMECKE & SCHAMSRAN 1979). Domestic camels and goats feed on Saxaul, but Khulan and wild camels are also known to browse it. A major problem is extensive firewood collection, and Saxaul is included in the Red Book of Mongolia (SHIIREVDEMBA et al. 1997). Growth height is also influenced by the local water regime and trees are higher where water is in surplus. The respective stands form a separate sub-community where the Saxaul is accompanied by a number of herbs, mainly annuals. Although these may be absent in dry years, stands show an overall higher biodiversity and vegetation cover (see fig. 6). In contrast, dry sites with low precipitation and no edaphic water surplus support mono-dominant stands of *H. ammodendron*.

Reaumuria soongorica - Haloxylon ammodendron community

On the more saline soils of the lower pediments, *Reaumuria soongorica - Haloxylon ammodendron* stands occur. They are also common in intra-montane depressions and basins and are thus found at relatively low altitudes. The soil matrix is more fine-grained than in the Saxaul stands described above. The shrub cover is lower than in the pure *Haloxylon* stands (see fig. 6b), yet the average shrub height is the same. Herbaceous plants are practically absent; hence the biodiversity is low overall.

Pure Reaumuria soongorica community

Reaumuria soongorica stands without Saxaul are restricted to intra-montane depressions with very saline soils. Typically, these have a clayey to silty soil texture with few stones in the matrix. They grow on higher altitudes than the latter two communities and are likely to receive more rainfall. Moreover, the digital elevation model proved that they benefit from water surplus accumulating from the surrounding water catchments.

Iljinia regelii community

Iljinia regelii forms a true desert community. The vegetation cover is always below 4 %, median cover is 2 %. Shrubs grow hardly higher than 20 centimetres, and the average rainfall is well below 60 mm/a (see fig. 6f). Stands grow in the lowermost depressions of the study area. The huge depression north of the Atas Bogd and the Tsagaan Bogd lies below 1000 m asl. Mean annual precipitation is estimated to be below 40 mm there, which is not sufficient to support permanent vegetation. In dry years there are hardly any plants, while a few annuals may grow in years with more favourable conditions.

The soils are deflated, their surfaces are sealed by a stone pavement, and continuous evaporation resulted in the formation of gypsum crusts in the soil. The vegetation is contracted and restricted to small depressions or drainage lines where plants get some limited surplus water.

Extra-Zonal vegetation

Stands of *Populus diversifolia* are characteristic for the Transaltay Gobi (HILBIG 1995). We sampled eight different stands: five in larger oases (e.g. Echijn Gol, Shar Huls) and three by linear drainage lines with some limited edaphic water surplus. Poplar stems can reach well above 10 metres in height while the undergrowth is often dominated by root suckers of *P. diversifolia*. Clonal growth is a characteristic phenomenon of poplar stands all over Central Asia (MANEGOLD et al. 2003). Some typical salt-tolerant species are also found in the shrub and herb layer. These unique habitats host a high biodiversity regarding both plant and animal life (CHIMEDREGZEN 2000).

Stands of *Tamarix* species (*T. ramosissima*, *T. gracilis*, *T. leptostachys*) are even more common, but depend also on a high groundwater table and are therefore found mainly in oases.

Some sites were however dry river beds with some available groundwater. At such sites, we occasionally found holes dug by Khulans in search for water.

Where the water surplus guarantees an almost permanent water flow, *Phragmites australis* is found. Reed beds are strictly confined to riverine spots, oases and gorges. Cover of herbaceous plants is much higher than in all other mapping units and the reed may reach several metres in height. In larger oases extensive reed beds are intermingled with small patches of saline meadows around open water. These contained the highest vegetation cover and are among the most species-rich of all plant communities in the GG'A' SPA, but were too limited in spatial extent to be mapped separately.

Comparison with other southern Mongolian protected areas

The Great Gobi 'A' Strictly Protected Area is the driest region of Mongolia (see tab. 1). There are two high mountain areas situated in the southern part (see fig. 2), but even in the summit regions precipitation is hardly higher than at e.g. lower pediments in the eastern Gobi Gurvan Saykhan National Park, whereas mountains there receive a mean annual precipitation of up to 200 mm. This explains the overall sparse vegetation cover in the GG’A' SPA. The general trend of increasing moisture towards the East is reflected by similarly sparse vegetation in the western part of the Gobi Gurvan Saykhan National Park, while the desert steppes in the East of the Gobi Gurvan Saykhan show a much higher cover of grasses and herbs (WESCHE et al. 2005). These are prominent grazing grounds for Khulans (READING et al. 1999).

In south-eastern Mongolia, the two Small Gobi Strictly SPA (fig. 1) host large proportions of the Mongolian Khulan population (M. STUBBE pers. comm., P. KACZENSKY pers comm., own observations). The lower elevations in the Small Gobi ‘A’ SPA show some similarities to the Transaltay Gobi in terms of both precipitation patterns and vegetation. Most plants in both regions are Central Asian elements and the zonal vegetation is dominated by only a few species. Dry semi-deserts dominate the Small Gobi 'A' SPA, while the Small Gobi 'B' SPA receives more monsoonal precipitation from the south-east. At a given elevation, vegetation cover is higher in the eastern part of the SPA (personal observation 2005). Not surprisingly, the climate model indicates the highest average rainfall of all protected areas in the Mongolian Gobi, although the Small Gobi 'B' lacks any high mountain ecosystems.

The Dsungarian Gobi in south-western Mongolia is much drier than the Small Gobi SPAs, but western disturbances are responsible for slightly higher levels of precipitation in the Great Gobi 'B' SPA compared to the Transaltay Gobi. Winter snow is especially important in the Dsungarian Gobi. Its vegetation is also dominated by semi-deserts, which do however show a higher vegetation cover and biodiversity than the dry Transaltay area (von WEHRDEN & TUNGALAG 2004).

The Great Gobi 'B' SPA is blocked by huge mountain ranges to the East, which render migration of its large Khulan population difficult. Thus, the Great Gobi 'A' SPA may be regarded as a border region separating the two larger populations from the East (Gobi Gurvan Saykhan National park and Small Gobi SPA) and the West (Great Gobi 'B' SPA). Although human impact is limited, the Transaltay Gobi probably would not be able to independently support a Khulan population, the main reason clearly being the low precipitation and the subsequent poor vegetation.

Conclusions - Prospects for nature conservation

We have shown that information on climatic conditions and vegetation is increasingly becoming available and can contribute to the understanding of Khulan distribution and migration. Climatic models provide reasonably reliable information on spatial patterns of precipitation and temperature, but detailed data on the vegetation are much more limited. Available vegetation maps of southern Mongolian protected areas are on a relatively limited scale (RACHKOVSKAYA 1993, ANONYMOUS 1990, GUNIN et al. 1999). Moreover, most accounts of plant community composition focus on entire Mongolia (LAVRENKO & KARAMYSHEVA 1993; HILBIG 1995, 2000;

KARAMYSHEVA & KHRAMTSOV 1995), and do not always reflect small-scale local differences. A few inventories of desert vegetation composition and spatial distribution were compiled by mainly Russian colleagues, but these cover only small sections of the Gobi that are in most cases not located in the protected areas with a high resolution (regions of Echijn Gol, Bulgan Sum, VOSTOKOVA & GUNIN 2005).

The case of the Transaltay region is of special interest since the impact of livestock is remarkably low. The nearby Gobi Gurvan Saykhan National Park is heavily grazed by livestock making a detailed management concept a necessity (BEDUNAH 1998; BEDUNAH & SCHMIDT 2000). Other Mongolian regions face similar problems (FERNANDEZ-GIMENEZ 1999; 2000), and most regions of Inner Mongolia are also subject to intense human land use (ZHANG 1995). In contrast, human impact in the Great Gobi 'B' Strictly Protected Area is limited thanks to an integrated management plan (see www.takhi.org). Yet the region was grazed by livestock before the reserve was gazetted, while human influences in the Transaltay have always been comparably low. This is due to several facts: The precipitation is low leading to low vegetation cover. Permanent watering places and wells, which are a daily necessity for all domesticated animals except camels, are almost totally absent. Thus, competition between wildlife and livestock as described for other Gobi regions (CAMPOS-ARCEIZ et al. 2004) is not applicable to the Great Gobi 'A' SPA. Only the surroundings of some military camps near the inter-state boundary - the oasis of Echijn Gol situated in the northeast of the protected area and small parts of the south-eastern mountain ranges - are influenced by livestock at all. Because there are only a few people in the region, the influence of poaching is also limited. Thus, the GG'A' SPA most probably will continue to offer extensive habitats for rare species such as wild camel (GONCHIGIIN 2002; MIX et al. 2002), Gazella, Ibex (SCHALLER 1995), and Gobi Bear. This could also refer to the Khulan, but the general dryness of the sites apparently renders complete colonisation unlikely.

Clearly, more information on habitat patterns is needed for a full understanding of these issues. Vegetation maps for the Transaltay Gobi and the Small Gobi are currently being compiled. For the GG'A' SPA, 13 communities or community groups were included in the preliminary map. Nine communities represent zonal vegetation, whereas the other four are azonal communities restricted to special sites such as oases. The overall accuracy based on the error matrix is so far > 88 %. Montane sites are more heterogeneous than the lowland deserts and semi-deserts. Thus, even though the latter have a generally lower vegetation cover, they were still mapped with a higher accuracy. The azonal habitats are limited in spatial extension, but were also mapped with a high accuracy as they show extremely dense vegetation.

An analysis of NOAA and MODIS timelines is the next logical step to assess the seasonal and interannual changes in Khulan habitats (BURKART et al. 2000 present a general example from north-western Mongolia). This may also help to quantify long-term trends in the vegetation development (CHRISTENSEN et al. 2004). The last step planned within our project is a compilation of all spatial information in a GIS-system that should provide baseline data for nature conservation. This can serve as a starting point for further ad hoc inventories (GUNIN et al. 1999), can help to identify trends within the ecosystem (GUNIN et al. 2001), and will be crucial in the ongoing attempts to model Khulan migration and distribution.

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Literature

ANONYMOUS (1990): Atlas of Mongolia. - Ulaan Baatar.

BADARCH, G.; WINDLEY, B.F.; KROENER, A. (2000): Geology and plant tectonic evolution of Mongolia. - Berliner Geowiss. Abh. A **205**: 118-121.

BANZRAGCH, S. (1998): Nature conservation and the establishment of protected areas in Mongolia. – In: DÖMPKE, S.; SUCCOW, M. (EDS.): Cultural landscapes and nature conservation in northern Eurasia. - Bonn, Naturschutzbund Deutschland, pp. 238-244.

BARTHEL, H. (1990): Mongolei - Land zwischen Taiga und Wüste. - Gotha, VEB H. Haack.

BARTHEL, H. (1983): Die regionale und jahreszeitliche Differenzierung des Klimas in der Mongolischen Volksrepublik. Studia Geographica **34**: pp. 3-91.

BEDUNAH, D. (1998): Livestock management issues for the Gobi Gurvan Saikhan National Conservation Park. - Ulaan Bataar, GTZ Nature Conservation and Buffer Zone Management Project, pp. 1-50.

BEDUNAH, D.; SCHMIDT, S.M. (2000): Rangeland of Gobi Gurvan Saikhan National Conservation Park, Mongolia. - Rangelands **22** (4): 18-24.

BOBROVSKAJA, N.I. (1985): Wasserhaushalt der Wüsten- und Wüstensteppenpflanzen in der Nord- und der Trans-Altay-Gobi. - Feddes Repertorium **96** (5-6): 425-432.

BURKART, M.; ITZEROTT, S.; ZEBISCH, M. (2000): Classification of vegetation by chronosequences of NDVI from remote sensing and field data: the example of the Uvs Nuur Basin. - Berliner Geowiss. Abh. A **205**: 39-50.

CAMPBELL, J.B. (1996): Introduction to Remote Sensing. - New York, Taylor & Francis.

CAMPOS-ARCEIZ, A.; TAKATSUKI, S.; LHAGVASUREN, B. (2004): Food overlap between Mongolian gazelles and livestock in Omnogobi, southern Mongolia. - Ecol. Res. **19** (4): 455-460.

CHIMEDREGZEN, L. (2000): Distribution, importance and protection of natural oases in the Gobi desert of Mongolia. - Marburger Geograph. Schr. **135**: 134-139.

CHRISTENSEN, L.; COUGHENOUR, M.B.; ELLIS, J.E.; ZUO, Z.C. (2004): Vulnerability of the Asian typical steppe to grazing and climatic change. - Climatic Change **63**: 351-368.

FERNANDEZ-GIMENEZ, M.E. (1999): Sustaining the steppes: a geographical history of pastoral land use in Mongolia. - Geograph. Rev. **89** (3): 315-342.

FERNANDEZ-GIMENEZ, M.E. (2000): The role of Mongolian nomadic pastoralists: Ecological knowledge in rangeland management. - Ecol. Applications **10**: 1310-1326.

GONCHIGIIN, T. (2002): The vegetation and flora in pastures used by Wild Bactrian Camels. In: READING, R.; DULAMTSERENGIIN, E.; TUVDENDORJIIN, G. (eds.): Ecology and conservation of Wild Bactrian Camels. - Ulaanbaatar, Mongolian Conservation Coalition, pp. 95-108.

GRUBOV, V.I. (2000): Plants of Central Asia **2**. Chenopodiaceae. - Enfield, Sci. Publ. (and subsequent volumes).

GRUBOV, V.I. (2001): Key to the vascular plants of Mongolia. Vol. **I** & **II**. Plymouth, Sci. Publ.

GUBANOV, I.A. (1996): Conspectus of the Flora of Outer Mongolia (Vascular Plants). - Moscow, Valang Publ.

GUNIN, P.D.; DUGARZHAV, C.; VOROBJEV, K.A.; SANDAAR, M.; PRISHEPA, A.V.; ANDREEV, A.V. (2001): Inventory of ecosystems diversity and assessment of nature degradation of Mongolia, using GIS. Change and sustainability of pastoral land use systems in temperate and central Asia. - Ulaanbataar, Mongolia (Conference proceedings).

GUNIN, P.D.; VOSTOKOVA, E.A.; DOROFEYUK, N.I. (1999): Vegetation dynamics of Mongolia. - Dordrecht, Boston, Kluwer; Acad. Publ.

HELMECKE, K.; SCHAMSRAN, Z. (1979): Ergebnisse ökologischer Untersuchungen in der Gobi der Mongolischen Volksrepublik. 2. Untersuchungen über die osmotischen Verhältnisse ausgewählter Pflanzenarten. - Archiv Naturschutz u. Landschaftsforsch. **19**: 81-95.

HELMECKE, K.; SCHAMSRAN, Z. (1985): Ergebnisse ökologischer Untersuchungen in der Gobi der Mongolischen Volksrepublik. - Archiv Naturschutz u. Landschaftsforsch. **19**: 1-22.

HIJMANS R.J.; CAMERON S.E.; PARRA J.L.; JONES P.G; JARVIS A. (2005): Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* **25**: 1965–1978.

HILBIG, W. (1990): Pflanzengesellschaften der Mongolei. - Erforsch. Biol. Ress. MVR **8**: 5-146.

HILBIG, W. (1995): The vegetation of Mongolia. - Amsterdam, SPB Acad. Publ.

HILBIG, W. (2000): Kommentierte Übersicht über die Pflanzengesellschaften und ihre höheren Syntaxa in der Mongolei. -Fed. Repert.**111** (1-2): 75-120.

KARAMYSHEVA, Z.V.; KHRAMTSOV, V.N. (1995): The steppes of Mongolia. Braun-Blanquetia **17**: 5-79.

KÜRSCHNER H. (2004): Phytosociological studies in the Alashan Gobi - a contribution to the flora and vegetation of Inner Mongolia (NW China). - Phytocoenologia **34**:169-224.

LAVRENKO, E.M.; KARAMYSHEVA, Z.V. (1993): Steppes of the former Soviet Union and Mongolia. In: Natural Grasslands. Ecosystems of the world 8b. - R. T. Coupland. Amsterdam, London, New York, Tokyo, Elsevier, pp. 3-59.

LEHMKUHL, F. (2000): Alluvial fans and pediments in Western Mongolia and their implications for neotectonic events and climatic change. - Berliner Geowiss. Abh. A **205**: 2-8.

MANEGOLD, M.; JANDT, U.; GRIES, D.; THOMAS, F.M.; RUNGE, M.; BRUELHEIDE, H. (2003): Clonal structure of *Alhagi sparsiflora* and *Populus euphratica* populations in the Taklamakan desert. – Verhandl. Ges. Ökol. **33**: 349.

MIX, H.M.; READING, R.P.; BLUMER, E.S.; BADAMJAVIIN, L. (2002): Status and distribution of Wild Bactrian camels in Mongolia. - In: READING, R.; DULAMTSERENGIIN, E.; TUVDENDORJIIN, G. (eds.): Ecology and conservation of Wild Bactrian Camels. - Ulaanbaatar, Mongolian Conservation Coalition, pp. 39-48.

RACHKOVSKAYA, E.I. (1993): Rastitel'nost' gobijskich pustyn' Mongolii. - Mongol orny govijn urgamalzil. - Nauka, Sankt Peterburg

READING, R.P.; AMGALANBAATAR, S.; LHAGVASUREN, L. (1999): Biological Assessment of Three Beauties of the Gobi National Conservation Park, Mongolia. - Biodiv. Conserv. **8**: 115-137.

SCHALLER, G.B. (2000): Wildlife of the Tibetan Steppe. - Chicago, Univ. Chicago Press.

SHIIREVDAMBA T.; SHAGDARSUREN, O. & ERDENJAV, G. (1997): Mongolian Red Book. - Ministry for Nature and Environment of Mongolia, Ulaanbaatar.

TURNER, M.G. (1989): Landscape ecology: The effect of pattern on process. – Ann. Rev. Ecol. Syst. **20**: 171-197.

ULIKPAN, K. (2004): Some studies in the Trans Altai Gobi ecosystem. - Proc. UNDP project “Conservation of the Great Gobi and its umbrella species”.

von WEHRDEN, H.; TUNGALAG (2004): Mapping of vegetation units of the Great Gobi B National Park. - Final report for the Prezwalski Horse Project. - Univ. Marburg, Fac. of Geogr. Report, accessible at www.takhi.org.

von WEHRDEN H.; WESCHE K.; HILBIG W. (2006a): Plant communities of the Great Gobi A Special Protected Area in the Mongolian Transaltay Gobi. Fed. Repert. **117**: 526-570.

von WEHRDEN, H.; WESCHE, K.; REUDENBACH, C.; MIEHE, G. (2006b): Mapping of large-scale vegetation pattern in southern Mongolian semi-deserts - an application of LANDSAT 7 data. - Erdkunde **60**: 261-272.

VOSTOKOVA, E.A.; GUNIN, P.D. (chief eds.)(2005): Ecosystems of Mongolia - Atlas (General Scientific Edition). - Moscow, Russ. Acad. Sci.

WALTER, H. (1974): Die Vegetation Osteuropas, Nord- und Zentralasiens. - Stuttgart, G. Fischer.

WEISCHET, W.; ENDLICHER, W. (2000): Regionale Klimatologie. Teil **2**. Die Alte Welt. - Stuttgart, Leipzig, Teubner.

WESCHE, K.; MIEHE, S.; MIEHE, G. (2005): Plant communities of the Gobi Gurvan Sayhan National Park (South Gobi Aimag, Mongolia). - Candollea **60**: 149-205.

ZEMMRICH A. (2005): Die Steppengliederung der Mongolei aus Sicht der russischen und mongolischen Geobotanik. - Arch. Naturschutz u. Landschaftsforsch. **44**: 17-35.

ZHANG, W. (1995): Vegetation dynamics in relation to livestock grazing in a semi-arid steppe in Inner Mongolia. – A. Univ. Upsaliensis **130**: 1-28.

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