The Northern Part of Khovd Province – An Ecological Introduction

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1 Geography

The western Mongolian Khovd province extends from the southwestern border of Mongolia with China northward between Bayan-Ölgiy province in the west and Gov-Altay and Zavkhan province in the east touching the Uvs province in the north. Khovd province covers landscapes of the Great Lake Basin in the northeast, those of the Central Mongolian Altai in the northwest and in the middle and of Dzungarian Gobi in the south of its territory. Thus, it is cutting across different vegetation zones and altitudinal belts with desert steppes, northern desert steppes, mountain steppes and high alpine vegetation (for the classification of steppe vegetation of Russian and Mongolian geobotanical school see ZEMMRICH 2005).

Important landscapes include:

- the Argalant mountains and Agvash Uul peninsula within the Great Lake Basin in the northeastern part of the province, covered with desert steppe vegetation
- the transition of the Great Lake Basin to the Mongolian Altai around Khovd province centre, representing the northern desert steppe belt
- Tsagduult Uul mountain with mountain steppe in the lower and alpine steppe in the upper part and
- Tumtiyn Nuruu mountain range of the Central Mongolian Altai with alpine steppe and high alpine vegetation

The entire area is situated in the northern part of Khovd province and covers an altitudinal gradient of 1150 m a.s.l. at northern shore of Lake Khar Us Nuur to 3050 m a.s.l. of Tumtiyn Nuruu mountain range at the border to Bayan Ölgiy province (Fig. 1).

The northern part of Khovd province belongs hydrographically to the drainless basin of Inner Asia that is regionally fed by the Khovd Gol and further smaller rivers from the Mongolian Altai and Khangay. A set of larger and smaller lakes in the western part of the Great Lake Basin forms a network of interconnected freshwater lakes without discharge that ends in the saline lakes of Dörgön Nuur and Khyargas Nuur (latter is situated in northern Uvs province). The lakes are surrounded by softly undulating pediments of adjacent mountain ranges as e.g. Argalant and Zhargalant mountains that are considered to be a part of the Mongolian Altai system (MURZAEV 1954). The extended pediment area is shaped by salt pans, small hills and dry river valleys sporadically bearing water (in Russian: sayr). In western direction, the pediment area merges into a steeply inclined mountain foreland and further into the Mongolian Altai mountain ranges in a short distance of 20 to 50 km from western shore of Khar Us Nuur. The mountainous area consists of separate ridges in latitudinal arrangement divided by intermountain depressions or connected by saddles. The surface is covered with gravelly and rocky erosion debris predominantly consisting of granite and slate rock (MURZAEV 1954).

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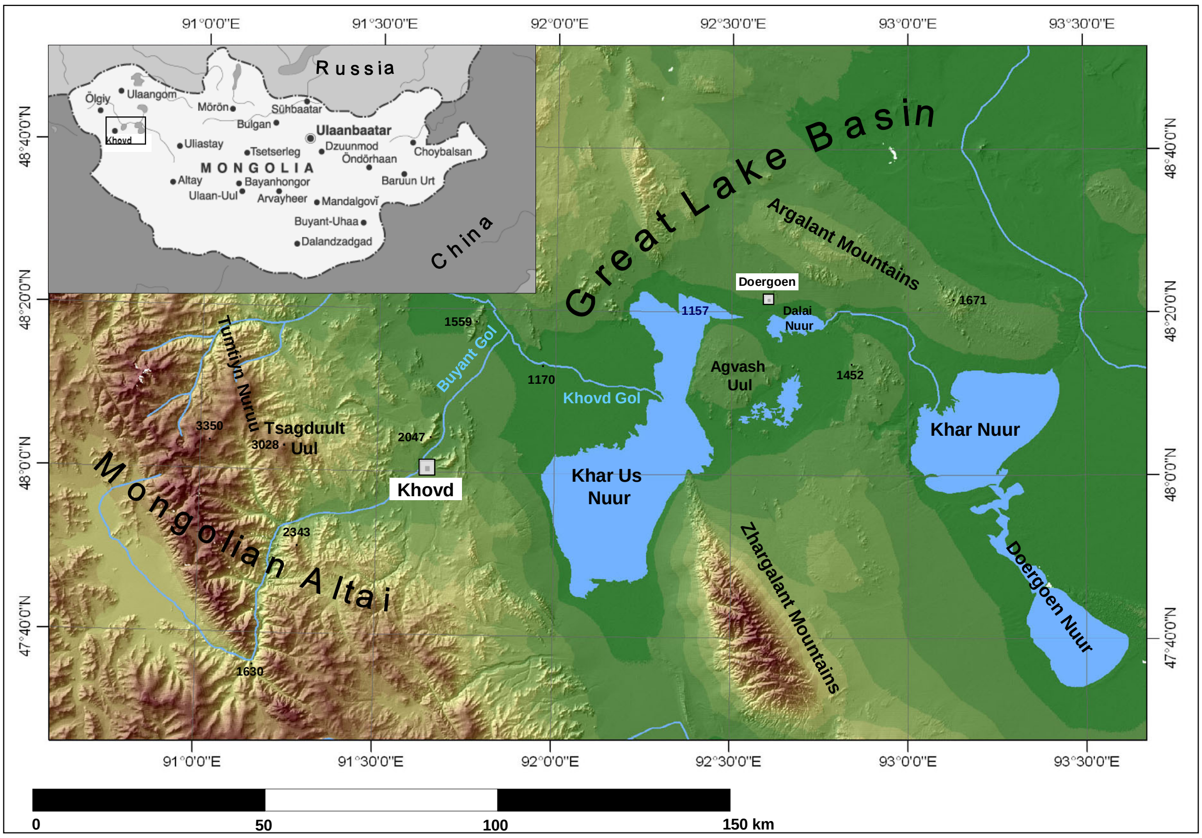

Fig. 1: Map of northern part of Khovd province with main study areas covering the western part of the Great Lake Basin and the east slope of Central Mongolian Altai (Sources: KRETSCHMER 2004; TIBET FAMILY, TOURS AND TRAVEL 2006, modified).

2 Climate

The northern part of Khovd province is located in a sheltered position (Tannu Ola Mountains north, Khangay Mountains east, Gobi Altai south, and Mongolian Altai west) that causes an extremely continental and dry climate (WEISCHET & ENDLICHER 2000) supporting the maximum northern extent of desert vegetation up to the Uvs Nuur Basin (KARAMYSHEVA et al. 1986). The Pacific monsoon effects can only be traced up to 110-120° E (GUNIN et al. 1999), without ever reaching the province territory of Khovd. The stable Siberian anticyclone causes long, cold, and dry winters with mean January temperatures of -22 °C. The climatic factors, relevant for plant growth, are provided in the climate diagram (Fig. 2).

Frost periods with mean monthly temperatures below 0 °C persist from October through April. First and last frosts appear in May and September. Frostfree periods are only found in the plains between June to August. Winter precipitation is low, failing to create an isolating snow cover. As a rule, the soil remains deeply frozen, except for thin top layers where melting occurs during the short summer period. In winter, extensive temperature inversions involving warm airmass in lower mountain regions superimposed above cold airmass in the plains, lead to relatively warm conditions on the winter pastures at approx. 2000 m a.s.l. (BARTHEL 1983). In spring, high atmospheric pressure conditions are replaced by the influence of the westerly wind zone. Westerly winds bring warm and humid airmass, but rarely make it across the mountain barriers of Mongolian Altai (BARTHEL 1983; GUNIN et al. 1999). Thus, precipitations have convective character (WEISCHET & ENDLICHER 2000).

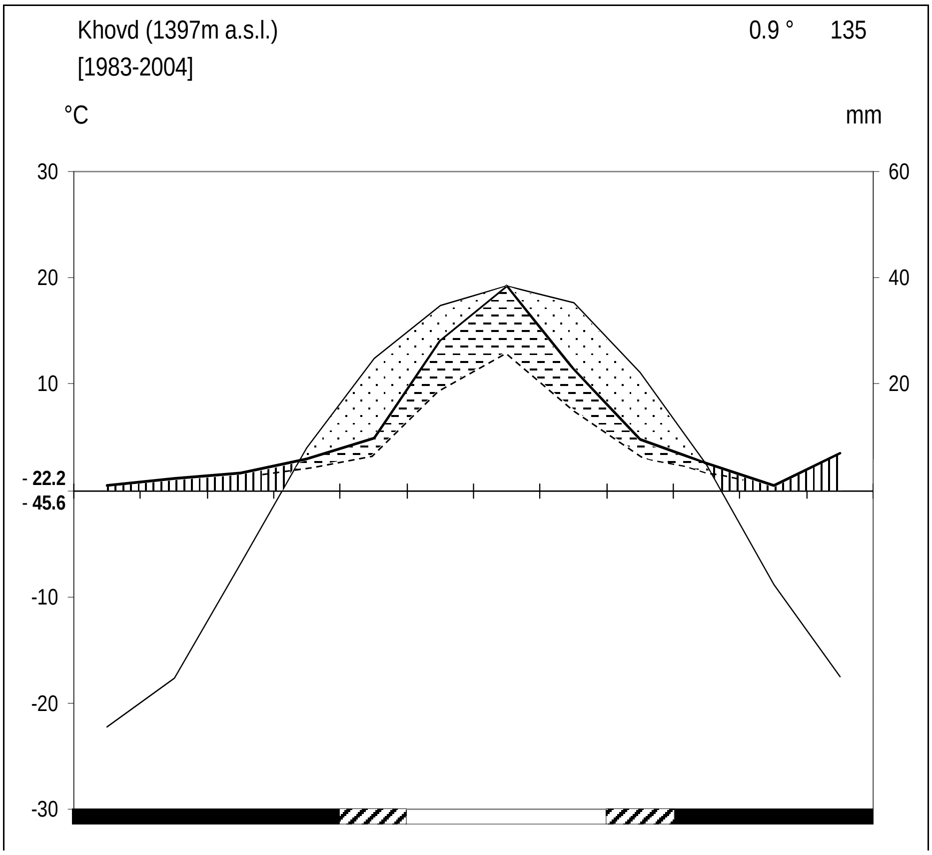

Fig. 2: Climate diagram with mean monthly/yearly data according to WALTER (1955) of climate station Khovd situated in the centre of northern Khovd province within the northern desert steppe belt (Source: Climate Station Khovd 1983-2004).

Summers are short and warm at mean July temperatures of 19 °C. About 70-90 % of annual precipitation occurs in summer, even though quantities may vary considerably over the years. For example, mean annual precipitation in the lowlands of northern desert steppe amounts to 135 mm, but only 78 mm occurred in 2002 as opposed to 223 mm in 2003 (Climate Station Khovd 1983-2004). Since low precipitation is accompanied by high evaporation rates, the season from mid-April through mid-October is generally characterized by arid conditions and summer drought. Depending on summer precipitation quantities, the summer drought may be interrupted by wet weather conditions in July, the month with highest rainfall. Despite substantial evaporation but due to the coincidence of rainy and warm season, the natural process of soil salinization of uppermost top soil is prevented, thereby causing calcium carbonates and soluble salts to leach out of the top soil layers (HAASE 1983). From mid-October to mid-April, mean monthly temperature drops below 0 °C. According to the drought index (Trockengrenze) applied in climate diagrams according to WALTER (1955), this period is considered humid due to very low temperatures, despite very low winter precipitation[2]. The spring and autumn transition seasons are very short. Major daily and annual temperature fluctuations are typical of the region's continental climate (numerical values of climate data taken from Climate Station Khovd 1983-2004; BARTHEL 1990; GUNIN et al. 1999).

The altitudinal gradient across the plains of southwest Great Lake Basin to the top of Central Mongolian Altai ranges is at the same time a gradient of increasing humidity shifting from arid conditions with mean annual precipitation of 62 mm in the desert steppe lowlands between Lakes Khar Nuur and Khar Us Nuur to 135 mm in the northern desert steppe lowlands around Khovd city, 325 mm in the

[2] The drought index (Trockengrenze) by WALTER (1955) is based on mean monthly temperatures in discrete proportion to monthly precipitation for easy worldwide comparison of commonly available climate data. It makes no distinction between higher daily temperatures with arid conditions caused by high evaporation rates and low overnight temperature with humid conditions during wintertime. HAASE (1983) considers winter frost periods as arid conditions, while WALTER (1955) describes they imply humid conditions. Application of the drought index by WALTER (1955) is discussed and criticised by LAUER (1960).

mountain steppe belt, and up to 350-450 mm under humid conditions in the alpine belt (Climate Station Khovd 1983-2004; Climate Station Dörgön 1985-2004; Climate Station Khovd a, b; JANZEN & BAZARGUR 2003). Following the climatologic rule - the lower the long-term mean annual precipitation, the higher the precipitation variability over the years (BLÜTHGEN & WEISCHET 1980; SULLIVAN & ROHDE 2002) - the gradient of increasing humidity is associated with a decreasing year-to-year precipitation variability. In addition, the altitudinal gradient is accompanied by decreasing length of vegetation period expressed by the sum of hours above 10 °C. It ranges from 1500 – 2000 hours per year in the desert steppe, via 700 – 1000 hours per year in the mountain steppe, up to 500 – 1000 hours per year in the alpine belt (Climate Station Khovd a, b).

3 Soil and vegetation

3.1 Desert steppe

Desert steppe vegetation covers the lowlands around the lakes in northern Khovd province between 1150 m and 1700 m a.s.l. and is divided according to Russian and Mongolian vegetation classification in desert steppe s. str. and northern desert steppe[3] (cf. ZEMMRICH 2005). The lowlands around the lakes up to an altitude of 1460 m a.s.l. belong to desert steppe s. str. that represents the drier sub-belt. Northern desert steppe is tied to higher altitudes between 1400 to 1700 m a.s.l., receives higher precipitation, and is characterised by *Caragana*[4] and *Krascheninnikovia* shrubs and steppe grasses such as *Cleistogenes squarrosa, Stipa glareosa, Agropyron cristatum* and *Stipa krylovii.* While the desert steppe s. str. is considered as the transition from Eurasian steppe zone to Central Asian desert zone in southward direction by EVSTIFEEV & RACHKOVSKAYA (1976), LAVRENKO (1978), RACHKOVSKAYA (2001) and RACHKOVSKAYA & VOLKOVA (1977), it is explicitly referred to as Central Asian desert zone by GRUBOV (1990). Their high proportion of xerophilous grasses in a composition with onion geophytes and shrubs, a peculiarity of Mongolia's desert steppe zone (EVSTIFEEV & RACHKOVSKAYA 1976; LAVRENKO 1978; YUNATOV 1950, 1974), represents one reason for this dispute. It is based among others on the low salinity rate of Mongolia's soils in contrast to soils of Central Asia of former Soviet republics with spring precipitation (HAASE 1983; LAVRENKO & KARAMYSHEVA 1993).

The sparse vegetation of desert steppe s. str. covers between 5 and 15 % of soil surface, comprising approximately 83 species of vascular plants and is dominated in foliar cover by perennial dwarf semi-shrubs (e.g. *Anabasis brevifolia*, *Artemisia xerophytica*, *Asterothamnus heteropappoides*), small bunchgrasses (*Stipa glareosa*, *Cleistogenes songorica*), and onion geophytes (*Allium mongolicum*, *Allium polyrrhizum*). In years rich in precipitation, annual species (*Aristida heymannii*, *Eragrostis minor*, *Enneapogon borealis*, *Lappula intermedia*, *L. granulata*) attain dominance covering up to 30 – 40 % of soil surface (LAVRENKO & KARAMYSHEVA 1993; own observations 2002-2003). In transition to the northern desert steppe or under specific site conditions of dry valleys or steep inclined slopes rich in gravel and debris, shrub communities of *Caragana leucophloea* and *Krascheninnikovia ceratoides* appear.

Prevailing soil type of desert steppe represents a weak alkaline Burozem (World Reference Base for Soil Resources, henceforth called WRB: Calcisol)[5] with shallow soil depth, very low accumulation of humus and intense calcium carbonate dynamics (HAASE 1983; ZECH & HINTERMEIER-ERHARD 2002). The incomplete relocation of secondary calcium carbonate and its accumulation in deeper horizons represents the main soil-forming process. It leads to the presence of calcium carbonate along the entire soil profile in contrast to Kastanozem soils of mountain steppes, that are decalcified in the upper soil hori-

[3] Originally, it is denominated as 'opustynennyy steppe', which means translated word-by-word 'desertified steppe' (EVSTIFEEV & RACHKOVSKAYA 1976, YUNATOV 1974). Since this translation evokes an impression of anthropogenic impact, ZEMMRICH (2005) suggested the term 'northern desert steppe' regarding its geographical position.

[4] Nomenclature of species name follows GUBANOV (1996).

[5] Names of soil types refer to regional classification according to Haase (1983). The international equivalence according to FAO (1998) is given in brackets.

zons. The coincidence of rainy season with warm summer season enables a downward percolating water regime through the uppermost topsoil layers and the formation of the diagnostic carbonate horizon in a soil depth between 10 cm and 30 cm below soil surface. Furthermore, it prevents the salinization and accumulation of gypsum and secondary carbonates at soil surfaces as it is known for Central Asian Burozem soils of Central Asian republics of former Soviet Union with spring precipitation. The risk of salinization is further limited by frozen soils during season of lowest precipitation in winter, preventing the ascent of soil solutions (HAASE 1983). The precipitation of secondary carbonates is observed as pseudo-mycelias and small concretions, diffusely distributed as soft powdery lime or as crusts at the bottom sides of stones. The high permeability of coarse and sandy soil substrates supports the leaching of topsoil layers. The generally dry climatic conditions cause low biomass production, subjected to high mineralization rates due to the coincidence of rainy season with warm summer season (HAASE 1983). Both lead to low humus accumulation with soil organic matter (henceforth SOM) below 1 % and thin humus layers less than 30 cm.

Desert steppe s. str. of northern Khovd province comprises several characteristic plant communities, e.g., *Anabasis brevifolia - Allium mongolicum* desert steppe, *Artemisia xerophytica* semi-shrub desert steppe, and *Krascheninnikovia ceratoides* shrub desert steppe (plant communities according to ZEMMRICH 2006). The plant communities were named according to characteristic species. Species names are followed by respective plant formation names (e.g., desert steppe). Furthermore, to emphasize apparent differences in vegetation structure of communities belonging to the same plant formation, the terms semi-shrub and shrub were applied.

Anabasis brevifolia - Allium mongolicum desert steppe and *Artemisia xerophytica* semi-shrub desert steppe are distributed on light Burozem (WRB: Haplic Calcisol). Light Burozem differs from typical Burozem in low humus accumulation below 1.5 % and higher C/N ratio (HAASE 1983). The WRB denomination 'Haplic Calcisol' refers to the typical performance of Calcisol features (FAO 1998). In dry river valleys and on river terraces with periodically higher groundwater level, the *Krascheninnikovia ceratoides* shrub desert steppe occurs on Gypsisols (FAO 1998), a soil type not described by HAASE (1983). Similar to Calcisol, Gypsisols are characerised by a cemented gypsic horizon but differ in a higher salinity and lower humus content in the upper soil layers. *Artemisia xerophytica* semi-shrub desert steppe is distributed only adjacent to Lake Khar Us Nuur at peninsula of Agvash Uul while *Anabasis brevifolia - Allium mongolicum* desert steppe and *Krascheninnikovia ceratoides*-shrub desert steppe are found at several altitudes from the pediment area to upper parts of Argalant Mountains up to 1460 m a.s.l. These areas are situated in the colline belt, characterised in the Central Mongolian Altai by its foreland position and the presence of desert steppe vegetation (WEINERT 1966). The present article follows the concept of altitudinal belts of Eurasian vegetation outlined by WEINERT (1966) in order to be consistent with HILBIG (1995), who also adopted this concept in his vegetation monograph.

3.2 Mountain steppe

The altitudinal belt of mountain steppes in the Central Mongolian Altai, situated between 1900 and 2200 m a.s.l., is located at much higher altitudes than in Khangay Mountains due to the aridity of the region (YUNATOV 1950). The vegetation covers between 20 and 55 % of the land surface, and is dominated by perennial xerophilous bunch grasses such as *Stipa krylovii*, *Koeleria cristata* and *Agropyron cristatum* and the dwarf semi-shrub *Artemisia dolosa*. It comprises approx. 94 species of vascular plants. Summer annuals such as *Salsola collina*, *S. tragus* and *Dontostemon integrifolius* are abundant in moist years. Single mountain steppe communities comprise shrubs of the genus *Caragana* that are common in Mongolian Altai (BUYAN-ORSHIKH 1992; KARAMYSHEVA & KHRAMTSOV 1995).

The mountain steppe belt is similar to the zonal dry steppe of Central Mongolia, manifested by its sparse foliar cover and the dominating xerophilous bunch grasses *Stipa krylovii* and *Agropyron cristatum* (KARAMYSHEVA & KHRAMTSOV 1995). The presence of *Festuca lenensis* and further alpine species marks the vegetation as mountain steppe belt. The tufts of the dominating bunch grasses are densely covered by dead leaf sheaths accumulating snow, water and fine soil that improves the ability of water retention.

Thus, this growth form is well adapted to unfavourable conditions of water shortage, low temperatures with insignificant snow cover, and grazing by herbivores (LAVRENKO 1941 cited in KARAMYSHEVA & KHRAMTSOV 1995).

While Mongolian Altai slopes in the Uvs province further north show striking contrasts with *Larix sibirica* forest steppes at north-facing slopes and meadow steppes at south-facing slopes (HILBIG 1995; KNOTHE et al. 2001), mountain steppes of northern Khovd province do not indicate obvious exposure-related differences, neither regarding the occurrence of different vegetation types nor plant communities. Only the position of upper and lower border of the vegetation zones differ (BEKET 2003). Pronouncedly arid conditions caused by the sheltered leeward position east of Central Mongolian Altai prevent the development of those contrasts (VOLKOVA 1994; BEKET 2003).

Soils of mountain steppes comprise light, middle and dark Kastanozems (WRB: Kastanozem). As a result of natural erosion truncated Kastanozems (WRB: Leptosol) occur occasionally. Kastanozems have varying content of humus (between 1 to 5 % of SOM in topsoil layer) due to high supply of root biomass. Besides humus enrichment, further features of soil formation of Kastanozem soils comprise bioturbation caused by small burrowing mammals (*Ochotona spec.*, *Citellus spec.*), leaching of calcium carbonate in the upper soil layer within 30 cm from soil surface, and enrichment of secondary carbonates and soluble salts in lower soil layer. While HAASE (1983) explains the typical chestnut colour of Kastanozem soils by the existence of soil particle envelopes rich in iron oxide, this fact is no longer mentioned in recent literature (ZECH & HINTERMEIER-ERHARD 2002). It is explained instead by lower contents of SOM (than in Chernozem soils) and higher contents of secondary carbonates as a result of drier climatic conditions accompanied by lower moisture penetration of soils (GENNADIEV 1990). Mongolian Kastanozem soils in contrast to Central Asian Kastanozem soils of former Soviet republics with spring precipitation have lower content of salts and are decalcified in the upper soil horizons (HAASE 1983).

Stipa krylovii - Artemisia dolosa mountain steppe and *Rhinactinidia eremophila - Stipa krylovii* mountain steppe can be considered as typical plant communities of the mountain steppe belt of northern Khovd province .

Stipa krylovii - Artemisia dolosa mountain steppe occurs on middle and dark Kastanozems (WRB: Haplic and Calcic Kastanozems), while *Rhinactinidia eremophila - Stipa krylovii* mountain steppe is distributed on light, middle Kastanozems (WRB: Haplic Kastanozems) and on truncated Kastanozems (WRB: Leptosol). The latter soil type indicates that *Rhinactinidia eremophila - Stipa krylovii* mountain steppe is adapted to shallow soils with initial soil development. Light Kastanozem shows a depth of humus horizons of 20 – 40 cm with content of SOM below 2 %. Secondary carbonates are located between 10 and 20 cm from soil surface. Middle Kastanozem has a depth of humus horizon from 30 - 50 cm, a content of SOM between 2 to 4 % and secondary carbonates below 20 cm from soil surface. Depth of humus horizons of dark Kastanozem reaches 50 – 60 cm with a content of SOM of more than 4 % (HAASE 1983). The Calcic Kastanozem that is not additionally distinguished by HAASE (1983) is indicated by an accumulation horizon of secondary calcium carbonate as concretions, pseudomycelias or crusts between 50 and 100 cm from the soil surface (FAO 1998). Mountain steppe soils at steep slopes are affected by soil erosion, further enhanced by sparse vegetation cover, and change into truncated shallow Kastanozems (WRB: Leptosol) with less than 10 % fine soil to a depth of 75 cm or parent rock within 25 cm from the soil surface (FAO 1998).

In the Central Mongolian Altai where forests are absent, the transition of the colline belt to the montane belt is marked by the occurrence of steppes (WEINERT 1966). Hence, the mountain steppe vegetation represents the montane vegetation belt.

3.3 Alpine belt

In accordance with YUNATOV (1950), who describes the lower border of the alpine belt in Mongolian Altai between 2300 – 2400 m a.s.l.., alpine vegetation comprises alpine steppes in the lower alpine belt between 2300 m and 2600 m a.s.l. Furthermore, it includes cryophyte steppes at the slopes of the upper alpine belt between 2650 m and 3050 m a.s.l. and sedge mats on the wet bottom of alpine valleys.

Alpine steppes cover between 50 and 80 % of soil surface, comprise approx. 76 species of vascular plants and are dominated by perennial grasses such as *Koeleria cristata*, *Festuca lenensis* and *Festuca sibirica* accompanied by sedges (*Carex rupestris*, *C. pediformes*) and dwarf semi-shrubs (*Artemisia dolosa*, *Arenaria meyeri* and *A. capillaris*). Along the entire altitudinal gradient from desert steppes to the alpine belt, mosses occur for the first time in the alpine steppe belt. The species composition points to a cryo-xerophytic character of the vegetation as exemplified by small bunch grasses and sedges (*Festuca lenensis* and *C. pediformes*) and cushion plants (*Arenaria meyeri* and *A. capillaris*), that has no analogy in the zonal steppe (POLYNOV & KRASHENINNIKOV 1926 cited in YUNATOV 1950; VOLKOVA 1994; KARAMYSHEVA & KHRAMTSOV 1995). This cryo-xerophytic character prompted WALTER (1974) and YUNATOV (1950) to reject the term meadow steppe for alpine steppes of Mongolia except for *Kobresia* vegetation. According to VOLKOVA (1994), meadow steppes are only rarely distributed at small areas in the high mountain belt of Mongolian Altai.

Alpine steppe occurs on dark and truncated Kastanozems (WRB: Haplic Kastanozem, Calcic Kastanozem, Mollic Leptosol) and on Chernozem (WRB: Haplic Chernozem). Kastanozem soils are more frequently distributed under alpine steppe while Chernozem soil appears only at water surplus sites such as channels along mountain slopes or depressions. A Chernozem represents a humus-rich soil that has a thick topsoil layer with high base saturation (referring to the diagnostic mollic horizon) directly above the C-horizon, which is hardly affected by pedogenetic processes. The higher moisture supply in alpine steppes enables an enhanced biomass production and promotes an intense bioturbation by earthworms and rodents in contrast to Kastanozem soils of mountain steppes. Mineralization processes in the alpine belt are similarly limited due to short summer seasons and dry and cold winters. As a result, SOM of Chernozem is much higher than in Kastanozem soils of mountain steppe (more than 20 % are found in northern Khovd province). C/N ratios in Chernozems are slightly lower (ZECH & HINTERMEIER-ERHARD 2002). Instead of specific chestnut colour of topsoil horizons, Chernozem soils have dark brown or black colour. Higher precipitation leads to complete decalcification of humus horizons up to a soil depth between 60 to 80 cm and to the accumulation of secondary calcium carbonate in the subsoil. Dark Kastanozems of alpine steppe differ from Kastanozems of mountain steppe in higher content of humus (SOM 5 - 8 %) and a deeper leaching of calcium carbonates. Within 40 cm below soil surface, an increasing enrichment of secondary carbonates could be observed.

The cryophyte steppe covers between 30 and 80 % of soil surface depending on the amount of boulders that are common in this altitude. It comprises approx. 42 species of vascular plants. Dominant species include perennial grasses and sedges (*Festuca lenensis*, *Elytrigia geniculata*, *Carex rupestris*, *C. pediformes*) and cushion plants (*Oxytropis oligantha*, *Arenaria meyeri*, *A. capillaris*, *Stellaria pulvinata*), pointing to harsh and dry climatic conditions. The steppe character of the high alpine vegetation of Mongolian Altai (POLYNOV & KRASHENINNIKOV 1926 cited in YUNATOV 1950; BUYAN-ORSHIKH 1992) was the reason for Russian and Mongolian botanists to designate this vegetation type as cryophyte steppe (BUYAN-ORSHIKH 1992, VOLKOVA 1994). Similar vegetation types are distributed in the Eastern Pamir, Tibet and Central Tian Shan but show different species compositions (VOLKOVA 1994).

Cryophyte steppes occur on Dernozem soils (WRB: Cryosol, Leptosol) and Derno-Cryosol soils (WRB: Cryosol, Leptosol). Dernozem soils are shallow soils characterised by high humus accumulation, dense root thickets of the grass cover, and slightly to moderately acid pH. Underneath the dark-coloured topsoil horizon, humus content rapidly decreases. Prevailing low temperatures and short summers of the alpine belt do not permit intense mineralization and provide only low biological activity in soil. As a result, an intense accumulation of humus in topsoil with SOM of more than 10-20 % within a soil depth of

20 cm can be observed. Due to the high precipitation and low soil pH in the alpine belt, chemical weathering plays an enhanced role in soil development and causes an increased disintegration of parent rock with high content of fine soil fractions (HAASE 1983). The Corg/N ratio below 11 found in northern Khovd province does not conform to the wide range between 13 and 16 mentioned by HAASE (1983) and indicates a better decomposition rate. The release of iron, its oxidation and a slight argillization as further processes characterising Dernozem soils (HAASE 1983) could not be detected. Derno-Cryosol is a further soil type beneath cryophyte steppe. It represents a transitional soil type between Dernozems and Cryosols showing a lawn surface with a dense root horizon, as well as a thick A-horizon with an intense humus accumulation typical for Dernozem soils (HAASE 1983). Furthermore, polygonal patterns of soil surface caused by cryoturbation indicate temporary water saturation in the A-horizon. The water saturation supports the humus accumulation and prevents mineralization that leads to high contents of SOM of more than 30 % within the topsoil layer. The water saturation is also indicated by an oxidation horizon in the subsoil. The latter is an effect of melting permafrost during the summer season. An oxidation horizon atop the permafrost horizon represents a typical property of a Cryosol soil. Sufficient water saturation enabling cryoturbate motions is a local phenomenon of Dernozem soils while oxidation horizons formed by melting permafrost indicate a Cryosol. According to FAO (1998), Dernozem and Derno-Cryosol soils can appear as Histic Cryosol, Mollic and Humic Leptosol depending on the content of SOM and base saturation of topsoil horizon (distinguishing mollic, histic, and humic type) and total soil depth and content of coarse soil (separating the Leptosol from other soil types).

In a close contact to cryophyte steppes, sedge mats are distributed at moist sites such as valley bottoms and other water surplus habitats. Vegetation cover is almost closed. Cover values of 65 - 80 % of soil surface must be attributed to boulders and rocks scatterly distributed. Sedge mats comprise approx. 58 species of vascular plants and are dominated by species of *Carex* and *Kobresia*. *Kobresia* communities are described by HILBIG (2000) within the alliance of Kobresion myosuroidis MIRKIN et al. 1983 em. HILBIG 2000. Moist site conditions are particularly indicated by the occurrence of *Kobresia smirnovii*, which preferably grows at wetter sites compared to *Kobresia myosuroides* (VOLKOVA 1994).

Sedge mats occur on Cryo-Gley soils (WRB: Gelic Gleysol). Owing to high water saturation, harsh climatic conditions, and the presence of permafrost, soils are characterised by intense freeze-thaw processes and gleyic processes during summerly melting periods. These conditions lead to a high humus accumulation in the topsoil layer, that can result in peat layers due to reduced decomposition of rich biomass in the short and cold summer period. As a result of freezing processes of water saturated active topsoil layers, soil surface forms thufur mounds with a mineral core inside covered with turf shaping polygonal patterns. Topsoil is furthermore characterised by low pH values as a consequence of less decomposed SOM, high cation exchange capacity (CEC) and cryoturbate properties. Already the lower part of topsoil shows oxidation marks followed by a distinct oxidation horizon. The reduction horizon of the summerly wet and winterly frozen subsoil constitutes the final horizon of Gley soils.

According to HILBIG (1995), *Kobresia* communities are also distributed on Derno-Golez soils (WRB: no corresponding soil type), which represent drier edaphic conditions of the alpine *Kobresia* belt (HAASE 1983). In contrast to Dernozem soils, they contain a high proportion of debris or rock material and are characterised by sorting of fine and coarse soil and further cryoturbation effects, accumulation of SOM, release of iron, and gleyzation of subsoil.

Under the dry climatic conditions of Central Mongolian Altai where a forest belt and a subalpine belt rich in shrub vegetation are absent, the lower part of alpine belt is marked by the occurrence of high mountain species in combination with species of montane steppes (WEINERT 1966). In northern Khovd province, this combination of species is represented by alpine steppes and cryophyte steppes. At locally moister conditions, the alpine belt is additionally characterised by the occurrence of *Kobresia* and *Carex* communities.

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