

## VEGETATION MAP OF THE BATURA VALLEY (HUNZA KARAKORUM, NORTH PAKISTAN)

With 2 figures, 1 table, 7 photos and vegetation map 1:60 000 (Supplement I)

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*Zusammenfassung:* Die Vegetation des Batura-Tals (Hunza-Karakorum, Nord-Pakistan)

Die vorliegende Arbeit erläutert die beigegebene Vegetationskarte mittleren Maßstabs (1:60 000) des Batura-Tales, Hunza-Karakorum (Pakistan, Northern Areas). Das Arbeitsgebiet liegt zwischen 36°27'N/74°30'E und 36°40'N/74°54'E und umfasst eine Fläche von ca. 700 km<sup>2</sup> in Meereshöhen zwischen 2.450 m (Passu) und 7.785 m (Batura I). Die Obergrenze des Vorkommens von Gefäßpflanzen liegt bei 5.000–5.200 m. Der subtropischen Breitenlage und dem ariden Klima entsprechend ist der generelle Vegetationsaspekt des Batura-Tales wüstenhaft oder steppenartig. Die Vegetation ist artenarm (ca. 380 Gefäßpflanzenarten) und bedeckt insgesamt nur ca. 10% der Gesamtfläche entlang des Batura-Gletschers, eines der größten Auslassgletscher außerhalb der Polargebiete. In allen, auch den unteren, Höhenstufen sind gewaltige Massen von Gletschereis, Fels und mobilem Schutt völlig oder nahezu frei von Pflanzen. Trotz ihrer insgesamt arm erscheinenden Gesamtausstattung ist die Vegetation des Batura-Tals stark differenziert, sowohl horizontal als auch über einen weiten Höhengradienten, der sich von der warm-temperierten submontanen Stufe bis zu den alpinen und subnivalen Höhenstufen erstreckt. Sechszwanzig Vegetationsformationen wurden kartiert. Offene Kraut- und Zwergstrauchvegetation herrscht vor, während Waldfragmente, dichteres Gebüsch und geschlossene Rasengesellschaften nur kleine Flächen einnehmen. Der menschliche Einfluss auf die Vegetationsdecke, hauptsächlich durch Weidewirtschaft, ist generell als hoch anzusehen. Aktueller Status, Art und Umfang sowie spezifische Effekte des anthropo-zoogenen Einflusses sind jedoch lokal stark differenziert und unterliegen aufgrund der aktuellen sozioökonomischen Transformation in der Region offensichtlich auch rezenten Veränderungen. Neben einigen typischen pflanzengeographischen und ökologischen Aspekten werden der derzeitige Status und mögliche Entwicklungen im Zusammenhang mit der menschlichen Beeinflussung der Vegetationsdecke des Batura-Tales diskutiert.

*Summary:* An annotated medium-scale vegetation map (1:60 000) of the Batura Valley, Hunza Karakorum (Pakistan, Northern Areas) is presented. The study area covers ca. 700 km<sup>2</sup> (between 36°27'N/74°30'E and 36°40'N/74°54'E) along the Batura Glacier, one of the largest outlet glaciers outside the polar regions, and ranges in altitude from 2,450 m (Passu Village) to 7,785 m (Batura I). The upper limit of vascular plant life is situated at 5,000–5,200 m. Due to the subtropical latitude and generally arid climate, the Batura Valley presents a desert or steppe aspect. Vast expanses of glacial ice, rock and mobile scree are virtually devoid of plant life along the elevational gradient. Vegetation covers only ca. ten percent of the study area and is comprised of ca. 380 vascular plant species. 26 vegetation units are mapped. Open herbaceous or dwarf-shrub vegetation predominates. Fragments of forest, denser scrub and turf communities are confined to small areas. Despite its generally depauperate, fragmented and patchy character, the vegetation of the Batura Valley displays considerable local diversity and reflects a huge elevational gradient, ranging from warm-temperate (submontane) to alpine and subnival situations. The phytogeographic and ecological overview is augmented by a discussion of the present status and future prospects of the human impact on the vegetation of the Batura Valley. The human impact on the vegetation cover, mainly through grazing of domestic stock, is generally high. However, the exact nature and specific effects of anthropo-zoogenic interference vary and are also subject to recent socio-economic changes in the region.

### 1 Introduction

The Karakorum Mountains, the second-highest mountain system on earth, connect the plateaus of Tibet and the Pamir and form part of the political borders between Tajikistan, Afghanistan, Pakistan, India and China (Xinjiang and Tibet). The present knowledge of the distribution of vegetation types of the Karakorum is chiefly based on the extensive and conclusive phytosociological (BRAUN-BLANQUET 1964)

work of H. HARTMANN from the Braldo/Biafo region in the Central Karakorum and Ladakh (HARTMANN 1966a, 1966b, 1968, 1972, 1983, 1984, 1985, 1987, 1990, 1995, 1997, 1999). HARTMANN's findings have recently been taken up in a study on the vegetation of the Batura and upper Hunza Valleys (EBERHARDT 2004). On the basis of this phytosociological and phytogeographical investigation, the present paper provides a medium-scale vegetation map of the Batura Valley with a condensed description of vegetation units.

TROLL (1939) published a groundbreaking vegetation map of the Nanga Parbat area, West Himalaya. TROLL's map is the only medium-scale vegetation map (1 : 50 000) of an adjacent region, situated ca. 125 km south of our study area. In order to facilitate comparison and to highlight the striking environmental gradient between both areas, we have tried to adhere to some of TROLL's concepts and his map symbology. The taxonomy of the Nanga Parbat flora has recently been updated by DICKORÉ and NÜSSER 2000. Few vegetation maps of the West Himalaya and Karakorum at smaller scales or with different scopes have been published (SCHICKHOFF 1993, 1994; BRAUN 1996; NÜSSER a. DICKORÉ 2002). Additional information about biodiversity, vegetation and environmental gradients of the same geographical region is provided by DICKORÉ (1995), WEIERS (1995, 1998), MIEHE et al. (1996), CRAMER (1997), RICHTER et al. (1999), SCHICKHOFF (2000, 2002) and DICKORÉ and MIEHE (2002). The small-scale vegetation map of SCHWEINFURTH (1957) covers the entire Himalayas.

The purpose of the present study is to describe the principal characteristics of vegetation types, their distribution and spatial extent in the Batura catchment. Situated in the highly continental and arid part of the Central Asian high mountain system, the Batura Karakorum provides unique physical and ecological conditions on a grand scale. The Batura catchment with the more than 58 km long Batura Glacier, one of the largest outlet glaciers outside the polar regions (SHI a. ZHANG 1984), comprises an outstanding alpine environment and some of the highest and steepest of altitudinal gradients on earth. The present paper aims at understanding vegetation patterns under extreme ecological conditions that are largely detrimental to plant growth. While acknowledging specific methodological and scale problems of vegetation mapping in arid high mountains, we have also tried to assess the present status and future prospects of human impact on the vegetation of the Batura Valley.

## 2 Study Area

The study area encompasses the Batura Valley between the Batura Muztagh Range comprising the north-westernmost section of the NW-SE trending, extensively glaciated Karakorum main range (KMR) in the south and the Lupghar Range in the north (Photo 1) and the embayment of the Hunza River valley between the Batura terminus, the mouth of the Shimshal Valley, and Passu, approximately between 36°27'N/74°30'E and 36°40'N/74°54'E. The Hunza

River, incised to an elevation of less than 2,450 m into the KMR that reaches more than 7,700 m on either side, joins the Gilgit River, a tributary of the Indus, near Danyor, ca. 80 km south of the study area.

The vegetation map includes a surface area of ca. 687 km<sup>2</sup>, about 332 km<sup>2</sup> (48%) of which are covered by permanent ice and snow (BATURA GLACIER INVESTIGATION GROUP 1979; SHI a. ZHANG 1984). To the terminus of the Batura Glacier, the study area is accessible via the Karakorum Highway (KKH). The only permanent settlement within the range of the map is Passu (2,450 m). Names of seasonal settlements and other place names are indicated on the vegetation map.

The Karakorum is situated at the southern fringe of the intercontinental collision zone of the Indian and Asian plates. The Batura Muztagh is made up of mid-Cretaceous granodiorites, which crop out in the uppermost section of the Batura Valley and constitute the highest elevation of the study area (Batura I, 7,785 m). Granitoids continue in the middle section of the Batura Valley. To the north, the sediments of the North Karakorum Terrane adjoin. From SW to NE, the upper Paleozoic Passu Slates crop out north of the KMR and stretch between the south side of the lower and the north side of the upper Batura Valley (Yoksugoz Valley), followed by Permian to Mesozoic calcareous-dolomitic deposits on the northern side of the lower and middle section of the Batura Valley (GAETANI et al. 1990; ZANCHI a. GAETANI 1994; SEARLE 1991).

The overall relief of the area was shaped by glacial erosion during the Pleistocene. Subsequent to the Pleistocene maximum glaciation, debris cones and huge talus slopes were formed along the over-steepened valley flanks (GOUDIE et al. 1984). To the present day, the ice body of the Batura Glacier covers almost the entire valley bottom and extends right into the main Hunza Valley. The advances of the glacier threaten the Karakorum Highway (BATURA GLACIER INVESTIGATION GROUP 1979). The highest sub-recent (Little Ice Age) side moraines of the Batura Glacier are in some places accompanied by lateral valley side depressions, which are filled with scree fans (at Fatma hel), fluvial deposits of side valleys (Guchism, Midun) or fine-grained sediments of former or non-permanent lakes (below Yashpert, Barkakeshk area, Khorzoe). Older lodgement tills and meltout tills are abundant in mid-elevations (Wartom, Yoksugoz and Yunz valleys, between Kükhel and Yashpert) and form earth pyramids at several locations.

With regard to climate, the study area is situated alongside a large-scale humidity gradient, running south-west to north-east, from the humid monsoon climates of northern India and Pakistan to the high-alti-

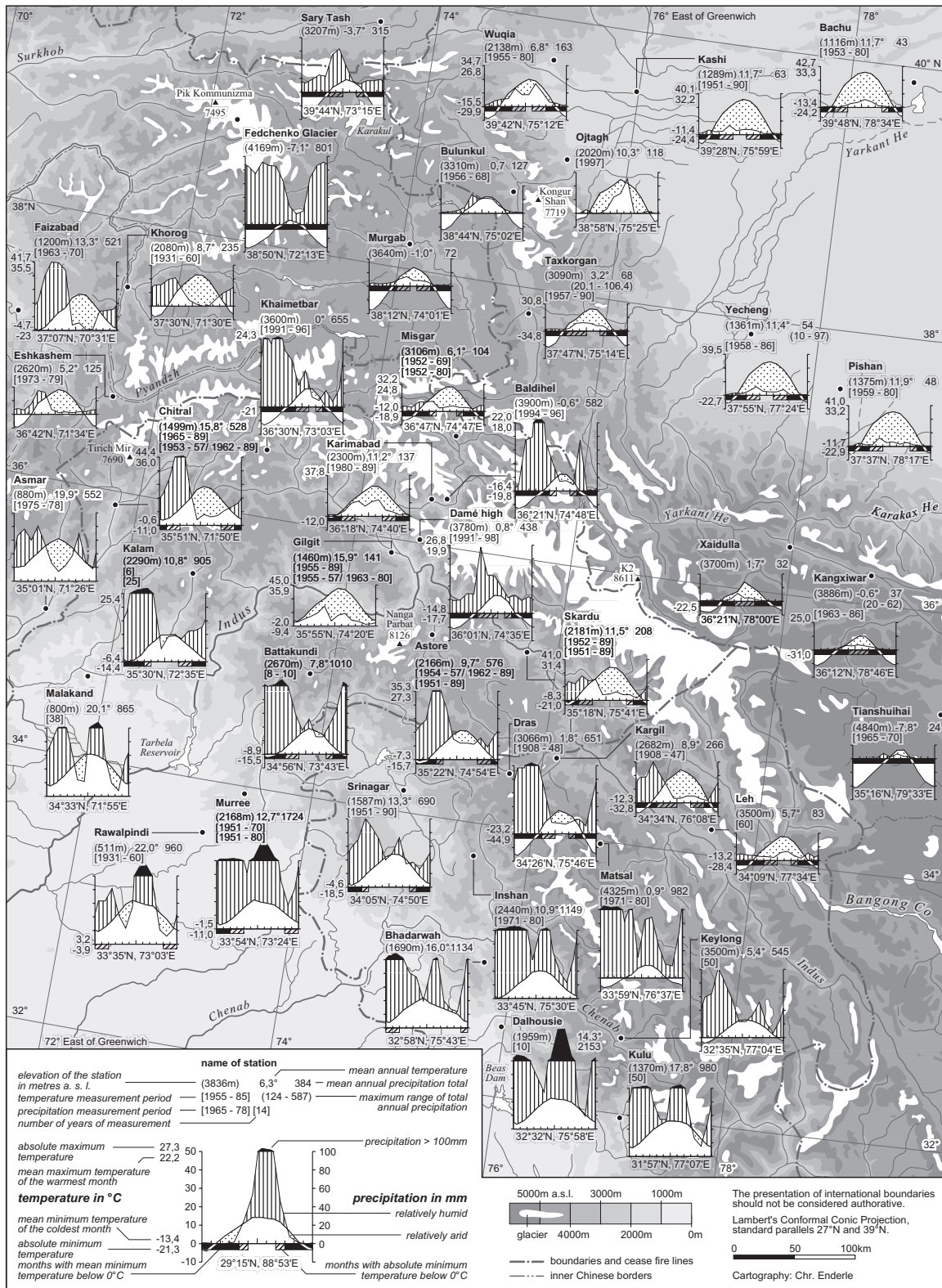


Fig. 1: Climate diagram map of northern Pakistan (EBERHARDT 2004, modified, MIEHE et al. 2001)

Klimadiagrammkarte von Nordpakistan (EBERHARDT 2004, verändert, MIEHE et al. 2001)

tude desert climates of the western Tibetan Plateau (Fig. 1; MIEHE et al. 1996; MIEHE et al. 2001; MIEHE et al. 2002). The gradient is reflected by the maximum northward extension of humid West Himalayan conifer forests (*Picea smithiana*, *Pinus wallichiana*) to the Rakaposhi (Lesser Karakorum Range) and the lower Hunza Valley, ca. 40 km south of the study area (SCHICKHOFF 2000). The humid low-level air streams of the western Himalayas, which may reach as far north as Nanga Parbat and the Gilgit-Indus Basin during the summer monsoon, do generally not enter the study area (WEIERS 1998).

Annual precipitation is less than 100 mm and mean annual temperature is 10 °C near the terminus of the Batura Glacier (2,560 m). Although increasing with altitude, precipitation resulting from high-altitude southwest currents peaks at above the snowline (ca. 5,000 m) at about ca. 5,700 m (WEIERS 1995, 1998), so that most precipitation is not directly available for plant growth. Mean annual temperature at the snowline is ca. -5 °C, where annual snow accumulation is equivalent to ca. 1,000–1,250 mm of (liquid) precipitation. Total annual precipitation, however, is assumed to be considerably higher due to intense evaporation from the glacier surface (BATURA GLACIER INVESTIGATION GROUP 1979).

Situated on the southern fringe of the Holarctic floristic realm, three major floristic regions meet in the Hindukush-Himalaya-Karakorum triangle (WALTER a. BRECKLE 1991, 24; NÜSSER a. DICKORÉ 2002): the Irano-Turanian region in the west with preponderant winter precipitation, the Sino-Himalayan region with summer rains in the south-east, and the permanently arid Central Asian region in the north (WALTER a. BRECKLE 1991, 24; NÜSSER a. DICKORÉ 2002). A floristic checklist of the Batura region comprising ca. 380 species of vascular plants has been provided by EBERHARDT (2004), which is referred to here with regard to additional species-related information, including taxonomic authors and further definitions<sup>1)</sup>. Phytogeographically, a relatively high proportion of Himalayan elements (Sino-Himalayan and West Himalayan, ca. 30% of species) has been observed (EBERHARDT 2004). This figure seems surprisingly high in view of the generally arid aspect of study area and its location north of the KMR. However, Central Asian (ca. 20%, including Tibetan) and Irano-Turanian (ca. 23%, including Pamirian) elements are also well represented. About 18% of the species display Eurasian or circumpolar dis-

tributions. The share of species endemic to the Karakorum and Eastern Hindukush is ca. 6%, which is about half the proportion of what has been reported from the mountain systems adjoining to the north and west (Tian Shan, Pamir and Hindukush: MAJOR 1988; AGAKHANJANZ a. BRECKLE 2002)<sup>2)</sup>. PAFFEN et al. (1956) proposed a decrease of total species numbers by about 50% from Nanga Parbat, the north-westernmost promontory of the Himalaya proper, to the Hunza/Batura region. This was supported by the more detailed investigations of DICKORÉ and NÜSSER (2000), DICKORÉ a. MIEHE (2002) and EBERHARDT (2004).

Apart from the most inaccessible and unvegetated sites, the Hunza catchment is an intensely used cultural landscape. Permanent settlements and irrigated arable land extend along the Hunza River and its major tributaries. The higher elevations, where accessible along the larger side valleys, are commonly used as drift pastures. The area north of the Batura Glacier is part of the common land of Passu village, the area south of the glacier of Hussaini village (some 2 km south of Passu at the KKH). Herding of goats, sheep, cattle and yaks as part of the local combined mountain agriculture follows a time schedule adapted to the seasonal weather and growing conditions (CLEMENS a. NÜSSER 1994). Seasonal transfers of the herds between various parts of the valley and altitudinal belts are carried out in order to optimise the usage of fodder resources. Transfer patterns of sheep and goats diverge to a certain degree from those of cattle and yaks. Bovines are only kept on the north side of the glacier. Especially the more resistant yaks are normally kept one stage higher up than the other animals, and in the higher side valleys with the climatically least favourable conditions (Wartom jerav, Yoksugoz jerav). Winter fodder supply is the limiting factor for herd size (CLEMENS a. NÜSSER 1994; SCHMIDT 2000).

### 3 Material and methods

The vegetation survey was carried out by the first author in 1994, 1998 and 2000 by direct investigation of all accessible sites during altogether five months of fieldwork. Vegetation formations were tentatively recorded in the field on an enlarged copy of the Chi-

<sup>1)</sup> Species names corrected or edited subsequent to EBERHARDT (2004) are referred to in footnotes.

<sup>2)</sup> Counts of endemic species must generally be considered even more cautiously than figures given for other phytogeographical elements. Comparisons between different sources are generally prone to considerable error on account of differing taxonomic and spatial definitions.



nese topographic base 'Map of the Batura Glacier 1:60 000' (INST. GLACIOL. ACADEMIA SINICA 1978) and confirmed by a classification of vegetation based on 281 phytosociological relevés and 6,330 herbarium voucher specimens collected in the Batura Valley (EBERHARDT 2004). We deliberately refrained from using remotely sensed data, as this would not have increased the resolution or precision of the map. No exact geo-referencing was available, and signals did not sufficiently distinguish between the structurally similar vegetation types. BRAUN (1996) has illustrated some of the problems related to remote sensing of vegetation in arid high mountains for the adjacent lower Hunza Valley.

Micro-relief features like stair-like terracettes resulting from frequent trampling (sheep track terracettes), browsing damage on vascular plants and dropping density were recorded as a surrogate for grazing impact on the vegetation. Altitudes were measured with a *Thommen* aneroid altimeter repeatedly calibrated with altitudinal readings from the base map. Place names and information about utilisation were obtained from the local people.

Vegetation units depicted in the map are primarily characterised by their physiognomic characteristics as vegetation formations in the sense of MUELLER-DOMBOIS and ELLENBERG (1974, 157–158). Species dominating the aspect, vegetation cover and presence or ab-

sence of different vegetation layers (i.e. herb and dwarf-shrub, shrub and tree layers) are the discriminating criteria. In the following, the term 'open' refers to a vegetation cover of 25–75% and 'very open' to a cover of less than 25%. A key linking the phytosociological classification to the mapping units is provided by EBERHARDT (2004).

Vegetation formations are marked in the map by a combination of colour and shape symbols. Colour symbols hold information on the layer with the highest degree of cover. This is, as a rule, the herb (and dwarf-shrub) layer, with the exception of *Salix karelinii* and *Hippophae rhamnoides* subsp. *turkestanica* thickets and *Salix pycnostachya* tree stands. Shape symbols are used for additional (shrub or tree) layers. This reflects the fact that closed forest stands are absent from the study area. Differences between the herb layers of adjacent stands, whether with or without scattered trees and larger shrubs, were usually considered to be insignificant. Large areas of rock faces, moraines and mobile screes almost or completely devoid of vegetation are a prominent landscape feature of much of the study area, and accordingly require an own colour symbol. An interesting feature of the Batura Valley is also the occurrence of isolated trees or small groves (*Populus pamirica*, *Betula jacquemontii*) on steep block slopes or scree, almost without accompanying vegetation and which have accordingly been depicted as shape symbols over bare ground.



Photo 1: Middle to lower Batura Valley. View SE from above Shendioz, 4,030 m, towards Disthegil Sar/Shimshal Valley in the background. In the foreground alpine steppe, 4,030 m. (Photo: EBERHARDT, 16.8.2000)

Mittleres und unteres Batura-Tal von der linken (nördlichen) Talseite, oberhalb Shendioz, 4.030 m, in Richtung SE auf den Disthegil Sar und das Shimshal-Tal. Im Vordergrund alpine Steppe

#### 4 Vegetation of the Batura Valley

As a main result of the present study, the distribution of vegetation in the Batura Valley is depicted on map 1. The following descriptions of mapping units include a brief ecological interpretation and notes on anthropozoogenous interactions. We have tried to distinguish between formations that occur over a particular elevational range and thus constitute the vegetation belts ('zonal' in the sense of WALTER 1954), and water surplus ('azonal') habitats that normally occur independent of constraints imposed by altitude. The sequence of 'zonal' formations follows a traditional system of altitudinal vegetation belts (submontane, montane, subalpine, alpine and subnival), which was earlier adapted and discussed for the Karakorum Mountains (DICKORÉ a. MIEHE 2002). Although distinct vegetation belts are a prominent physiognomic feature of the study area, definitions are difficult, and there is also a substantial altitudinal overlap in some formations. Water surplus vegetation along rivulets or artificial irrigation occupies small areas. However, due to the generally arid climate, many of the 'zonal' vegetation types do evidently depend to some degree on sub-surface waterflow or avalanche snow humidity.

##### 4.1 Submontane desert and semi-desert

The submontane belt extends along the bottom of the Hunza Valley and around the terminus of the Batura Glacier up to ca. 2,700 m. Its vegetation is desertic or semi-desertic throughout and presents a particularly barren aspect. Vegetation covers rarely more than 5% and comprises very open dwarf-scrub communities. These are strongly grazed by domestic stock, particularly during winter and spring. *Ephedra* spp. dwarf-shrubs rarely reach more than 30 cm in height, and much of the vegetation is grazed to the ground. Soils on the older ground moraines and river terraces are usually silty and relatively deep, but water availability is usually poor. In general, the environment is summer-hot and per-arid.

##### 4.1.1 *Artemisia fragrans*-*Ephedra intermedia* dwarf-scrub

Very open dwarf-scrub of *Artemisia fragrans*, *Ephedra intermedia* and a few other species is the most widespread formation in the Hunza main valley. Most habitats are situated on level or slightly inclined ground and comprise mostly older terraces and ground moraines. The species composition is heterogeneous. Different species can attain local dominance, apparently related to substrate, which varies from pure sand to silty and partially

calcareous sediments and boulders. *Capparis spinosa* is commonly found on silty tills around the terminus of the Batura Glacier. *Arnebia guttata*, *Artemisia scoparia* and *Chesneya depressa* occur on sand accumulations. Several thermophilous species are at the northern limit of their distribution in this part of the Hunza Valley (*Isodon rugosus*, *Chondrilla graminea*, *Daphne mucronata* and few dwarf trees of *Fraxinus xanthoxyloides*). *Tricholepis tibetica* is endemic to the Gilgit-Indus Basin and the occurrences of *Ephedra przewalskyi* form a southern outpost of its Central Asian distribution. Considerable areas of former *Artemisia fragrans*-*Ephedra intermedia* dwarf-scrub have apparently been transformed into irrigated farmland and fruit gardens. The persisting areas are subject to continued reclamation attempts.

##### 4.1.2 *Artemisia brevifolia*-*Haloxylon thomsonii* dwarf-scrub

*Artemisia brevifolia*-*Haloxylon thomsonii* dwarf-scrub is found in places along the Hunza River. This formation is similar to the preceding, but even poorer in species (3–5 species per 500 m<sup>2</sup>). The phytogeographical composition seems paradoxical in that *Haloxylon thomsonii* is an endemic of the (colline to submontane) dry valley system of Gilgit, Hunza and Indus, whereas the other species point to vegetation belts of higher altitudes (*Artemisia brevifolia*<sup>3)</sup> or have Central Asian affinities (*Halogeton glomeratus*, *Salsola jacquemontii*). These relationships are probably explained by cooler climatic conditions due to the topographical position or by a more pronounced salinisation of the topsoil. The habitats comprise mainly north-facing, old boulder-strewn terraces (west of Kandorinj). Less frequent companions are *Tanacetum fruticosum*, *Ephedra intermedia*, *Peganum harmala*, *Matthiola chorassanica* and *Arnebia guttata*. Similar desert-steppe communities with *Tanacetum fruticosum* and *Artemisia brevifolia* have been observed at the subalpine belt of Ladakh (HARTMANN 1983, 1995, 1999), but here they are relatively rich in species (9–21 species per 100 to 150 m<sup>2</sup>). The similarity between the desert steppe communities of Ladakh and the present study area may point to uniformity of the vegetation of the lower altitudinal belts within this large, arid valley system of the Karakorum and the adjacent Himalaya.

<sup>3)</sup> *Artemisia fragrans* (colline-submontane) substitutes *A. brevifolia* (montane-subalpine) at lower altitudes. They may, however, show considerable overlap in some areas, and are often difficult to distinguish. Both taxa belong to a difficult species complex, which (in the phytosociological literature) is usually treated collectively as *A. maritima* s.l., or, alternatively, is split up into numerous cryptic micro-species by some taxonomists.

Our classification is based on a small section of the Hunza Valley with a depauperised species spectrum and is thus not likely to have more than local significance.

#### 4.2 Montane steppe, dwarf-scrub and shrubland

The montane belt extends between ca. 2,600 and 3,900 m. Vegetation is often considerably denser and richer in species compared to lower altitudes and comprises steppe, dwarf-scrub and scrubland formations; forest is almost completely absent<sup>4</sup>). Junipers (*Juniperus semiglobosa*) occur regularly, in some places as isolated trees, but mostly forming very open shrubland, 2–3 m in height. This pattern may relate to both, aridity and human impact.

The montane vegetation is best developed on the south-facing slopes of the lower and middle sections of the Batura Valley, with fragmented occurrences in the upper section, and on the north-facing slopes of the lower section (with small and fragmented occurrences in the middle and upper sections). The vegetation of the montane belt is subject to grazing of large herds, mainly during spring and autumn. Most of the common herbs and dwarf-shrubs are apparently tolerant to grazing (*Piptatherum gracile*, *Galium verum*, *Scorzonera virgata*, *Elymus cognatus*, *Arnebia euchroma*, *Thymus linearis*, *Crucihimalaya mollissima*, *Crepis multicaulis*). Soils on the massive older tills with low stone content are of at least medium depth (about 50 cm) and display advanced soil development (initial or shallow B-horizons). However, the silt-rich material is prone to severe soil erosion, which may partly explain the generally low humus content of the shallow A-horizons. Entire slopes are often micro-terraced by sheep tracks.

##### 4.2.1 *Artemisia brevifolia*-*Stipa himalaica* steppe

*Artemisia brevifolia*-*Stipa himalaica* steppe occurs locally on dry, steep to moderately inclined flanks between the main Hunza and the lower Batura Valley, both above (north-facing slope of Kandorinj Rui, Photo 2) and below the lower Batura Glacier (eastern flank of Yunz Valley). Vegetation covers up to 20–25%; *Artemisia brevifolia*, *Stipa himalaica* and *Krascheninnikovia pungens* are the most common of relatively few species. Although this formation does not provide good fodder, the vegetation cover is apparently disturbed or degraded due to intense grazing in winter and spring.

<sup>4</sup>) In the adjacent Western Himalayas, northwards to Lower Hunza, Gilgit and Nanga Parbat, the montane belt is a stronghold of moist coniferous forest (TROLL 1939; DICKORÉ a. NÜSSER 2000; SCHICKHOFF 2002).

##### 4.2.2 *Artemisia brevifolia*-*Stipa himalaica* steppe, with *Juniperus semiglobosa* shrubs

This formation is found on the east-facing slope of the Yunz Valley above 3,250 m and differs from the preceding only by the occurrence of dispersed *Juniperus semiglobosa* shrubs<sup>5</sup>).

##### 4.2.3 *Koeleria cristata*-*Artemisia brevifolia* steppe

*Koeleria cristata*-*Artemisia brevifolia* steppe<sup>6</sup>) covers substantial areas mainly along the south-facing slopes of the Batura Valley. Vegetation cover normally ranges between 30 and 70%. This formation, alongside with similar formations enriched by juniper shrubs or trees, largely follows the spatial and altitudinal extension of the montane belt, but reaches also into the lower sub-alpine belt. *Artemisia brevifolia* is the most prominent species and gives the formation a characteristic aspect by its mint-green colour (Photo 3); other common dwarf or semi-shrubs are *Artemisia santolinifolia*, *Astragalus candolleanus* and *Ephedra gerardiana*. The herb layer is rich in species. *Koeleria cristata*, *Piptatherum gracile*, *Veronica biloba*, *Nepeta discolor*, *Leontopodium leontopodium*<sup>7</sup>), *Oxytropis humifusa*, *Carex plectobasis*, *Minuartia kashmirica* and *Eritrichium fruticosum* occur more frequently in the middle and lower sections of the Batura Valley. Species such as *Polygonum cognatum*<sup>8</sup>), *Rhodiola heterodonta*, *Poa attenuata* and *Lindelofia stylosa* occur rather towards the higher elevations or in relatively colder situations of the upper Batura Valley (west of Guchism). The *Koeleria cristata*-*Artemisia brevifolia* steppe is almost completely subject to extensive grazing, indicated by browsing damage and conspicuous terracettes.

<sup>5</sup>) Few shrubs of *Juniperus excelsa* subsp. *polycarpus* were found at lower elevations (3,030–3,100 m) on the south-facing slope of the Yunz Valley.

<sup>6</sup>) The term 'steppe' is disputable for this formation, since *Artemisia* semi- or dwarf-shrubs usually dominate over grasses. There are, however, structural links to other types of steppe and steppe forest. Since most of the literature records of *Artemisia* ('maritima') steppe from the Karakorum and adjacent areas refer to the same type of vegetation, we have in the following reverted to this term.

<sup>7</sup>) *Leontopodium leontopodium* (DC.) Hand.-Mazz. (= *L. brachyactis* Gand., *L. campestre* (Ledeb.) Hand.-Mazz.) has to be re-established as the accepted name for the subalpine taxon. In turn, former identifications of *L. leontopodium* (EBERHARDT 2004) must be referred to the alpine *L. ochroleucum* Beauv. Both species are sometimes difficult to distinguish and may possibly intergrade in intermediate altitudes.

<sup>8</sup>) *Polygonum rupestre* as reported by EBERHARDT (2004) is a synonym of *P. cognatum*.





Photo 2: Montane *Artemisia brevifolia*-*Stipa himalaica* steppe. Kadorinj Rui, 2,890 m, NNE-facing slope. (Photo: EBERHARDT, 24.7.1998)

Montane *Artemisia brevifolia*-*Stipa himalaica*-Steppe. Kadorinj Rui, 2,890 m, NNE-Exposition

#### 4.2.4 *Koeleria cristata*-*Artemisia brevifolia* steppe, with *Juniperus semiglobosa* shrubs

This formation differs from the preceding by the occurrence of scattered and only occasionally denser-growing shrubs of *Juniperus semiglobosa* (Photo 3).

#### 4.2.5 *Koeleria cristata*-*Artemisia brevifolia* steppe, with *Juniperus semiglobosa* shrubs and solitary trees

The occurrence of larger shrubs and individual trees and, rarely, small groves of *Juniperus semiglobosa* characterises this formation. There are only minor floristic dif-

ferences to the *Koeleria cristata*-*Artemisia brevifolia* steppe. A few species, such as e.g. *Androsace thomsonii*, possibly indicate some affinity to the steppe forest of the subalpine belt. *Comarum salesovianum* dominates the herb layer on generally north-facing scree cones of the lower Batura Valley.

#### 4.2.6 *Calamagrostis stoliczkae*-*Hedysarum falconeri* meadow

The *Calamagrostis stoliczkae*-*Hedysarum falconeri* meadow is a conspicuous formation on the outer slopes of the Little Ice Age lateral moraines of the Batura Glacier, through the montane and into the lower subalpine belt (the steep inner flanks towards the glacier are still almost devoid of vegetation). Large forbs or semi-shrubs (such as *Hedysarum falconeri*, Photo 4) tend to dominate over the few grasses. Further companions are various herbs (*Allium carolinianum*, *Lindelofia stylosa*, *Pedicularis pycnantha*, *Senecio korshinskyi*), subshrubs (*Ephedra Gerardiana*, *Semenovia lasiocarpa*, *Tanacetum baltistanicum*) and shrubs (*Spiraea lasiocarpa*). Larger and sometimes almost pure *Hedysarum falconeri* stands are found on sub-recent gravel terraces at side valley junctions of the upper Batura Glacier (Guchism, Wartom). The roots of *Hedysarum* obviously reach down into the groundwater. The species is probably an important pioneer due to symbiotic nitrogen fixation.

#### 4.2.7 *Calamagrostis stoliczkae*-*Hedysarum falconeri* meadow, with *Juniperus semiglobosa* shrubs and dwarf trees

*Juniperus semiglobosa* shrubs or trees in variable density contribute to this formation on the relatively more stable and older moraines. *Rosa webbiana* is another common shrub, which locally forms dense scrub, covering up to 50% of the ground (e.g. near Manzoor jhil). The floristic composition is otherwise similar to the preceding unit.

#### 4.2.8 *Elymus schugnanicus*-*Comarum salesovianum* dwarf-scrub

Patches of open *Comarum salesovianum* dwarf-scrub and a few tufted grasses (e.g. *Elymus schugnanicus*) colonise a variety of habitats mainly in the upper Batura and Wartom Valleys. The superficially dry, exposed habitats, such as rocks, scree, beds of meltwater streams and talus slopes, are typically situated within the *Koeleria cristata*-*Artemisia brevifolia* steppe. *Comarum salesovianum*, conspicuous by its dark-green foliage, tolerates scree movement and profits from deep underground water sources.





Photo 3: Montane *Koeleria cristata*-*Artemisia brevifolia* steppe with *Juniperus semiglobosa* shrubs (up to 4 m in height) near Yengeyar, 2 km E of Yashpert, 3,270 m, SSE facing slope. (Photo: Eberhardt, 16.7.1994)

*Koeleria cristata*-*Artemisia brevifolia*-Steppe mit *Juniperus semiglobosa*-Büschen (bis zu 4 m Höhe), bei Yengeyar, 2 km östlich Yashpert (3.270 m, SSE-Exposition)



Photo 4: *Hedysarum falconeri*, a tall suffruticose legume, forms locally denser stands along lateral moraines, in the background *Comarum salesovianum* dwarf-shrubs dotting mobile slate scree. Between Kirgaswashk and Khorzoe, valley side depression south of the lower Batura Glacier, 3,270 m. (Photo: Eberhardt, 15.7.1998)

Dichter Bestand des Halbstrauchs *Hedysarum falconeri* (*Leguminosae*) entlang der Seitenmoräne im Seitentälchen zwischen Kirgaswashk und Khorzoe auf der Südseite des unteren Batura-Gletschers. Im Hintergrund *Comarum salesovianum*-Zwergsträucher auf mobilem Schieferschutt, 3.270 m

### 4.3 Subalpine steppe, scrub, and treeline forest

The subalpine belt extends between ca. 3,500 and 4,400 m. Within the study area, the vegetation of the subalpine belt displays the highest level of structural variation and aspect divergence. Accordingly, the floristic delimitation towards both the montane and alpine belts is, in places, rather difficult, and the altitudinal extension of subalpine vegetation may vary by some 200–300 m between different aspects (Fig. 2). Relatively small and fragmented forest-like stands (*Juniperus semiglobosa*-*J. turkestanica* steppe forest) are almost exclusively confined to the south-east-facing slopes of the middle Batura Valley near Yashpert and Shendioz.

#### 4.3.1 *Oxytropis humifusa*-*Festuca olgae* steppe

*Oxytropis humifusa*-*Festuca olgae* steppe covers relatively large, although considerably fragmented areas at altitudes between ca. (3,600-) 3,800 and 4,350 m (Photo 1, foreground). Habitats mainly comprise moderately inclined, south- and west-facing slopes to the north of the middle and upper Batura Glacier. Fewer and smaller stands are found south of the lower Batura Glacier. The large tufts of *Festuca olgae*, a widespread subalpine grass of the Karakorum and adjacent high mountains (DICKORÉ 1995), are apparently avoided by grazing animals. The formation is relatively rich in plant species. Apart from some of the probably more characteristic

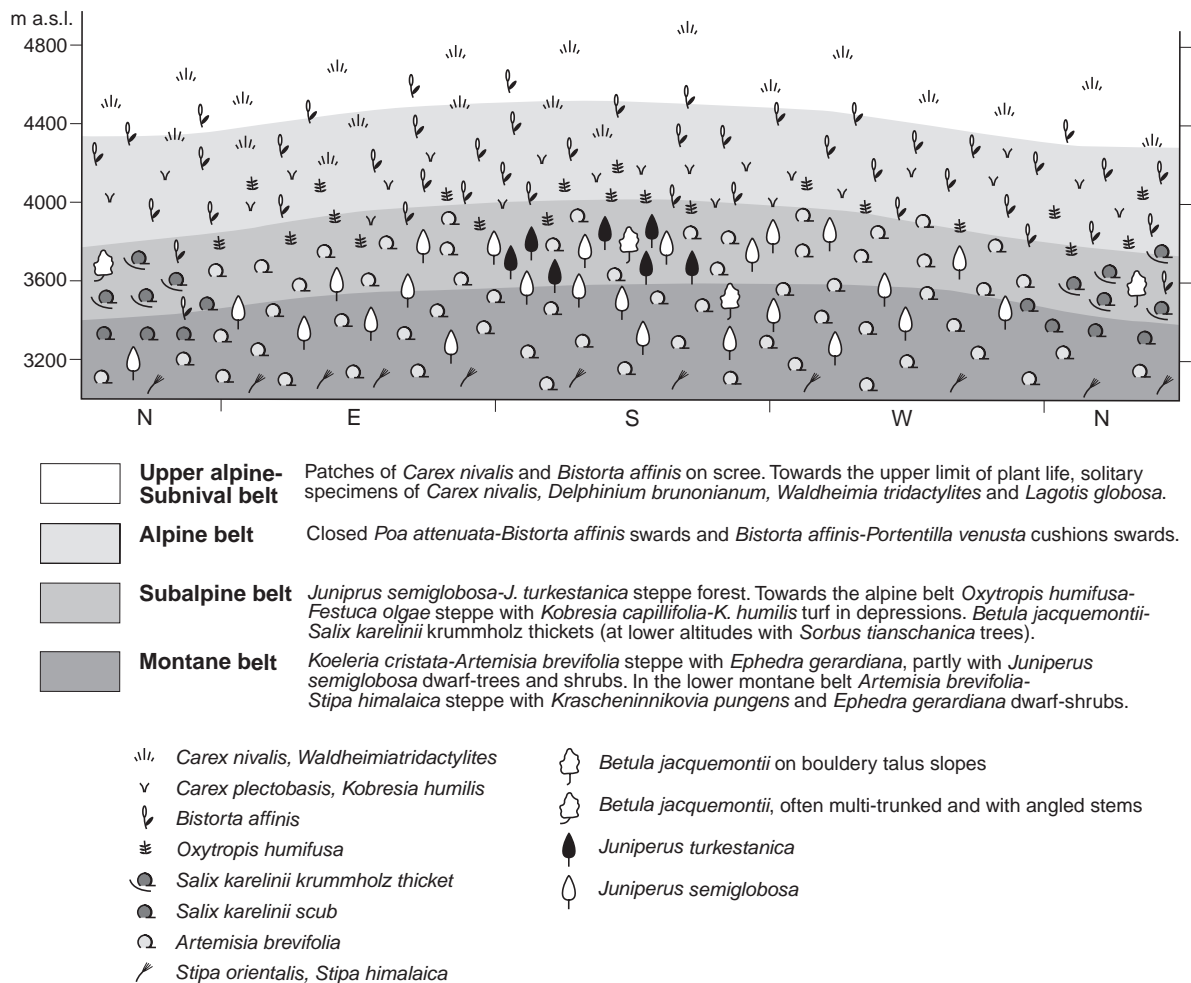


Fig. 2: Idealised distribution of vegetation formations in the middle Batura Valley corresponding to altitude and aspect (EBERHARDT 2004, modified)

Die Verteilung der Vegetation des mittleren Batura-Tals in Abhängigkeit von Höhe und Exposition (EBERHARDT 2004, verändert)





species (*Oxytropis humifusa*, *Androsace baltistanica*, *Bupleurum gracillimum*, *Polygonum cognatum*, *Draba lanceolata*, *Tanacetum pyrethroides*), many ubiquitous species occur. These include species from lower (*Carex plectobasis*, *Leontopodium leontopodinum*, *Astragalus candolleanus*, *Nepeta discolor*, *Thymus linearis*) or higher vegetation belts (*Dasiphora dryadanthoides*, *Rhodiola fastigiata*, *Lonicera semenovii*, *Potentilla pamirica*). The mostly small-growing herbs and dwarf-shrubs may locally form a closed sward of up to 90% cover. Patches of dense (sub-)alpine turf (Photo 5) with *Kobresia capillifolia*, *K. humilis*<sup>9)</sup>, *Poa alpina* and *Potentilla venusta* occupy slight depressions and temporary run-off channels (notably above Shendioz). Soils show relatively advanced development (at least shallow B-horizons) and have rather low stone contents. Grazing, mostly by yaks or game (ibex), seems to be of minor importance, which is probably due to impeded accessibility and fragmentation of the *Oxytropis humifusa-Festuca olgae* steppe among large areas of bare gravel and rocks at high altitudes.

Photo 5: Subalpine *Kobresia humilis* turf. Above Yengeyar, 2 km E of Yashpert, 3,840 m, WNW-facing slope. (Photo: EBERHARDT, 15.8.2000)

Subalpine *Kobresia humilis*-Matte. Oberhalb Yengeyar, 2 km östlich Yashpert, 3.840 m, WNW-exponiert.



Photo 6: Montane/subalpine *Juniperus semiglobosa*-*J. turkestanica* steppe forest with *Artemisia brevifolia* on south-east-facing slope. Near Shendioz, 3,540 m. *Juniperus* trees up to 10–14 m in height. (Photo: EBERHARDT, 16.8.2000)

Montaner/subalpiner *Juniperus semiglobosa*-*J. turkestanica*-Offenwald mit *Artemisia brevifolia* in der Krautschicht, bei Shendioz (3.540 m, SE-Exposition). *Juniperus*-Bäume bis 10–14 m hoch

#### 4.3.2 *Juniperus semiglobosa*-*J. turkestanica* steppe forest

Denser steppe forests append spatially and floristically to the montane juniper variants of the *Koeleria cristata*-*Artemisia brevifolia* steppe. These forests, which reach 12–14 m in height and ca. 20% tree cover, are the only habitat in the Batura Valley where mighty trees of *J. turkestanica* occur, alongside with the more widely distributed *J. semiglobosa* (Photo 6). The upper treeline position, presence of *J. turkestanica* and lower abundance of *Artemisia brevifolia* justify an assignment of this formation to the subalpine belt. The shrub layer is mainly composed of the same juniper species and, occasionally, *Spiraea lasiocarpa*, *Ribes himalense* and *Rosa webbiana*. *Juniperus communis* subsp. *alpina* may form a dwarf-shrub layer. *Androsace baltistanica*, *Gentiana tianschanica* and *Draba lanceolata* are diagnostic species among other more widely distributed herbs (*Bupleurum gracillimum*, *Oxytropis humifusa*, *Eritrichium fruticosum*, *Poa sterilis*). The juniper steppe forest is mainly confined to mainly south-east facing slopes in the lower part of the middle section of the Batura Valley (above Shendioz and Yashpert); one small grove occurs south of the middle Batura Glacier. Grazing by sheep, goats and cattle, and during spring and autumn also by yaks, seems rather intense, as indicated by sheep track density, browsing damage in the herb layer and presence of indicator species (e.g. *Plantago gentianoides* subsp. *griffithii* and *Thymus linearis*). However, rejuvenation of the junipers does not seem to be seriously impeded yet. Juvenile junipers are found considerably more abundantly in the forest than in the more open juniper stands.

#### 4.3.3 *Anaphalis nubigena*-*Salix karelinii* scrub

Open scrub of *Salix karelinii*, up to 0.8 to 1 m in height, is found on moraines, in valley side depressions and slopes with higher water availability. On the south-facing slopes, *Salix* scrub is confined to shady microhabitats with additional water provided by throughflow or above-surface flow. *Anaphalis nubigena*-*Salix karelinii* scrub covers considerable areas in the upper Batura Valley north of the glacier (Pupshkargah, lower Wartom Valley) and in the middle and upper valley south of the glacier (Kampire Dior and Sabzeg). Typi-

cal species of the herb layer are *Bistorta affinis*, *Poa attenuata*, *Carex nivalis*, *Epilobium latifolium*, *Astragalus madde-nianus*, *Cicer microphyllum*, *Erigeron acris*, *Calamagrostis stoliczkae*, *Arabis tibetica* and *Dasiphora dryadanthoides*.

Stands south of the glacier accompany the *Salix* krummholz (following unit) along both its lower and upper limits. At the upper limit of the *Anaphalis nubigena*-*Salix karelinii* scrub, the *Salix* shrubs become gradually smaller and colonise preponderantly sheltered relief situations.

#### 4.3.4 *Betula jacquemontii*-*Salix karelinii* krummholz

Dense, often almost impenetrable thickets of *Betula jacquemontii*-*Salix karelinii* krummholz are confined to the



Photo 7: Subalpine *Betula jacquemontii*-*Salix karelinii* krummholz thicket. Zogeplathk, near First Ice Flow, 3,900 m, on ca. 48° inclined, north-facing slope. *Betula* trees up to 9 m in height. (Photo: EBERHARDT, 23.07.1994)

Subalpine *Betula jacquemontii*-*Salix karelinii*-Krummholz. Zogeplathk nahe dem First Ice Flow, 3.900 m, N-Exposition, Hangneigung ca. 48°. *Betula*-Bäume bis zu 9 m hoch

<sup>9)</sup> *Kobresia humilis* (C. A. Mey. ex Trautv.) Sergievsk. (= *K. karakorumensis* Dickoré, as proposed synonym by KUKKONEN 1998). Although this recently described taxon may represent a geographically rather isolated race, extensive additional material, which became known only after its publication, suggests that it cannot be distinguished on morphological grounds from the widespread [Central Asian] *K. humilis*.



north-facing slopes of the middle and lower Batura Valley (Photo 7). They cover comparatively large areas, intersected by side-glaciers, on fine-grained substrates from around 3,420 m, near the First Ice Flow, to ca. 4,300 m. The shrub layer cover ranges between 40 and 90%. *Betula jacquemontii* trees, up to 9 m in height but often smaller and prostrate, accompany *Salix* up to 4,150 m, and solitary specimens of *Sorbus tianschanica* (5–7 m) occur up to 3,870 m. Snow pressure is an important ecological factor, affecting the growth forms of shrubs and trees. The mostly open or very open herb layer is relatively rich in species, and mean species number is substantially higher as compared to the *Anaphalis nubigena*-*Salix karelinii* scrub (22 vs. 13 species). Common herbs are *Hylotelephium ewersii*, *Festuca hartmannii*, *Arenaria neelgherrensis*, *Aegopodium kashmiricum*, *Astragalus tectimundi*, *Dracocephalum nutans*, *Erigeron multiradiatus*, *Bistorta affinis*, *Poa alpina*, *P. pratensis* subsp. *pratensis*, *Pedicularis pectinata*, *Stellaria fontana*<sup>10)</sup>, *Myosotis asiatica* and *Geranium himalayense*. Topsoils display considerable humus accumulation due to relatively high litter production and retarded decomposition.

#### 4.4 Alpine sward and meadow

Alpine vegetation roughly extends between 3,900 and 4,600 m. Considerable areas along the upper Batura Valley are covered by open to fairly closed alpine swards, in which mostly dicotyledonous herbs and dwarf-shrubs dominate. Neither 'typical' alpine turf (dominated by small *Cyperaceae* or grasses) nor communities dominated by dense cushions are common or conspicuous in the alpine belt of the Batura Valley.

##### 4.4.1 *Poa attenuata*-*Epilobium angustifolium* meadow

Alpine meadow or meadow steppe has a considerable proportion of tall forbs (*Epilobium angustifolium*, *Cicer microphyllum*, *Hieracium virosum*) and other, generally wide-spread, species (*Poa attenuata*, *Tanacetum senecionis*). This formation is confined to a small area south of the upper Batura Glacier (Sabzeg). Former grazing of cattle in this area was terminated in the mid-1980s. The meadow stand may thus represent a rare example of an advanced successional stage as compared to the normally intensely grazed alpine swards in the study area.

Habitats of the alpine meadows are stable talus slopes and soils covered at least by some centimetres of scree. Vegetation cover usually does not exceed 50% of the ground.

##### 4.4.2 *Poa attenuata*-*Bistorta affinis* sward

Fairly closed alpine *Poa attenuata*-*Bistorta affinis* sward, with ground cover frequently attaining 75% or more, is widespread on the generally south-facing slopes of the upper Batura Valley near Lupdor and in the Yoksugoz Valley between 4,000 and 4,600 m. Lower cover is reached where micro-lobes, indicating active solifluction, are colonised. Common species include a variety of herbs and grasses such as *Geranium himalayense*, *Arenaria neelgherrensis*, *Rhodiola pamiroalaica*<sup>11)</sup>, *Tanacetum senecionis*, *Erigeron uniflorus*, *Stellaria fontana*, *Tanacetum pyrethroides*, *Silene falconeri*, *Pleurospermum candollei*, *Saxifraga flagellaris* subsp. *stenophylla*, *Potentilla turczaninowiana*, *Waldheimia stoliczkae*, *Draba altaica*, *Carex nivalis*, *Trisetum spicatum* subsp. *himalaicum* and *Poa attenuata*. The often dominating *Bistorta affinis* tolerates strong grazing. The alpine swards are mostly grazed by yaks, but sheep and goats (herded in Guchism) also feed regularly on the lower edge.

##### 4.4.3 *Bistorta affinis*-*Potentilla venusta* cushion sward

The *Bistorta affinis*-*Potentilla venusta* cushion sward occurs towards the upper edge of the former unit, along the upper Wartom Valley, the right side of the lower Yoksugoz Valley, in the Lupdor area, and in places also in the Sabzeg area. This vegetation type comprises more isolated colonies of grasses and herbs, including a somewhat higher proportion of cushion-forming species, and small patches of sward among bare frost rubble. Abundant species are *Potentilla venusta*, *Rhodiola pamiroalaica*, *Carex nivalis*, *Erigeron uniflorus*, *Hylotelephium ewersii*, *Cerastium cerastioides* and *Waldheimia tridactylites*. In a few places only *Erigeron uniflorus*, *Elymus schrenkianus*, *Festuca hartmannii*, *Poa alpina*, *Sibbaldia cuneata*, *Poa pratensis* subsp. *pruinosa* and *Rheum spiciforme* occur.

#### 4.5 Subnival small turf spots, isolated herbs, and cushions

An apparently continuous transition leads from the upper alpine vegetation at 4,600 m to the upper limit of vascular plant growth at, estimatedly, 5,000–5,200 m. Most of the few subnival plant species occur also, and

<sup>10)</sup> H. HARTMANN and others erroneously used the name *Stellaria graminea* L., a widespread Eurosiberian species, for a taxon that was here tentatively identified as *Stellaria fontana* Bunge. However, the taxonomy of *Stellaria* is difficult and probably not fully understood.

<sup>11)</sup> *Rhodiola pamiroalaica* Boriss. (= *R. imbricata* Edgew.) substitutes earlier erroneous records of *R. wallichiana*, which is a different, Central Himalayan species.

often more commonly and vigorously so, in the alpine belt. However, there are probably also a few species specific to or endemic in the subnival belt of the Karakorum Mountains.

#### 4.5.1 *Delphinium brunonianum*-*Waldheimia tridactylites* isolated herbs

The subnival vegetation of the Batura Valley can be regarded as a single formation, which is comprised of isolated, scattered to somewhat aggregating individuals of a small number of species of mainly dicotyledonous vascular plants among expanses of sterile, coarse and mobile rock rubble, bare rock faces and permanent ice and snow. In places, epilithic lichens are common on shaded rocks, but are virtually absent from the vast areas of mobile screes with active cryoturbation and solifluction. Vascular plant species typically occurring in the subnival belt represent very different growth forms. Apart from a few cushion-forming species (*Saxifraga pulvinaria*), there are several surprisingly stout, up to ca. 50 cm high, herbs (*Delphinium brunonianum*, *Carex nivalis*, *Rheum spiciforme*). Some species are distinctly rhizomatous (such as *Lagotis globosa*, which occurs on fine-grained, frost-shattered slate rubble of the upper Yokusgoz Valley) or stoloniferous (*Saxifraga flagellaris* subsp. *stenophylla*, *Waldheimia tridactylites*). Other, probably typical species are *Waldheimia tomentosa*, *Potentilla gelida* subsp. *borissii*, *Draba oreades* and *D. glomerata*. Considerable areas of subnival vegetation were surveyed on the relatively stable and less inclined frost rubble of the upper Wartom Valley. The steep bedrock flanks and unstable talus slopes in most other parts of the Batura Valley at the respective altitudes are, apparently, devoid of vegetation.

#### 4.6 Water surplus vegetation

The water surplus vegetation legend unit comprises a variety of habitat and vegetation types, mostly confined to small areas and including alluvial scrub, rarely forest, the surroundings of flushes, as well as artificially irrigated and cultivated land. Alluvial scrub (*Hippophae rhamnoides*, *Tamarix ramosissima*) occurs locally along the Hunza River section of the study area. Much of the alluvium of the Hunza River, mostly steep terrace edges and riverside gravel, is completely devoid of vegetation, apparently due to extreme river dynamics.

##### 4.6.1 *Tamarix ramosissima* scrub

A single small stand (ca. 400 m<sup>2</sup>) of ca. 2 m high *Tamarix ramosissima* scrub (with *Myricaria germanica* subsp. *alopecuroides*) occurs on the banks of the Hunza River

opposite the Batura Glacier terminus (near junction of the Shimshal link road). Accompanying species were *Cymbopogon jvarancusa* subsp. *olivieri*, *Salsola jacquemontii* and *Perovskia abrotanoides*. Larger *Tamarix* stands were observed along the Hunza River outside the study area, both up- and downstream.

##### 4.6.2 *Hippophae rhamnoides* subsp. *turkestanica* thickets

In some places with restricted spatial extent, *Hippophae rhamnoides* subsp. *turkestanica* forms dense to almost impenetrable thickets reaching up to 1.80 m in height. Shrub cover reaches 60–70%, with *Rosa webbiana* as a common companion. Further associated are grasses and herbs such as *Calamagrostis pseudophragmites*, *Chenopodium botrys*, *Tanacetum baltistanicum* and *Salsola jacquemontii*. The only more substantial *Hippophae* stand is found in the lower Batura Valley north of the glacier (Zakh area, after the vernacular Wakhi name of *Hippophae*). This thicket is obviously affected by seasonal drought and intensely browsed by domestic animals. A few other *Hippophae* stands are mostly too small to show up on the vegetation map.

##### 4.6.3 *Salix pycnostachya* and *S. sericocarpa* groves

Near Vizokpart on the northern side of the Batura Glacier, a small grove of *Salix pycnostachya* and *S. sericocarpa* occurs on level, silty-clayey ground of the valley side depression. Associated with the 10–12 m high trees are a few shrubs (*Rosa webbiana*, *Myricaria elegans*, *Hippophae rhamnoides* subsp. *turkestanica*, *Juniperus semiglobosa*). Apparently due to seasonal flooding in early spring and to heavy grazing during the migration phases of the herds, a herb layer is almost absent or consists of ruderal elements and fragments of grazed turf.

##### 4.6.4 *Populus pamirica* groves

A few dozen individuals of ca. 3 m high *Populus pamirica* trees, occur in a small area on the gravel fan of the Dest Fatma hel Valley, situated in the valley side depression north of the middle Batura Glacier. The poplars grow preferably near streamlets and on intervening gravel bars<sup>12)</sup>. Water is constantly available, although already in early summer the discharge is relatively low. Flooding during springtime may occur, but does apparently not impede tree growth. Some *Betula jacquemontii* trees, more common on the boulder slopes

<sup>12)</sup> In the adjacent Pamir Mountains, *Populus pamirica* constitutes alluvial forests.

of the adjacent flanks, accompany the poplars in the drier eastern part of the fan<sup>13</sup>. Bare gravel is between the trees; shrubs are completely and herbs are almost absent.

#### 4.6.5 *Betula jacquemontii* groves and solitary trees

Bouldery talus slopes north of the Batura Glacier are locally colonised by isolated trees or small groves of *Betula jacquemontii*, almost without any accompanying shrubs or herbs. The trees, up to 10 m high, are commonly multi-trunked. Deformed, angled stems and typical bark damage indicate debris movement and frequent avalanching. The coarse boulder cover impedes evaporation, and most of these *Betula* stands occur below rock outcrops that canalise precipitation and melt water run-off. These 'one-species stands' of birch on mostly south-facing boulder slopes are thus very different from the subalpine *Salix-Betula* krummholz<sup>14</sup>.

#### 4.6.6 *Blysmus compressus* fen and flushes

Small examples of fen and flush vegetation are found, which inhabit flooded or water-logged areas north of the middle Batura Glacier. Just two fens are of larger spatial extent and are included in the map: at the junction of the Shendioz creek with the valley side depression, and downstream alongside the same creek near Yashpert. Water supply is very variable, both seasonally and diurnally. Small-scale mosaics of fen turf and a variety of other community fragments are formed, according to local water supply, salt content, substrate and grazing impact. Common species are *Blysmus compressus*, *Eleocharis quinqueflora*, *Equisetum ramosissimum*, *Plantago depressa*, *Carum carvi* and *Epilobium chitralense*. Similar wetland communities are probably widespread, though often highly fragmented, in the mountains of Central Asia or through the northern hemisphere. Structure and species composition in the Batura Valley must, however, be regarded as accidental (for details see EBERHARDT 2004).

#### 4.6.7 Village pastures

'Village pastures' mostly denote short-grazed turf (2–3 cm high covering up to more than 90% of the ground), where water is sufficiently available throughout the growing season, often through artificial irrigation. High grazing pressure and a comparatively high nutrient status (droppings) are characteristic. Some habitats

are former cultivated fields with silty topsoils. Common species are *Agrostis stolonifera*, *Elymus schrenkianus*, *Potentilla bifurca* subsp. *orientalis*, *Plantago depressa*, *Polygonum rottboelliioides*, *Leontopodium leontopodium*, *Taraxacum* spec., *Carum carvi* and *Malcolmia africana*.

#### 4.6.8 Irrigated fields, gardens and orchards

Artificially irrigated, green cultivated land, usually sharply contrasting with the surrounding desert, is one of the typical landscape features of the Hunza Valley. The relatively small areas suitable for cultivation are subject to considerable change in space and time, judging from the abandonment of some areas following natural disasters or just lack of water and reclamation attempts on others. In the study area, field crops are wheat, potatoes and lentils. Trees lining the irrigation canals or in house-yards and other suitable places are probably all planted, for fruit (apricot, apple and mulberry), timber and lopping (poplars and willows) or shade. North of Passu, a tree nursery has been established by the Aga Khan Rural Support Programme (AKRSP). Most of the cultivated field and garden area is situated within the submontane desert (*Artemisia fragrans-Haloxylon thomsonii* dwarf-scrub).

### 4.7 Non-vegetated and not investigated areas

#### 4.7.1 Permanent ice and snow

The area covered by permanent ice and snow is drawn from the base map (INST. GLACIOL. ACADEMIA SINICA 1978). Its extent was principally confirmed in the field, with the possible exception of small, recently de-glaciated areas around the glacier terminus. Much of the Batura Glacier tongue is covered by rubble and boulders (Photo 1). Isolated seedlings of vascular plants (*Crepis flexuosa*, *Epilobium latifolium*) are rarely found on the supraglacial tills.

#### 4.7.2 Bare rocks, scree and gravel

This mapping unit includes all ice-free areas accessible to direct investigation, but found almost or completely devoid of vegetation. Unvegetated rocks, scree and gravel occupy large areas throughout the altitudinal gradient.

<sup>13</sup> VISSER (1928) mentioned fir (*Abies*) from the same place, but the tree on his photograph was most probably a large juniper.

<sup>14</sup> This ties in with the general impression that the West Himalayan *Betula jacquemontii* occurs both in 'zonal' treeline habitats of the rather moister ranges (e.g. Rakaposhi, Nanga Parbat), in water surplus situations, including alluvial forest of the relatively drier areas and at relatively lower (montane) elevations (e.g. in Chitral, Misgar).

#### 4.7.3 Areas not investigated

The areas not investigated comprise ice-free areas within the confines of the vegetation map that were inaccessible to direct observation due to relief or altitude. For the most part, these areas can safely be expected to be almost or completely devoid of flowering plants, particularly so above 4,600–5,000 m and on steep bedrock outcrops at any elevation.

### 5 Conclusions and discussion

The vegetation map of the Batura Valley depicts the present status of the vegetation in a major glacier valley of the West/Central Karakorum Mountains. Owing to the poor historic botanical record existing for the study area proper, starting with the expedition of P. VISSER in 1925 (DOLK 1929; PAMPANINI 1930), our present first study of the vegetation of the Batura Valley cannot show any significant recent, climate-related or other changes in the vegetation. However, recent and ongoing climate change is suggested by the considerable downwasting of the Batura Glacier since the 1920s that is apparent from photographs published by VISSER (1928). The ice surface seems to have shrunk by some 20–30 m, leaving a presently much higher relief and increased drainage to the lateral moraines.

Distinct vegetation belts are a prominent physiognomic feature of the study area. The vertical zoning of vegetation is strongly affected by aspect (Fig. 2). The vertical shift of vegetation boundaries amounts to at least 200 m of absolute altitude between both main aspects (north and south). On the landscape scale, this pattern is superimposed by peculiarities of the local climate controlled by the Batura Glacier and its debris cover. As heat input over uncovered ice is largely consumed by melting (GOUDIE et al. 1984), air temperature is reduced and humidity increased along the southern fringe of the middle Batura Glacier, where large ice flows uncovered by debris enter the main glacier. These effects are further amplified by shading, cold catabatic winds from the First Ice Flow, and prolonged snow melting in avalanche deposition areas on the footslopes in spring. These climate- and relief-controlled parameters may explain occurrences of *Salix karelinii* and *Betula jacquemontii* krummholz at relatively low altitudes, as compared with the Rakaposhi and Nanga Parbat, where both these species form the upper treeline and a subalpine scrub (TROLL 1939; BRAUN 1996; MIEHE et al. 1996; RICHTER et al. 1999; DICKORÉ a. NÜSSER 2000). The stands on the slopes of the Batura Valley comprise the northernmost, and in the terminology of

WALTER (1954) ‘extra-zonal’, krummholz thickets in the Hunza catchment (EBERHARDT 2004). The area to the north of the Karakorum Main Range is thus probably more pronouncedly arid as has been assumed on the basis of a supra-regional comparison by MIEHE et al. (1996) (EBERHARDT et al. 2006).

Geomorphodynamics is generally very active in the Hunza river valley (GOUDIE et al. 1984). Thus, apart from climatic factors, direct and indirect effects of geomorphodynamics mainly control the distribution of different vegetation types in the Batura Valley. The most prominent direct effect is a high share of unvegetated talus and scree slopes over the entire elevational range of plant life. Other direct effects act on a smaller scale, e.g. the formation of solifluction micro-lobes that is most frequent in the *Bistorta affinis*-dominated vegetation types, or the formation of very long main roots by plants inhabiting creeping screes or talus (i.e. *Lagotis globosa*). Geomorphodynamics generally seems to produce site conditions detrimental to plant growth. The most important indirect effect of geomorphodynamics is the influence on substrate and soil formation, which in turn control water availability (SCHEFFER a. SCHACHTSCHABEL 2002, 220): fine-textured soils provide a higher water storage capacity but evaporation may be enhanced by higher rates of capillary rise. Cover by scree or boulders on the widespread bouldery talus slopes prevent evaporation by shadowing and wind speed reduction near the evaporating surface. In sandy soils evaporation is hampered by reduced capillary rise. In coarser materials in slope positions water availability is generally more affected by throughflow, enhanced or reduced according to local conditions. These differences come into effect in different weather situations and seasons. They may explain, combined with factors of minor importance, e.g. varying germination requirements, the occurrence of such differing vegetation types as, i.e. *Koeleria cristata*-*Artemisia brevifolia* steppe on soils with a high content of fine earth (i.e. the silty tills on the valley flanks) and *Betula jacquemontii* groves in the same elevational range on adjoining bouldery talus slopes on sunny slopes north of the Batura Glacier in the montane and subalpine belts.

The vegetation of the Batura Valley shows a number of interesting phytogeographical features. The study area is evidently situated on the very edge of distribution of juniper steppe forest towards the Central Karakorum. Potentially arboreal junipers are represented by three species (*Juniperus excelsa* subsp. *polycarpus*, *J. semiglobosa*, *J. turkestanica*). All three species have often been confused in literature and are usually summarised under the dubious name of ‘*J. macropoda* M. Bieb.’. Some ambiguity remains as to the identification of



many vegetative individuals<sup>15)</sup> and the exact ecological indication of the individual species. However, the following observations seem to apply to a wider area of the (west and south) Karakorum: *Juniperus semiglobosa* is the relatively most common species of the montane and subalpine belts, whereas the related *J. excelsa* occurs, rarely, at lower altitudes. *Juniperus turkestanica* seems more locally confined to denser, 'optimal' stands of treeline forest. The absolute north-west limit of moist coniferous forest (*Pinus wallichiana* and *Picea smithiana*) in the Karakorum Mountains extends along the ridge of Rakaposhi, approximately 40 km south of the study area (SCHICKHOFF 1995, 2000). Accordingly, and in contrast to the assumption of RICHTER et al. (1999), dark coniferous forests are neither known from, nor to be expected in, the Batura Valley. Towards the north, the next stations of coniferous forest (*Picea schrenkiana*) are then the north slopes of the western Kunlun Shan, ca. 250 km distant from the study area (WÜNDISCH et al. 2003). The record of a fir (*Abies*) from the banks of the Batura Glacier (VISSER 1928) is certainly erroneous; the next confirmed record of *Abies pindrow* is from the Naltar Valley near Gilgit (DUTHIE 1893), ca. 80 km south of the study area. The few additional, deciduous, tree species occurring in the study area are mostly rare and found as isolated individuals or in small groves and on the very edge of their distributions (*Betula jacquemontii*, *Populus pamirica*, *Salix sericocarpa*, *Sorbus tianschanica*); *Populus* and *Salix* are entirely confined to water surplus habitats. Among the relatively few species of taller shrubs, *Salix karelinii* may attain dominance on slopes of the subalpine belt.

With regard to biodiversity conservation, the presence of a number of endemic species or 'microarealophytes' in the study area is to be noted. Some of the species, endemic to the Karakorum or the Upper Indus Basin, such as *Calamagrostis stoliczkae* and *Haloxylon thomsonii*, may even attain considerable significance in the vegetation aspect. *Rhodiola saxifragoides*<sup>16)</sup> is probably the most prominent 'microarealophyte', which is only known from Gilgit and the Hunza Basin. Among the more spatially restricted endemic species are also *Saussurea elliptica* (DICKORÉ 2001), *Saxifraga duthiei*, *Scutellaria paulsenii*, *Tanacetum baltistanicum* and *Tricholepis tibetica*. The high-altitude vegetation in the north-west of the study area (Yoksugoz Valley) is characterised by the Karakorum endemic *Lagotis globosa* and a few rare Pamirian elements (*Oxytropis platonychia*, *Stellaria turkestanica*).

Human impact on the vegetation of the Batura Valley must be considered high in general. The exact sta-

tus of anthropo-zoogenous transformation or the degree of degradation of the vegetation cover is, however, difficult to assess. This is due to the absence of fenced experimental plots or other untouched vegetated areas for comparison. Short-term fencing experiments by KLÖTZLI et al. (1990)<sup>17)</sup> confirmed that the exclusion of grazing animals can lead to considerable increase of vegetation cover and height. Throughout the study area, obvious damage to soil and vegetation through browsing and trampling and a dominance of unpalatable or grazing-resistant plant species are commonly observed (e.g. *Aconogonon tortuosum*, *Astragalus candolleanus*, *Bistorta affinis*, *Thymus linearis*, *Artemisia santolinifolia*). Even the fact that off-farm income possibilities, e.g. tourism, have increased in the last decades, did apparently not lead to a decrease of herd sizes or to a reduction of grazing pressure. A comparison of mean numbers of livestock per family given by PAFFEN et al. (1956) and livestock numbers of the villages Passu and Hussaini of 1998 reveals a considerably higher present stocking level. This is primarily due to the increased number of households owing to population growth, and only secondarily because of increased livestock numbers per family. Precise data are only available for

<sup>16)</sup> *Rhodiola saxifragoides* (Fröd.) H. Ohba. This species was erroneously reported as *R. pachyclados*, which is a different though probably closely related species, apparently confined to Nuristan and the Safed Koh Range on the Pakistani-Afghan border. The type of *R. saxifragoides* was collected in the Hunza Valley, and this species does apparently not occur in or near the Kashmir Basin, as one might wrongly infer from the original description.

<sup>17)</sup> In *Artemisia* steppe of the Boibar Valley, ca. 15 km north of the study area; stands are supposed to be similar to the *Koeleria cristata*-*Artemisia brevifolia* steppe of the Batura Valley.

<sup>18)</sup> Regularly used seasonal settlements on the northern side of the Batura Glacier are Yashpert (used during late spring/early summer), Kükhel and Guchism (both in summer), while Vizokpart and Fatma hel are used irregularly. Shendioz is not used any longer. Lupdor is a former summer settlement recorded in many maps, but no houses are extant. This area is used as pastureland from Guchism for sheep, goats, and particularly for non-lactating yaks. South of the glacier, three hamlets are used regularly during summer: Malugin, Wudmur and Midun. A single stone hut is maintained as a rest place at Garben. In the Yunz Valley, two places (one and three houses) are used in spring and early autumn. Patundas is a high pasture settlement used by shepherds from Ghulkin (south of the KMR), but seems to be used only irregularly. The use of the pastures at Sabzeg (opposite of Guchism) was terminated in the mid-1980s. Cultivated fields were, reportedly, maintained in Yashpert, Shendioz, Fatma hel and Malugin until the mid-1970s, none today.

<sup>15)</sup> To distinguish these juniper species with some certainty, ripe cones are necessary.

Table 1: Change of household numbers and livestock herded in the Batura Valley 1990–1998 (EBERHARDT 2004, modified)

Veränderung der Zahl der Haushalte und des im Batura-Tal weidenden Viehbestands von 1990 bis 1998 (EBERHARDT 2004, verändert).

	1990		1998		change 1990–1998	
	Passu	Hussaini <sup>1)</sup>	Passu	Hussaini <sup>2)</sup>	Passu (abs.)	Passu (%)
Households	70	56	87	70	+17	+24
Sheep	505	320	468	214	–37	–7.3
Goats	1334	618	1547	677	+213	+16.0
Cattle <sup>3)</sup>	323	249	638	47	+315	+97.5
Donkeys	56	1	0	0	–56	–100.0

<sup>1)</sup> Figures from 1990 refer to the livestock of the whole village, of which at least cattle are to the most part herded outside the Batura Valley

<sup>2)</sup> livestock herded in the Batura Valley only, figures for sheep and goats comparable with 1990

<sup>3)</sup> including yaks

Source: 1990: AKRSP, unpubl. (data provided by H. KREUTZMANN, pers. comm. 1997); 1998: EBERHARDT 2004

the period from 1990 to 1998 (Tab. 1). In addition to the stocking rate, livestock mobility has to be considered in order to assess the impact of grazing. Recent socio-economic changes have led to a shortage of experienced agro-pastoral labour. As a result, the complex traditional rotation patterns as described by KREUTZMANN (2000) have begun to simplify, and stocks are increasingly kept near some of the more easily accessible or larger seasonal settlements<sup>18)</sup>. In the long run, the concentration of grazing animals in fewer locations will spatially concentrate, thereby amplifying the detrimental effects of grazing. In many pastoral areas in Asia there has been a change in pastoral management and a general reduction in livestock mobility over the twentieth century. As spatial flexibility is an important factor for making optimal use of the pastoral resources, pasture degradation is associated with the loss of mobility in pastoral systems (HUMPHREY a. SNEATH 1999; HOLZNER a. KRIECHBAUM 2000, 2001).

The ecological status of, and human impact on, the *Juniperus semiglobosa*-*J. turkestanica* forest of the Batura Valley are difficult to assess and controversially discussed in literature. SCHICKHOFF (2002), claiming that the crown cover does not exceed 40% due to the arid conditions, classified the juniper forest of the Batura Valley as relatively unchanged through human activity. The latter conclusion seems to be true only in view of the presently suspended use of wood from these forests. Grazing of domestic stock is, however, considerable, although presently it does not seem to affect juniper rejuvenation. On any scale, the juniper forests of the Batura Valley, and of similar stands in the adjacent Boibar Valley east of Markhun (EBERHARDT 2004), are

the remains of an important natural heritage. The juniper forests of the Karakorum Mountains, and the individual species as such, have to be considered as generally highly endangered and in need of serious conservation efforts.

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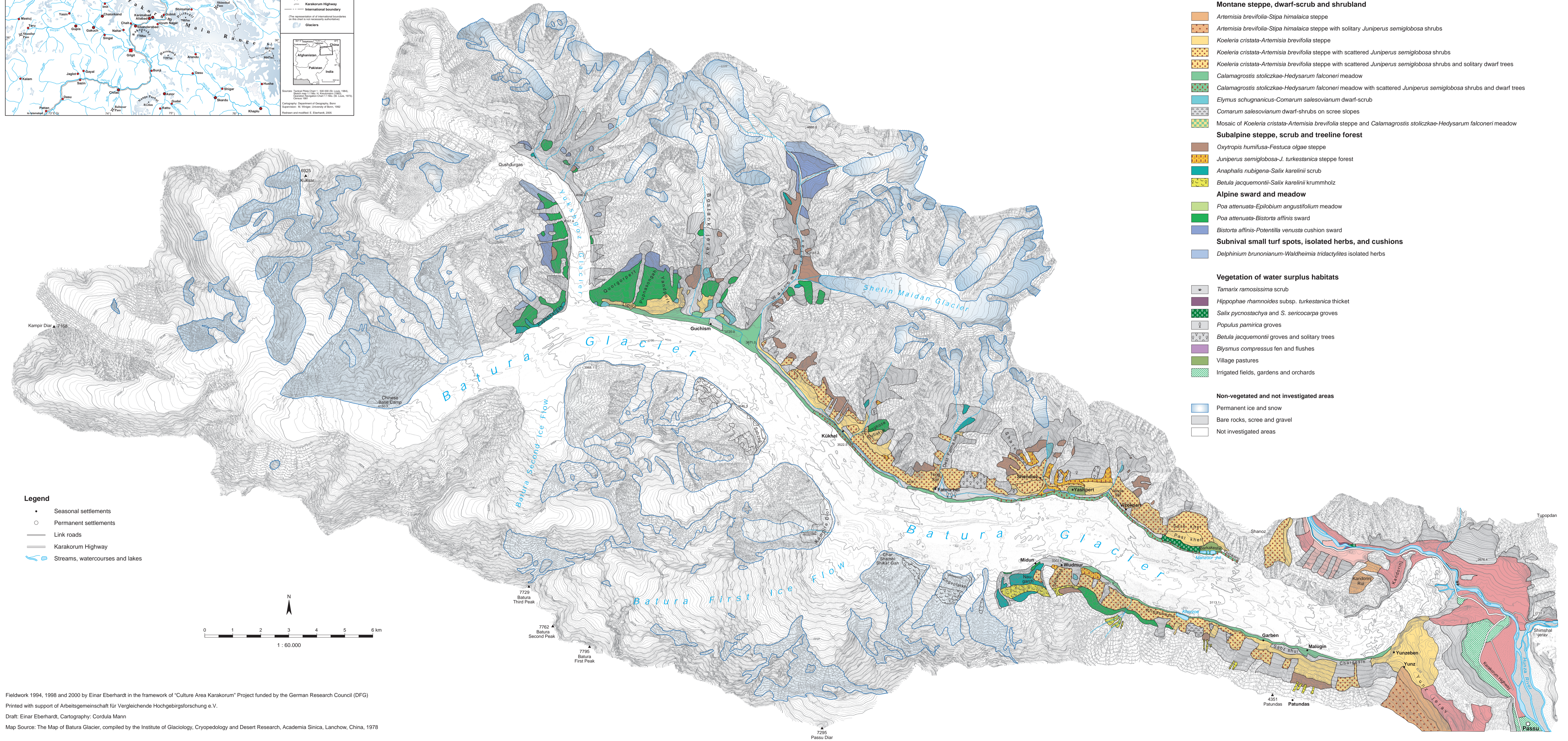
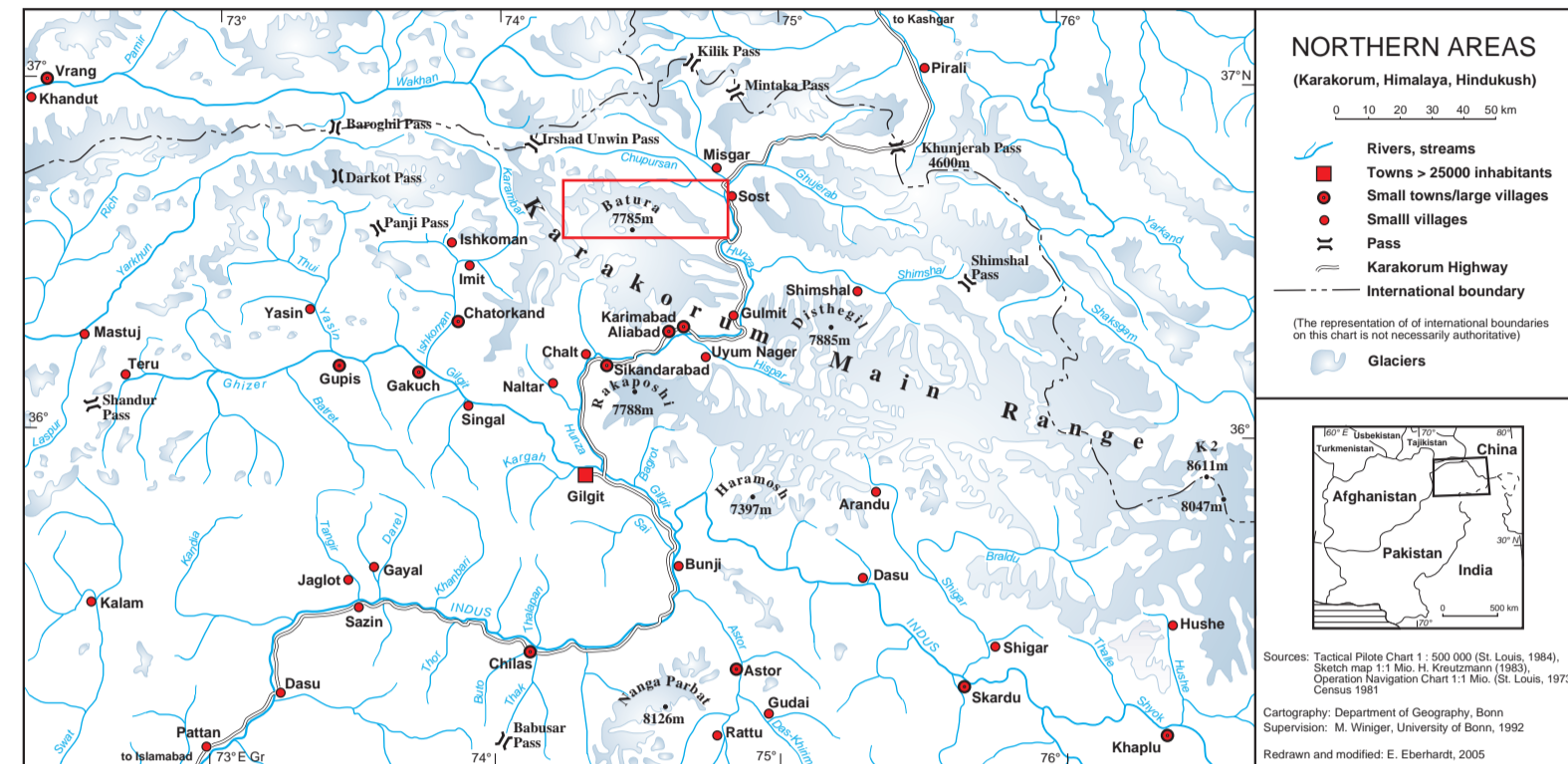
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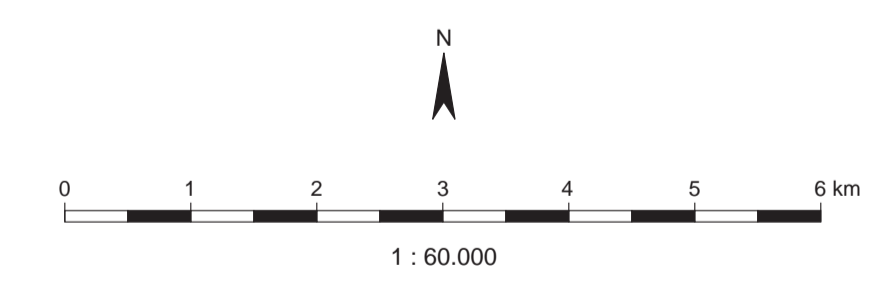


# The Vegetation of the Batura Valley



- Submontane desert and semi-desert**
- Artemisia fragrans-Ephedra intermedia* dwarf-scrub
  - Artemisia brevifolia-Haloxylon thomsonii* dwarf-scrub
- Montane steppe, dwarf-scrub and shrubland**
- Artemisia brevifolia-Stipa himalaica* steppe
  - Artemisia brevifolia-Stipa himalaica* steppe with solitary *Juniperus semiglobosa* shrubs
  - Koeleria cristata-Artemisia brevifolia* steppe
  - Koeleria cristata-Artemisia brevifolia* steppe with scattered *Juniperus semiglobosa* shrubs
  - Koeleria cristata-Artemisia brevifolia* steppe with scattered *Juniperus semiglobosa* shrubs and solitary dwarf trees
  - Calamagrostis stoliczkae-Hedysarum falconeri* meadow
  - Calamagrostis stoliczkae-Hedysarum falconeri* meadow with scattered *Juniperus semiglobosa* shrubs and dwarf trees
  - Elymus schuganicus-Cornarum salesovianum* dwarf-scrub
  - Cornarum salesovianum* dwarf-shrubs on scree slopes
  - Mosaic of *Koeleria cristata-Artemisia brevifolia* steppe and *Calamagrostis stoliczkae-Hedysarum falconeri* meadow
- Subalpine steppe, scrub and treeline forest**
- Oxytropis humifusa-Festuca olgae* steppe
  - Juniperus semiglobosa-J. turkestanica* steppe forest
  - Anaphalis nubigena-Salix karelinii* scrub
  - Betula jacquemonti-Salix karelinii* krummholz
- Alpine sward and meadow**
- Poa attenuata-Epilobium angustifolium* meadow
  - Poa attenuata-Bistorta affinis* sward
  - Bistorta affinis-Potentilla venusta* cushion sward
- Subnival small turf spots, isolated herbs, and cushions**
- Delphinium brunonianum-Waldheimia tridactylites* isolated herbs
- Vegetation of water surplus habitats**
- Tamix ramosissima* scrub
  - Hippophae rhamnoides* subsp. *turkestanica* thicket
  - Salix pycnostachya* and *S. sericocarpa* groves
  - Populus pamirica* groves
  - Betula jacquemonti* groves and solitary trees
  - Blisum compressus* fen and flushes
  - Village pastures
  - Irrigated fields, gardens and orchards
- Non-vegetated and not investigated areas**
- Permanent ice and snow
  - Bare rocks, scree and gravel
  - Not investigated areas

- Legend**
- Seasonal settlements
  - Permanent settlements
  - Link roads
  - Karakoram Highway
  - Streams, watercourses and lakes



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