A TANGLE IN THE TRIANGLE: VEGETATION MAP OF THE EASTERN HINDUKUSH (CHITRAL, NORTHERN PAKISTAN)

With 2 figures, 10 photos and 1 supplement (I)

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Zusammenfassung: Das ‚Dreiecks-Zono-Ökoton' des östlichen Hindukusch: Eine Vegetationskarte von Chitral, Nordpakistan

Das Hochgebirgsgebiet des östlichen Hindukusch mit der Region Chitral liegt am Südrand des holarktischen Florenreiches und lässt sich dem ‚Dreiecks-Zono-Ökoton' im Überschneidungsbereich der irano-turanischen, zentralasiatischen und sino-himalayischen Florenregionen zuordnen. Klimatisch sind diese drei Florenregionen durch saisonal unterschiedliche Niederschlagsregime und -summen differenziert. Während die irano-turanische Region durch vorherrschende Winterregen und die sino-himalayische überwiegend durch monsunale Sommerniederschläge gekennzeichnet ist, umfasst die zentralasiatische Florenregion die permanent trockenen Gebiete. Flora und Vegetation der Talschaft Chitral bilden diese Übergänge im Längsprofil und in den Höhenstufen ab. Der gesamte Höhengradient der Vegetation von Chitral umfasst mehr als 4000 m. Ein ausgeprägter, von Süden nach Norden gerichteter Gradient abnehmender Niederschläge zeigt sich im Vorkommen von Wäldern in den mittleren Höhenstufen der südlichen Täler, während der Norden von Chitral vollständig waldfrei ist. Neben diesen ausgeprägten klimatischen Gradienten besitzen auch anthropo-zoogene Faktoren im Kontext regionaler Landnutzungssysteme und Waldwirtschaft einen bedeutenden, lokal variierenden Einfluss auf die Vegetationsverteilung. Weiterhin tragen historisch-biogeographische Faktoren, die die Verbreitungsmuster zahlreicher Taxa beeinflussen, zum komplexen Vegetationsmuster von Chitral bei.

Der Beitrag liefert eine kommentierte Vegetationskarte, die durch visuelle Interpretation von Fernerkundungsdaten des Sensors Landsat TM in Kombination mit einer umfangreichen Auswertung eigener botanischer Sammlungen und weiterem Herbarmaterial erstellt werden konnte. Feldarbeiten und Analysen der floristischen Datengrundlage ermöglichen eine Diskussion der Höhenstufen und Vegetationstypen auf regionaler Ebene.

Summary: Chitral is the meeting ground of three major climatic, floristic and ecological regions. The eastern Hindukush Mountains delimit the Irano-Turanian (winter rain), Sino-Himalayan (summer rain), and the Central Asiatic (permanently arid) regions. Flora and vegetation mirror the transitional status of the Chitral triangle. Arranged along prominent altitudinal belts, the vegetation of the eastern Hindukush displays complex regional and local patterns. Variation of total humidity and seasonal distribution of precipitation are key factors in determining ecological conditions. The most prominent climate gradient of Chitral is a sharp decrease of precipitation from south to north. This is overlaid and modified by a general trend towards winter precipitation in the west and summer rain in the east. The vegetation of Chitral includes a fairly diverse array of formations ranging from various forest types to desert, along an altitudinal gradient covering more than 4000 m. Besides these prominent climatic gradients, properties and distribution features of vegetation types have been modified, to a locally different extent, by human impact in the context of mixed mountain agriculture and forest exploitation. Furthermore, historical biogeographical constraints obviously had a significant influence on distribution patterns of many individual taxa.

This paper presents an annotated vegetation map, based on a combined approach using remote sensing data (Landsat TM) and floristic data from the authors' own collections and additional herbarium material. Ground checks and analyses of the extensive floristic database render it possible to discuss altitudinal zonation and vegetation types in Chitral on a regional scale.

1 *Introduction and objectives*

Although being predominantly arid, Chitral is an area of great floristic variety (STEWART 1982, 70). Throughout all altitudinal belts, vegetation of the eastern Hindukush apparently mirrors an over-all prominent gradient of decreasing annual precipitation from southeast to northwest. Another obvious characteristic is a conspicuous altitudinal zonation of vegetation spanning more than 4000 m. The eastern Hindukush forms a triangular 'zono-ecotone' (WALTER u. BRECKLE 1991, 24), which delimits the Irano-Turanian, the Sino-Himalayan, and the Central Asiatic floristic regions. The northern boundary of West Himalayan montane coniferous forests runs through southern Chitral, whereas northern Chitral and the inner valley floors are substantially treeless. The subalpine and alpine belts are predominantly covered by thorn-cushion and dwarf-scrub vegetation, which contains many Irano-Turanian and Pamirean floristic elements. From west to east, Chitral comprises a region of considerable species turnover, which, though rather inconspicuous in the vegetation physiognomy, apparently reflects the differences of seasonal rainfall.

However, in analysing properties and distribution of vegetation types, a considerable human impact has also to be taken into account. Over a long period of time, the landscape and vegetation of Chitral have been modified by various impacts of the regional land use system, which combines irrigated crop cultivation and mobile livestock keeping. In different altitudinal belts and subregions, land use and vegetation cover changes become obvious in various forms. Characteristic sequences of vegetation transformation range from the conversion of different dwarf-scrub types to irrigated mountain oases (in the colline and submontane belt) through degradation of forest and scrub communities (in the montane belt) to distinct changes in the floristic composition of steppes and grasslands as a result of pastoral utilization (predominantly in the subalpine and alpine belts).

The objective of this study is to classify vegetation types of Chitral in their regional context and to analyse their status and spatial distribution. The resulting vegetation map (supplement) fills some of the 'white patches' on SCHWEINFURTH's (1957) classic map of Himalayan vegetation, which have not been tackled in the interval of the last decades (see SCHWEINFURTH 1958; 1981; 1992).

Constraints during the mapping process, partly due to the lack of ground checks are discussed. Phytogeographical setting and diversity properties are also sketched, in order to provide baseline data for a high mountain area, which is characterized by a phytogeographical key position and which is remarkable regarding various cultural geographical issues. Increasing population pressure raises questions of sustainable land use and environmental degradation. Accordingly, present status and future prospects of human impact on the vegetation of Chitral are also considered.

2 Material and methods

Vegetation mapping was carried out using a two-fold semi-quantitative approach, based on remote sensing data (Landsat TM 151/35 from 29.8.1993) and ground-checks including an extensive floristic database. Satellite imagery has been geo-referenced according to the Soviet topographical map (Generalni Stab, series 1:100 000, 1974–1985). Standardized procedures of digital image processing have been carried out to obtain a data set, which was optimized for non-numerical visual interpretation and classification of vegetation and land use patterns. Basic characteristics of the image used during visual interpretation were spectral properties, shape, size, pattern, tone, texture, shadows, and associations between observed features, identified objects and topographic site. The heterogeneity – homogeneity ratio of image structures determined the spatial resolution of visual interpretation. Discernible landscape structures and vegetation patterns were digitized on a screen. The interpretation procedure began with an extraction of the topographical and geomorphological landscape features (e.g. ridges, drainage lines), followed by comparative vegetation types and land use structures (e.g. settlements, irrigated fields, forests). Extant areas of montane forests, distributed in a very patchy and disrupted pattern throughout the southern parts of the mapped area, were mostly directly digitized according to their spectral signatures. Ground-checks, field notes, sketch maps, photographic documentation and an evaluation of literature were incorporated during this step.

Classification and delimitation of vegetation types were mainly based on original floristic data from our own field studies, including extensive specimen collections, related literature records and herbarium material. These data were assembled in the 'Flora Karakorumensis' database which then held approximately 10,500 relevant records for the study area. Based on a regionalization of Chitral and adjoining areas, the related altitudinal information was directly converted to the hypsozonal classification of vegetation. The altitudinal zonation of vegetation could thus be identified, being of a prominent nature throughout the area. Due to the general paucity of phytomass and related low spectral differentiation between vegetation types, these, in turn, are scarcely discernible on satellite imagery, except for the south of the mapped area. Local altitudinal gradients were examined in order to refine this extrapolation for the widespread steppe and desert areas of northern Chitral.

3 Study area

3.1 Location and accessibility

Chitral comprises the northernmost district of Pakistan's North-West Frontier Province (N.W.F.P.), bordering the provinces of Kunar (Nuristan) and Badakhshan of Afghanistan to the west and north. The narrow strip of the Wakhan Corridor separates Chitral from Tadjikistan to the north. The Northern Areas of Pakistan with the Ghizer district adjoin Chitral to the east, and the western part of Kohistan with the Dir and Swat

a)

b)

Photo 1: Lowari Pass (3122 m), the most important transit route between Chitral and the lowlands of Pakistan. The slopes are covered with moist montane coniferous forests, dominated by *Cedrus deodara* and *Pinus wallichiana*; Photo a) oblique aerial view taken during flight Chitral-Peshawar, view towards south (2.8.1997, M. NÜSSER); Photo b) taken from 3290 m, above Lowari Pass, view towards north (12.6.1997, M. NÜSSER)

Lowari-Pass (3122 m): wichtigste Verbindungsroute zwischen der Talschaft Chitral und dem pakistanischen Tiefland. Auf den Hängen sind feuchte montane Koniferenwälder (*Cedrus deodara, Pinus wallichiana*) erkennbar. Photo a) Schrägluftaufnahme in südliche Richtung (2.8.1997); Photo b) Blickrichtung Nord, Standort 3290 m, oberhalb Lowari-Pass (12.6.1997)

regions border to the southeast (Fig. 1).[1)] Important passes linking Chitral with the adjoining areas are Lowari (3122 m, Photo 1) in the southern, Dorah (4554 m) in the western, and Baroghil (3804 m) in the north-eastern corner of the roughly triangular shaped Chitral

[1)] Administrative subdivisions of Chitral District, aligned to some of the major valley sections and tributaries are the 'Tahsils' of Drosh and Chitral in the southern part and those of Lutkho, Mulkho, Turkho and Mastuj in the western, northern and eastern parts of the valley system.

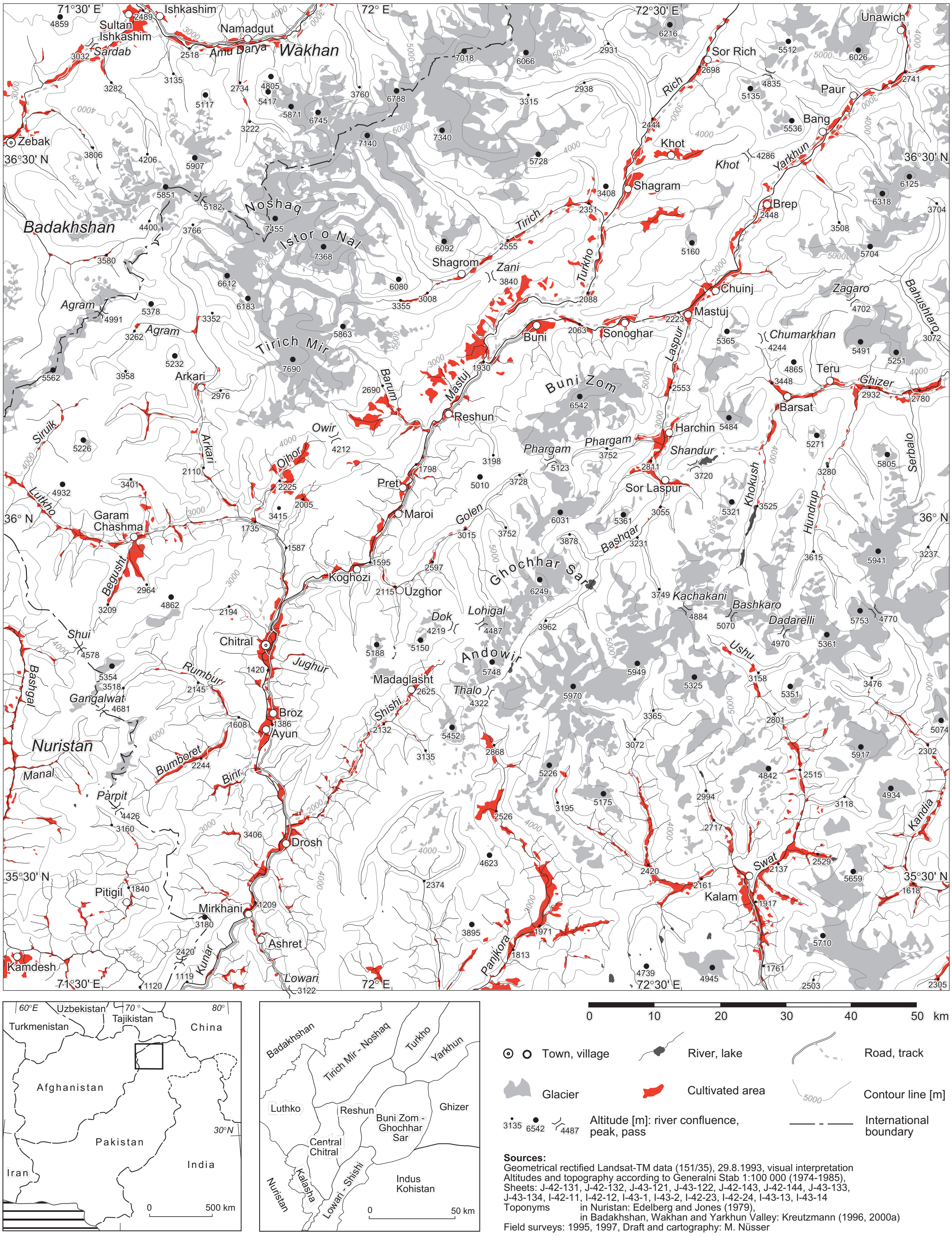

Fig. 1: Map of Chitral and adjacent areas in the eastern Hindukush

Karte von Chitral und angrenzenden Gebieten im östlichen Hindukusch

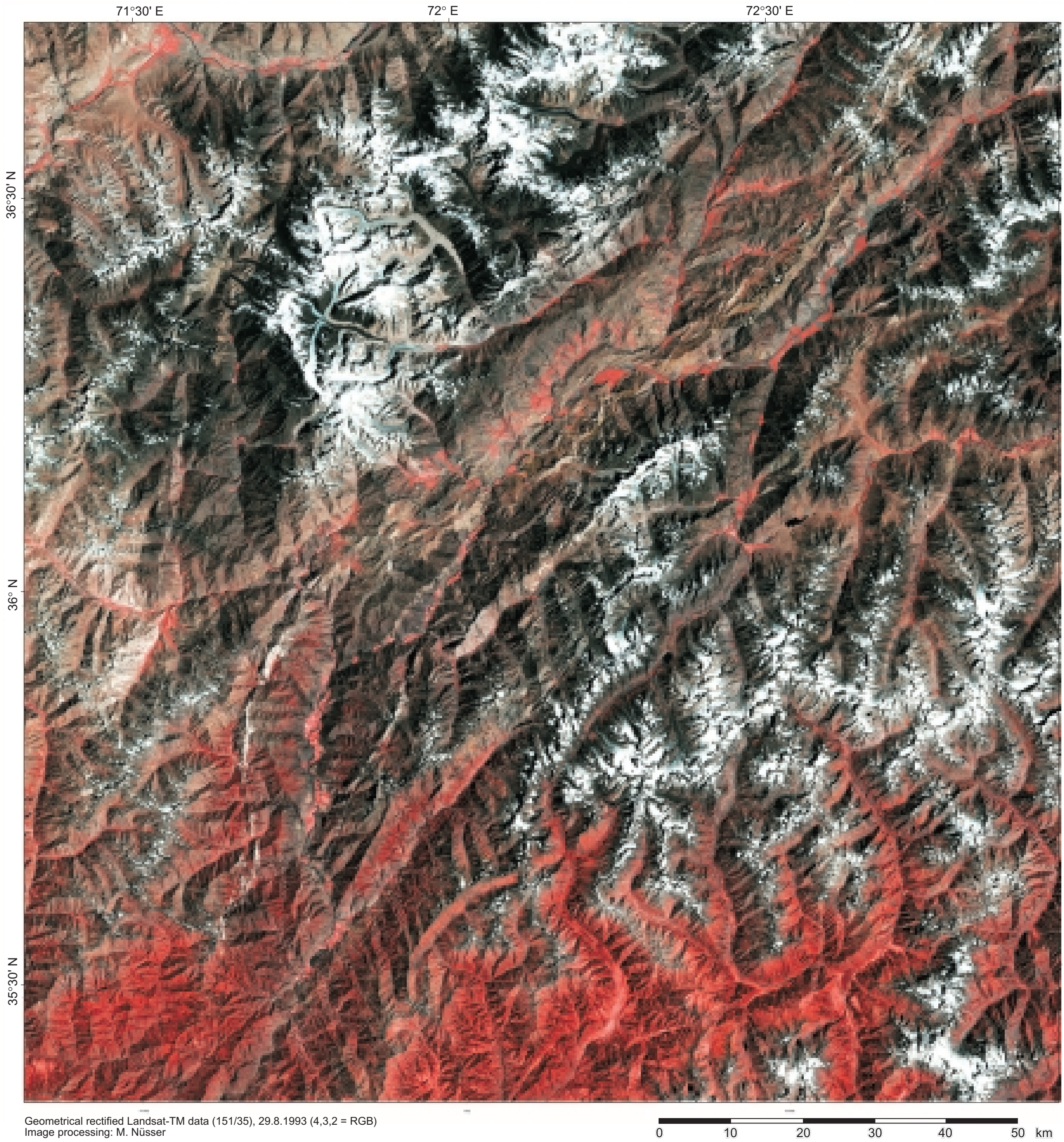

Fig. 2: Geo-referenced colour composite of a Landsat TM image from Chitral and adjacent areas in the eastern Hindukush (151/35, 29.8.1993)

Georeferenzierte Farbkomposite eines Landsat TM-Bildes von Chitral und angrenzenden Gebieten im östlichen Hindukusch (29.8.1993)

valley system, and Shandur (3720 m) to the east. Due to the closure of international borders since the early 1980s Chitral has lost its earlier key position as a transit corridor in the network of trade routes between Central and South Asia.[2)] Thus, the economic importance of the Hindukush passes of Dorah and Baroghil, leading to Afghan territory declined. To the present day the peripheral mountain region is characterized by a low grade of accessibility for motorized transport, since the only road to Peshawar (about 400 km to the south) is impassable between November and May because Lowari Pass remains snowbound. Since colonial times the route via the Laspur Valley and the Shandur Pass between Chitral and Gilgit played an important role as an alternative trade and communication line (General Staff India 1928, 289–291). Until the road between Chitral and Mastuj was completed in the end 1940s, the route over the Phargam Pass (5123 m) between the Golen and Phargam Valleys was used regularly between mid-July and mid-September.

3.2 Orography and geology

The predominantly NE-SW orientated Chitral Valley constitutes a major drainage system between the Hindukush and the Northwest Himalayas. Drainage of Chitral is completely towards the Kabul River, a major western tributary of the Indus. The valley floor of the main river, termed Kunar in lower, Mastuj in middle, and Yarkhun in its upper portion, extends between 1000 and 2800 m along a distance of approximately 300 km. The Lowari Range to the southeast divides drainage towards the Swat River, another tributary of the Kabul River, whereas the Shandur Pass and the ridges east of the Yarkhun Valley (often referred to as Hindu Raj) divide Chitral from the Gilgit river basin, a direct tributary of the Indus. The mountains along the northern and western border of Chitral, north of the Baroghil Pass and west of the Dorah Pass, form part of the main continental divide towards the interior Amu Darya (Oxus River) drainage system. The Baroghil Pass area also marks the junction between the major orographical systems of the Pamirs to the north, the Karakorum to the east, and the Hindukush to the west. The Lowari Range and the border areas towards the Afghan Kunar province in southern Chitral (Kalasha or Kafiristan) constitute a western extension of the High Himalayas. Towards all sides except the southwest, the main Chitral Valley is surrounded by high mountains, the most prominent of which being Tirich Mir (7690 m, Photo 2) and Noshaq (7455 m) on the Afghan border, the Buni Zom Massif (6542 m) towards the Gilgit border, and Ghochhar Sar (6249 m) towards the upper Swat Valley in Kohistan (Fig. 1).

The study area is part of the plate boundary system comprising the western fringe of the collision zone between the Indian and Asian plates and the volcanic Kohistan island-arc-batholith sandwiched between the continental plates. Geological maps by SEARLE (1991), SEARLE a. KHAN (1996), HILDEBRAND et al. (2000) and ZANCHI et al. (2000) depict the plate boundaries between the northern margin of the Kohistan Terrane to the south and the highly deformed southern rim of Eurasia to the north. Major fault systems align to the orography of the study area. The most prominent geological and tectonic structures are clearly discernible on satellite imagery (Fig. 2). The Shyok (or Northern) Suture Zone marks the late Cretaceous closure of a back-arc basin and separates rocks of the Kohistan island-arc from the Karakorum (Asian) Plate. This thrust fault can be traced from the Drosh area along the Shishi River across to the Laspur River. It contains a mélange of marine sedimentary rocks, which accommodate small blocks of serpentinites (SEARLE 1991, 88). The Reshun Fault separates slates, associated greenschists and a characteristic band of early-mid-Cretaceous limestones of the Karakorum Southern Metamorphic Belt from Devonian limestones, dolomites and quartzites of the Karakorum Northern Sedimentary Belt (SEARLE 1991; HILDEBRAND et al. 2000). The Reshun Formation, which contains red shales, conglomerates and limestones comprises the youngest sedimentary sequence. These late Cretaceous to early Tertiary rocks are interpreted as a post-collision continental Molasse sequence, deposited after closure of the Shyok Suture Zone (SEARLE 1991, 97). The rocks of the Hindukush Terrane in the northwestern part of the study area include partly metamorphosed late Palaeozoic to Mesozoic sedimentary rocks, which were intruded by the mid-Cretaceous Tirich Mir Pluton and leucogranite domes (e.g. Garam Chashma Pluton). A narrow belt of mantle peridotites, amphibolites, metagabbros and gneisses characterize the Tirich Boundary Zone, which represents another suture zone remnant (ZANCHI et al. 2000).

Research on the quaternary landscape evolution in Chitral mainly focussed on the extent of the pleistocene glaciation. Quaternary moraines and glacio-fluvial sediments are widespread, and loess and limnites are more locally distributed in Chitral. Concentrating on the sequence and geomorphological setting of valley sediments, HASERODT (1989) and KAMP (1999) present interpretations and maps regarding timing and style of late quaternary glaciation. The soils in the dry valleys

[2] The persisting strategic interest in the region started during colonial times with the 'Great Game' between the empires of British India and Russia at the end of the 19th century; continued with the Soviet invasion in Afghanistan (1979–1989) during the Cold War period; and lasts until the present day with the ongoing civil war and political instability in Afghanistan. Historical aspects of colonial politics and trade relations have been analysed by KREUTZMANN (1996; 1998) and recent political and socio-economic developments in the adjacent Wakhan Corridor are discussed by KREUTZMANN (2000a).

a)

b)

Photo 2: Tirich Mir (7690 m), the highest mountain of the Hindukush and its southern declivity. Photos taken from 4450 m, above Owir Pass. Photo a) view north towards summit of Tirich Mir; the alpine belt displays arid conditions (18.8.1997, M. Nüsser); Photo b) view towards east, the broad montane belt is covered by steppe and dwarf-scrub, which contain characteristic Irano-Turanian and Pamirean floristic elements, sharply delimited cultivated areas in the Owir Valley on the left side; Buni Zom group (6542 m) in the background (18.8.1997, M. Nüsser)

Südabdachung des Tirich Mir (7690 m), der höchsten Erhebung des Hindukusch. (Standort 4450 m, oberhalb Owir Pass, 18.8.1997). Photo a) Blickrichtung Nord, aride Bedingungen in der alpinen Stufe; Photo b) Blickrichtung Ost, die weitflächigen Steppen der montanen Höhenstufe sind durch charakteristische irano-turanische und pamirische Florenelemente gekennzeichnet, scharf begrenztes Kulturland im Owir-Tal im linken Bildbereich, die Buni Zom-Gruppe (6542 m) im Hintergrund

of Chitral can be characterized as Regosols, whereas at higher altitudes (e.g. in the areas of Shandur and Zani Passes) the soils can be classified as Ochric Cambisols and Leptosols (Peer 2000; Peer et al. in press).

3.3 Climate

The climate setting of the eastern Hindukush is characterized by the transitional position between the humid monsoon regime along the southern declivity of the Himalayas, the semiarid winter-rain conditions of Southwest Asia and arid Central Asia. A steep south – north gradient of decreasing annual precipitation, which characterizes the mountain belts of northern Pakistan is modified by the orographic structure and seasonally alternating circulation systems (REIMERS 1992; WEIERS 1995; 1998). The horizontal differentiation is overlaid by pronounced vertical climatic gradients (MIEHE et al. 1996), which range from the arid valley floors to humid nival climates within a short distance. Southern Chitral receives higher amounts of summer rainfall from monsoonal depressions. Central and northern Chitral show a more arid regime that is influenced by winter precipitation from western disturbances. Data from climatic stations compiled in the Climatic Diagram Map of High Asia (MIEHE et al. 2001) may be used for a rough climatic regionalization of the eastern Hindukush and adjacent regions. The climate of Asmar in Nuristan (880 m, mean annual temperature: 19.9 °C, mean annual precipitation: 552 mm) offers a pronounced winter maximum of precipitation, and is apparently sufficient to support submontane and montane forests. The same holds true for Drosh in southern Chitral (1465 m, mean annual temperature: 17.5 °C, mean annual precipitation: 640 mm, REIMERS 1992). Increasing monsoonal influence, i.e. distinct summer maxima of precipitation, becomes obvious in the southern part of the mapped area. Kalam / Swat (2290 m, 10.8 °C) receives 905 mm of precipitation annually; Malakand (800 m, located south outside the mapped area, 20.1 °C, 865 mm) demonstrates an even more conspicuous summer maximum of precipitation. Ishkashim / Badakhshan (2620 m, 5.2 °C) on the other hand, receives only 125 mm of mean annual precipitation and displays the pronounced aridity of the Amu Darya Valley. Located in the transition zone between the arid valleys to the north and the humid south, Chitral Town (1490 m, 15.9 °C, 441 mm) still offers a notable maximum of winter precipitation.

3.4 Regionalization of Chitral and adjacent areas

The political borders of Chitral and adjacent areas were largely also employed for recording plant distribution (DICKORÉ 1995). In order possibly to identify distinct climatic, vegetation or phytogeographical regions, Chitral is here further divided into nine subregions, comprising its major massifs, drainage systems and valley sections, which intentionally comprise fairly homogenous landscape units (Fig. 1, inset):

- Lowari – Shishi includes the northern declivity of Lowari Pass (3122 m), the lowest portions of the main valley adjacent to the Afghan border, and the Shishi Valley east of the Kunar River. The Lohigal (4487 m) and Dok (4219 m) Passes connect with tributaries of the upper Golen Valley.
- Kalasha[3] consists of the Rumbur, Bumboret, Birir Valleys and all tributaries west of the lower Kunar River. The Parpit and Gangalwat Passes connect with Nuristan.
- Central Chitral comprises the main Kunar Valley and the lower sections of the tributaries between Drosh and Koghozi (with Birmoghlasht and Chitral Gol). It further includes the Ojhor Valley leading to the Owir Pass (4212 m) south of Tirich Mir.
- Lutkho, in western Chitral, consists of the Lutkho Valley, leading to the Dorah Pass (4554 m, outside the mapped area) and the Arkari Valley between Tirich Mir and the adjacent areas of eastern Badakhshan.
- Reshun includes the main Mastuj Valley between Koghozi and Sonoghar together with the western section of the Golen Valley in the south. The Owir (4212 m) and Zani (3840 m) Passes connect the area to the valleys of the Tirich Mir Massif towards the northwest.
- Tirich Mir – Noshaq comprises the central section of the main Hindukush Range, respectively its largest and highest mountain massif, bordering the Wakhan Corridor to the northwest. It contains the summits of Tirich Mir (7690 m), Noshaq (7455 m) and Istor-o-Nal (7368 m) together with the Tirich Valley and the upper portion of the Barum Valley.
- Turkho encompasses the Turkho and Rich Valleys which form a major drainage system from the north between the Tirich Mir – Noshaq Massifs and the Yarkhun Valley.
- Yarkhun consists of the upper section of the main Yarkhun Valley, leading to the Baroghil Pass (3804 m, outside the mapped area), which connects the northernmost portion of Chitral with the Wakhan Corridor.
- Buni Zom – Ghochhar Sar comprises the second highest mountain massif of the study area in eastern Chitral bordering Ghizer and Swat / Indus-Kohistan. It includes the Laspur Valley with the high tributaries of Phargam and Bashqar and the Shandur

[3] Historical sources refer to this area as Kafiristan (e.g. ROBERTSON 1894; 1896; VOIGT 1933).

Pass (3720 m) leading to Ghizer / Gilgit in the east. The upper Golen Valley drains the southwestern flank of Buni Zom (6542 m) and the western edge of Ghochhar Sar (6249 m).

The mapped area further incorporates fractions of neighbouring Afghan Nuristan (Kunar Province), northeastern Badakhshan to the west, and Wakhan to the north. The valleys of Indus-Kohistan, draining directly to the Indus River (Panjkora / Dir, Swat, and Kandia), append to the south, and the upper Ghizer Valley, respectively the upper section of the Gilgit River, to the east.

4 *Flora and vegetation*

4.1 Botanical exploration

Vegetation mapping strongly depends on a detailed and sound floristic record, which across the expanses of Central Asia is still fragmentary or controversial in many areas. Notable recent national and international biotaxonomic efforts in the region include FLORA IRANICA, FLORA OF PAKISTAN, FLORA OF CHINA, PLANTAE ASIAE CENTRALIS, FLORA TADZHIKISTANA. Regarding the flora of Chitral and adjoining areas, knowledge seems still poor and patchy as compared to the size and biogeographical significance of the study area.

Early botanical exploration of Chitral and adjoining Nuristan, as summarized by STEWART (1982), dates back to the 'Great Game' period of colonial times. It was initially linked to British border operations, particularly the 'Gilgit Mission' (LOCKHART a. WOODTHORPE 1889, 224–262), during which G. M. J. GILES was the first[4] to collect in Chitral (1884–1885), and the 'Chitral Relief Expedition' (DUTHIE 1898; YOUNGHUSBAND a. YOUNGHUSBAND 1895). F. E. YOUNGHUSBAND, W. GATACRE, S. A. HARRISS, and S. M. TOPPIN are among these early explorers.[5] The 'German Hindukush Expedition 1935' examined forest distribution (KERSTAN 1937), grain crop varieties (ROEMER u. VON ROSENSTIEL 1937) and aspects of land use (SCHEIBE 1937) in Chitral and Nuristan. Only preliminary identifications of the botanical collections, mainly made by G. KERSTAN, have been published (HAECKEL u. TROLL 1938).[6] As a member of a Norwegian mountaineering expedition, WENDELBO (1952) presents a detailed account on flora and vegetation of the Barum Valley, south of Tirich Mir.[7] During the era of R. R. STEWART, from the 1950s onwards, exploration by collectors from Pakistan also starts, with important collections made by HASSAN-UD-DIN, I. I. CHAUDHRI, M. A. SIDDIQI, A. RAHMAN BEG, and others; CHAUDHRI (1957) presents a first overview of the flora of Chitral.[8] In 1958, J. D. A. STAINTON and S. A. BOWES LYON did extensive collecting in Chitral, but no list was published.[9] PODLECH u. ANDERS (1977)[10] and HUSS (1978)[11] provided baseline information on flora and vegetation of the Wakhan. No consistent information is available for the rest of Badakhshan, whereas Nuristan was further collected by L. EDELBERG[12], D. PODLECH, and others. Japanese expeditions, from 1957 onward covered the flora and vegetation of Swat / Indus-Kohistan and Ghizer (KITAMURA 1964; OGINO et al. 1964).[13] Swat was also dealt with by a check list of STEWART (1967).[14] Contemporary identifications of most of these collections from Afghanistan and Pakistan, and of numerous other and more recent ones were incorporated into the monumental FLORA IRANICA and FLORA OF PAKISTAN; and at best knowledge also into the present study.[15]

4.2 Classification and distribution of vegetation

SCHWEINFURTH (1957) combined scattered information based on previous investigations, including travel reports of British officers from Chitral (e.g. DURAND 1894; OTTLEY 1936; SCHOMBERG 1934; 1936a,b) into

[4] He was apparently only preceded by W. GRIFFITH during the 1840s who explored Afghanistan and part of today's Pakistan. GRIFFITH's collections are though largely unlocalized.

[5] Specimens are located at the Royal Botanic Gardens Kew (K), Calcutta (CAL), and several other institutions.

[6] Specimens are at Halle (HAL).

[7] Specimens are at Oslo (O), duplicates at K.

[8] Specimens are at Rawalpindi (RAW), duplicates at K and many other Herbaria.

[9] Specimens are located in the Natural History Museum, London (BM), with duplicates distributed to Edinburgh (E), K, and various other institutions.

[10] Specimens are at Munich (M) and Vienna (W).

[11] Specimens are at Graz (GZU).

[12] Specimens are at W.

[13] Material preserved mostly at Kyoto (KYO).

[14] Specimens are at K, Karachi (KUH), Rawalpindi (RAW), and several other herbaria.

[15] Including material collected by the authors and / or historic collections in Berlin (B), Göttingen (GOET), Zurich (Z), and many of the above herbaria. Specimens collected by J. P. Gruber, A. Millinger and T. Peer of Salzburg University were also examined. See online database and distribution maps at http://www.bot.sbg.ac.at/pakistan/.

a consistent vegetation map of the Himalayas. However, due to its scale this benchmark map provides little differentiation of the extensive areas of 'alpine steppe' in the north and leaves blank considerable portions of the study area. HASERODT (1980) provides a vegetation transect of Chitral in diagram form.

To the east of Chitral, the unparalleled vegetation map of Nanga Parbat (TROLL 1939) serves for comparison.[16] Following TROLL's example, the vegetation map of the Kaghan Valley (SCHICKHOFF 1993; 1994), and related works from the Hunza-Karakorum (PAFFEN et al. 1956; BRAUN 1996) provide further information from adjacent areas. DICKORÉ a. MIEHE (2002) investigate altitudinal diversity properties of the Karakorum divide. A physiognomic approach to the vegetation zonation of a similar transect is given by RICHTER et al. (1999). To the west, the vegetation of eastern Afghanistan is described and mapped by FREITAG (1971a,b; 1982).[17]

Local studies cover the *Quercus baloot* forest of Chitral and Swat (BEG a. KHAN 1980; 1984) and the vegetation of scree slopes in Chitral Gol (BEG a. BAKHSH 1974). Working plans for Chitral forests and range management surveys have been carried out by the Pakistan Forest Institute (e.g. AYAZ 1965; KHAN a. KHAN 1980; SHEIKH a. KHAN 1983).

4.3 Mapping units (Supplement I)

(1) Colline belt

The colline belt comprises the warm-temperate zone of the valley floors and adjacent lower slopes. Except for the southernmost localities in Nuristan, southern Chitral, Dir, Swat and Indus-Kohistan, the colline belt is arid.[18] Closed forests are naturally absent in the north, apart from alluvial *Tamarix*, *Elaeagnus*, *Salix* or *Populus* groves or plantations within the irrigated and cultivated areas. The colline belt shows a considerable increase of its upper limit from 2100 m in the south to about 2400 m in the north. This is, however, distinctly less than the increase of the effective lower valley floor from slightly above 1000 m to above 2500 m in the north. All vegetation types of the colline belt are used as winter pastures.

(1.1) Subhumid scrub

Characteristic species: *Dodonaea viscosa, Indigofera heterantha, Monotheca buxifolia, Phacelurus speciosus, Psoralea drupacea, Quercus incana, Zizyphus jujuba*

The natural vegetation of the comparatively moist southern valleys is largely removed by wood-cutting and irrigated cultivation, or highly degraded through grazing. Remaining examples of this vegetation type resemble the 'subtropical thorn steppe' in the sense of SCHWEINFURTH (1957). This is apparently a replacement community of thermophilous broad-leaved and *Pinus roxburghii* forests on the northwestern margin of their distribution. The moist thermophilous forest comprises a very characteristic outer West Himalayan formation. The vegetation type is originally relatively rich in tree and shrub species, but under the present utilization mostly degraded, depauperate or reduced to single trees or minute patches of forest vegetation. Badlands covered by almost monospecific stands of *Dodonaea viscosa* represent extreme stages of degradation. Along steep valley and gorge sections (Lower Kunar Valley), *Quercus baloot* and other submontane species (*Prunus cornuta*), descend into the colline belt. A certain west – east gradient is also apparent. *Monotheca buxifolia* (= *Reptonia buxifolia*) characterizes the Afghan fraction of the area. *Quercus incana* and an increasing proportion of Himalayan species is found from Dir and Swat eastwards. However, the small, isolated, and degraded representations of the semihumid colline belt do not allow a further distinction as different mapping units.

(1.2) Arid desert scrub

Characteristic species: *Artemisia fragrans, Haloxylon griffithii*, *Haplophyllum dubium*, *Olea cuspidata*, *Phagnalon acuminatum*, *Piptatherum vicarium*, *Pistacia atlantica* subsp. *cabulica*, *Pistacia khinjuk*, *Pulicaria salviaefolia*

The dry colline belt of the main valley floors of Chitral and lower Wakhan is a rather uniform and species-poor formation of desert scrub and occasional small desert trees (*Pistacia*). *Haloxylon griffithii* and *Pulicaria salviaefolia*, the latter usually occurring on the upper edge of the colline belt, extend into the Turkho and Yarkhun Valleys to an altitude of approximately 2400 m. Besides many widespread and common taxa, including scattered small trees of *Pistacia atlantica* subsp. *cabulica* and *P. khinjuk* in fissures of rock outcrops, the arid colline belt of the main Chitral Valley seems to be characterized by a few endemics (*Bupleurum gilesii)* and occasional eastern outposts of West Pamirean and Irano-Turanian elements (*Gontscharovia popovii*, *Celtis*

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[16] For taxonomy see DICKORÉ a. NÜSSER (2000).

[17] BRECKLE (1971; 1975; 1988), BRECKLE u. FREY (1974) and FREY u. PROBST (1978; 1979; 1983a) provide further transects and vegetation maps of the central Hindukush. Investigations into the regional ecology and vegetation patterns of Nuristan and adjacent Kafiristan are delivered by KERSTAN (1937), EDELBERG a. JONES (1979), and FREY u. PROBST (1982; 1983b). The forests of Nuristan are described by FISCHER (1970), RATHJENS (1974) and GILLI (1977).

[18] KHAN (1991) delivers phytosociological data for the dry valley floors of the colline belt.

Photo 3: Open conifer forest near the northern limit of forest distribution east above Chitral Town. Forest belt mostly composed of *Pinus gerardiana*, with *Cedrus deodara* and *Pinus wallichiana* towards the upper edge. Logging trails from the forests are visible below the stands. View from 2580 m, Birmoghlasht, towards east (28.8.1995, M. NÜSSER)

Offener Koniferenwaldgürtel im Bereich der nördlichen Grenze der Waldverbreitung östlich des Ortes Chitral. Im unteren Bereich *Pinus gerardiana,* darüber *Cedrus deodara* und *Pinus wallichiana.* Unterhalb der Waldbestände sind Schleifbahnen zu erkennen. Standort 2580 m, Birmoghlasht, Blickrichtung Ost (28.8.1995)

caucasica). Accordingly, the arid colline belt of the main Chitral Valley seems to be more closely related to similar formations of the eastern Irano-Turanian region from Badakhshan, than to that of the Gilgit-Indus basin. Minute fractions of the study area (Ghizer and Kandia Valleys) are characterized by *Haloxylon thomsonii* and *Haplophyllum gilesii*, vicariant endemics of the upper Indus Valley.

(2) Submontane belt

The submontane belt shows a slight increase of its absolute upper limit from 2600 m in the south to 2800–2900 m in the north. In the same direction, a substantial change of vegetation character is obvious, from forest to scrub, 'steppe'[19] and desert steppe, occasionally with tree groves. The submontane belt is comparatively rich in herbaceous and shrubby species, which represent a transition from dominant (inner) West Himalayan elements in the south to Irano-Turanian and West Pamirean elements in the north. All vegetation types of the submontane belt are modified by pastoral utilization.

(2.1) Subhumid sclerophyllous oak forest

Characteristic species: *Dianthus khirghizicus*, *Diospyros lotus*, *Parrotiopsis jacquemontiana*, *Piptatherum vicarium*, *Quercus baloot*, *Tricholaser ovatilobum*, *Viburnum cotinifolium*

Evergreen sclerophyllous oak forest of *Quercus baloot* is a conspicuous and characteristic vegetation type on the lower edge of the submontane belt in East Afghanistan and the West Himalayas. The rather diverse companion flora, which also contains a number of spring therophytes and geophytes, is poorly understood (BEG a. KHAN 1980). *Diospyros lotus* and *Parrotiopsis jacquemontiana*, the latter a characteristic companion of *Cedrus* further east, are apparently confined to the south slopes of Nuristan, lowermost Chitral, Dir and Swat. The altitudinal distribution of *Quercus baloot* in Chitral extends from below 1250 m south of Mirkani to 1300–1850 m on northern aspects in the extreme south. On south-facing slopes, altitudes between 1900 and 2350 m (HASERODT 1980; 1989), occasionally up to 2500 m are occupied by *Qu. baloot* woodlands. Observations and records on altitudinal limits of *Quercus baloot* in adjoining areas vary between 1300–2100 m in Nuristan (FREITAG 1971a, 323; RATHJENS 1972, 211; EDELBERG a. JONES 1979, 31), 1000–2100 m in Swat (BEG a. KHAN 1980, 111), above 1200 m in Darel and Tangir (SCHICKHOFF 1995, 71) to 2300–2700 m in Gor (DICKORÉ a. NÜSSER 2000, 108). The lowest occurrences of *Qu. baloot* in southern Chitral and Nuristan descend into the colline belt (subhumid scrub). The evergreen oak is an important fodder tree for livestock (especially goats) and apparently a managed resource of local stockholders (KERSTAN 1937; SCHEIBE 1937; HASERODT 1989). In many places along the main pastoral migration routes (e.g. in Shishi Valley) *Quercus baloot* stands have been degraded to a great extent.

(2.2) Semiarid steppe pine forest

Characteristic species: *Acantholimon kokandense*, *Artemisia chitralensis*, *Astragalus erionotus*, *Cousinia racemosa*, *Lonicera quinquelocularis*, *Onosma dichroanthum*, *Pinus gerardiana*, *Saponaria griffithiana*

[19] Usage of the term 'steppe', which originally refers to grass- or herb-dominated communities of temperate summer-dry climates, is often somewhat misleading or inadequate in the area. Dwarf-shrubs and shrubs usually constitute a substantial fraction of the respective communities in Chitral, grasses are not generally well represented (partly due to overgrazing). Whereas these formations are probably better referred to as '(dwarf) shrublands', more typical steppes are developed towards the higher altitudes.

Naturally open *Pinus gerardiana* forest, regularly occurring near the absolute drought limit of forest distribution, is of patchy and disjunct distribution on the upper edge of the drier submontane belt, succeeding *Quercus baloot* and often followed above by montane *Cedrus deodara* and *Pinus wallichiana* forest. Within the map area, substantial stands of *P. gerardiana* concentrate on the slopes around Chitral Town, at altitudes between approximately 2200 and 2600 m (Photo 3). As for the quite isolated occurrences around Nanga Parbat (DICKORÉ a. NÜSSER 2000) and a small outpost in the Chaprot area of the Hunza Valley (Karakorum), the companion flora of *Pinus gerardiana* seems to be quite rich in characteristic species. Several of its Irano-Turanian and West Pamirean elements (*Acantholimon kokandense, Astragalus erionotus*, *Cousinia racemosa*) are on their absolute east border of distribution in Chitral. Shelter provided by *P. gerardiana* seems to be an important precondition for a well-developed herbaceous and shrubby companion flora, including therophytes and geophytes, which in places provides relatively rich grazing grounds. Wood and the edible seeds of *P. gerardiana* are another valuable resource, the importance or management of which can presently not be assessed.

(2.3) Semiarid to arid steppe, deciduous and juniper steppe-forest groves

Characteristic species: *Acanthocephalus benthaminanus*, *Artemisia persica*, *Astragalus strobiliferus*, *Crataegus songarica*, *Fraxinus xanthoxyloides*, *Gypsophila floribunda*, *Juniperus excelsa* subsp. *polycarpos*, *Mattiastrum himalayense*, *Onobrychis laxiflora*, *Prunus kuramica*, *Rosa beggeriana*, *Scabiosa olivieri*, *Saussurea leptophylla*, *Scutellaria multicaulis, Tricholepis toppinii*

Open 'steppe' and dwarf-scrub formations, in which Irano-Turanian and West Pamirean elements prevail (*Scabiosa olivieri, Saussurea leptophylla, Scutellaria multicaulis*), including therophytes and geophytes, occupy considerable areas of central Chitral. Many of the characteristic species are at their eastern limit of distribution, but some (*Artemisia persica, Fraxinus xanthoxyloides*) re-occur in the dry valleys of Gilgit, Baltistan and Ladakh. Groves of *Prunus kuramica*, *Juniperus excelsa* subsp. *polycarpos,* and other xerophytic trees occur regularly, but occupy only minor fractions of the area. The submontane vegetation belt seems to disappear towards northern Chitral, although some of its apparently thermophilous species may ascend to higher belts. Obviously, considerable portions of the submontane steppe, especially on the more gentle slopes of the Buni-Reshun Basin, covered by loess and limnic sediments, are transformed into irrigated cultivation.[20)]

(3) Montane belt

In Chitral, the montane belt ranges from 2600–3200 m in the south and from 2800–3500 m in the north. Basically it is a belt of dark 'boreal' coniferous forests in the south, whereas almost treeless steppes are found generally to the north of Chitral Town, with some isolated outposts in the Golen Valley. Even in the humid southern part of Chitral and adjacent areas, the montane forest is discontinuous and restricted to smaller isolated patches, mostly on north-facing slopes, alternating with 'steppe' and scrub vegetation on south-facing slopes. This pattern is apparently related to climatic properties, but also to various levels of anthropo-zoogenic disturbance. Vegetation cover is variable and depends strongly on the intensity of pastoral utilization. Although the vegetation may be highly degraded in the vicinity of grazing settlements and pastoral migration paths, these patterns do not seem to inflict the general altitudinal zonation. In other parts of northern Pakistan, the montane belt has been identified as being the relatively richest in species (DICKORÉ a. NÜSSER 2000; DICKORÉ a. MIEHE 2002), which also seems to apply to Chitral. According to the floristic approach of MILLINGER (1999) and PEER et al. (in press), the steppes of northern Chitral can be differentiated into 'semi-desert steppe' (2600–3000 m), '*Artemisia*-steppe' (2800–3400 m) and 'thorn-cushion steppe' (3400–3600 m).

(3.1) Humid mixed deciduous and laurophyllous oak forest

Characteristic species: *Acer cappadocicum, Aesculus indica, Quercus dilatata, Qu. semecarpifolia*

Rather small and disjunct forest areas dominated by mixed deciduous trees and laurophyllous oaks occur in the south of the study area (Nuristan, Dir, Swat) and in Kalasha. These evergreen mixed forests contain *Quercus dilatata* (2000–2400 m) and *Qu. semecarpifolia* (2400–2900 m), and are confined to the most humid situations (FREITAG 1971a, 324–326). The mixed deciduous and laurophyllous oak forest is at its western limit in Nuristan, and apparently depauperate as compared to the area of more continuous distribution along the southern slopes of the West Himalaya, from Hazara and Kashmir eastwards. It is nevertheless probably rich in species. This forest type is apparently under high threat and has possibly been widely cleared for grazing or cultivation. Mixed or conifer-dominated stands

[20)] Rather substantial areas of moderately thermophilous steppe and cultivation present in the Buni-Reshun Basin are apparently related to the distinctive glacial geomorphology of this area, as a major tongue basin with widely distributed moraine and loess deposits (KAMP 1999), including a possibly underestimated representation of lacustrine sediments.

are included in the mapping unit of humid montane coniferous forests.

(3.2) Humid coniferous forest

Characteristic species: *Abies pindrow, Anaphalis contorta, Artemisia vestita, Carex cardiolepis, Cedrus deodara, Picea smithiana, Pinus wallichiana, Podophyllum hexandrum, Pseudomertensia parviflora, Pseudostellaria himalaica, Saussurea chitralica*

The montane belt of southern Chitral accommodates West Himalayan coniferous forests. Four conifers (*Abies pindrow*, *Cedrus deodara, Pinus wallichiana* and *Picea smithiana*) characterize this formation, which is widely distributed from East Afghanistan to West Nepal. Already GRIFFITH (1847, cited after SCHWEINFURTH 1957, 20) stated that "every plant from the Kafir hills convinces me that they are Himalayan in their features." Throughout the southern part of the study area, closed montane forests are confined to fragmented, relatively small stands that concentrate on north-facing slopes. Spatial and altitudinal distribution of individual conifer species are very similar throughout Chitral (see distribution maps by SCHICKHOFF 1995; 2000). This situation is rather different from that of the Gilgit-Indus Basin to the east. In the southwestern Karakorum and in the Nanga Parbat area, *Picea* and *Pinus wallichiana* range further north, whereas *Abies* is mainly restricted to the southern declivity of Nanga Parbat and the Astor Valley, and *Cedrus* extends north only to the Chilas section of the Indus Gorge (TROLL 1939; SCHICKHOFF 1995; DICKORÉ a. NÜSSER 2000). This may be due to higher demands of humidity with regard to *Abies* and of higher temperatures in the case of *Cedrus*. In a wider geographical perspective, the latter is accordingly more conveniently referred to the submontane belt. No such ecological distinction is possible in Chitral, where most stands are mixed. *Cedrus deodara* though usually dominates towards the lower edge of the montane forest (c. 2450–3050 m), and *Pinus wallichiana* towards the higher altitudes (Photo 4); *Abies* and *Picea* are relatively rare. The cedar is regarded as the most valuable timber resource and management is urgently needed to preserve these stands and their sustainable utilization.[21] Disturbance and degradation

Photo 4: Montane conifer forest of *Pinus wallichiana* and *Picea smithiana* in the upper Shishi Valley. A small tree grove and alpine mats are visible on the upper slopes. View east from above Madaglasht, 3050 m, towards the Andowir group (13.7.1997, M. NÜSSER)

Montaner Koniferenwald mit *Pinus wallichiana* und *Picea smithiana* im oberen Shishi-Tal. Auf den höheren Hangbereichen sind eine Baumgruppe und alpine Matten erkennbar. Blickrichtung Ost auf die Andowir-Gruppe, Standort 3050 m oberhalb Madaglasht (13.7.1997)

of small conifer stands in the upper Shishi Valley and in the southern tributaries of the Golen Valley reflects the scarcity of fuel-wood along the northern margin of moist coniferous forests (HASERODT 1989, 66; NÜSSER 1999, 122). The shrub and herb layers of well-developed *Cedrus deodara* forests can be rich in West Himalayan (*Carex cardiolepis, Parrotiopsis jacquemontiana, Podophyllum hexandrum*) and endemic elements (*Saussurea chitralica*). However, most Chitral forests are probably depauperate in species.

(3.3) Subhumid meadow, steppe and scrub

Characteristic species: *Artemisia brevifolia*, *Cotoneaster nummularia, Lepechiniella microcarpa, Poa sterilis, Pseudosedum lievenii, Solenanthus circinnatus, Trigonella emodi*

Considerable areas in the moist montane belt are either naturally covered by, or anthropo-zoogenously converted into dwarf-scrub, scrub, tall forb or meadow-steppe vegetation. With regard to the forest patches of the former unit embraced by this vegetation type, the extent of transformation by human impact is difficult to assess. It is certainly high and much of the area may be potentially wooded. In places, edaphically or climatically treeless south-facing slopes covered by *Artemisia brevifolia*, dwarf-scrub and open scrub formations must, however, also be considered a quasi-natural vegetation type. The mapping unit is apparently a rather diverse and an essentially anthropogenic mixture, characterized by many rather ubiquitous species of mesophilous and moderate xerophilous affinities, including many weeds.

[21] According to colonial reports (LOCKHART a. WOODTHORPE 1889, 267) *Cedrus* – the only wood exported to down country – was cut in Shishi Valley and other southern valleys and floated down to the Kabul River. The massive exploitation of cedars, mostly organized by contractors from Dir / Kohistan, continued until the 1970s, before deforestation in Chitral was limited to some extent by the Forest Department (HASERODT 1989, 135–136).

Photo 5: The yellow inflorescences of *Eremurus stenophyllus* and *Eremostachys speciosa* are a characteristic sight in the montane belt on the eastern border of the Irano-Turanian region. North-facing slope in the Tirich Valley at 3420 m (4.7.1997, M. NÜSSER)

Die gelben Infloreszenzen von *Eremurus stenophyllus* und *Eremostachys speciosa* zeigen einen charakteristischen Aspekt der montanen Stufe an der Ostgrenze der irano-turanischen Region. Nordexponierter Hang im Tirich-Tal bei 3420 m (4.7.1997)

(3.4) Semiarid to arid montane steppe and scrub

Characteristic species: *Arenaria griffithii, Artemisia brevifolia, A. persica, Asyneuma argutum, Cotoneaster nummularia, Carex koshevnikovii, Codonopsis obtusa, Draba olgae, Eremurus stenophyllus, Juniperus semiglobosa, Krascheninnikovia ceratoides, Lagochilus cabulicus, Linaria odora, Prangos pabularia, Rheum ribes, Rosa webbiana, Solenanthus circinnatus, Stipa himalaica, Stipa turkestanica, Winklera silaifolia, Tanacetum griffithii, Tetrataenium olgae*

Considerable areas of central and northern Chitral are covered by montane steppe and scrub. The semiarid montane belt is substantially treeless, apart from occasional *Juniperus semiglobosa* groves, mostly in water-surplus situations on slopes, and small patches of riverine forest (*Betula utilis* subsp. *jacquemontii*, *Populus nigra*, *P. pamirica*). The widespread *Artemisia brevifolia*, *A. persica*, *Krascheninnikovia ceratoides*, and some other species, which often ascend to the subalpine belt, connect the montane belts of Chitral and the upper Indus basin of the southwestern Karakorum. On the other hand, the dry montane flora of Chitral seems to display distinctive features in accommodating a fair number of Pamirean and Irano-Turanian elements that eventually cross the Shandur, Chumarkhan or Darkot Passes, but actually do not occur further east than the upper Yasin and Ghizer Valleys on the east margin of the map (*Asyneuma argutum*, *Eremurus stenophyllus* (Photo 5), *Prangos pabularia*, *Winklera silaifolia*). Accordingly, in a wider perspective, the montane and also the subalpine vegetation of Chitral and adjacent Badakhshan including Wakhan appears to be reasonably distinct from that of Gilgit and Baltistan.

(4) Subalpine belt

The subalpine belt comprises the zone around the (potential) upper treeline and extends between 3200–3800 m in the south and from 3500–4000 m in northern Chitral. Species composition of the subalpine belt comprises balanced proportions of montane and alpine species. However, the definition of the subalpine belt is more difficult in the treeless north, where a scrub belt can be absent too. Local variation of subalpine vegetation types is high due to various natural and anthropogenic factors. In avalanche trails and around the major high mountain massifs, subalpine and alpine vegetation may locally descend to lower altitudes. *Betula utilis* subsp. *jacquemontii*, probably the most common and distinctive subalpine tree of the western Himalayas, is generally rare at its northern limit of distribution in Chitral, and rather confined to montane water-surplus habitats (e.g. the riverine forests in the upper Tirich Valley, which are also mentioned by LAWDER 1936, 54). Low scrub of *Salix karelinii* leads to the lower alpine belt. A moist and a drier subalpine formation can be distinguished in the area.

(4.1) Humid treeline forest, scrub, dwarf-scrub and meadow

Characteristic species: *Androsace harrissii*, *Berberis parkeriana*, *Betula utilis* subsp. *jacquemontii*, *Eremurus himalaicus*, *Juniperus squamata*, *Lonicera obovata*, *Oxytropis mollis*, *Rheum webbianum*, *Salix denticulata*

A subalpine tangle wood ('krummholz') belt is developed along the upper edge of montane forests through the south of the study area. It is characterized by shrub species of a wide West- or Pan-Himalayan distribution (*Juniperus squamata*, *Lonicera obovata*, *Salix denticulata*), with occasional *Betula utilis* subsp. *jacquemontii* groves or some stunted conifer trees from the montane belt below. Throughout Chitral and adjacent areas, however, the treeline ecotone does rarely show regular 'textbook example' patterns, which is probably due to steep microclimatic exposure gradients and often strong human interference (grazing, burning, selective cutting). Even in the relatively humid areas, the subalpine belt rather comprises a fragmented mosaic of forest, scrub, dwarf-scrub and meadow patches. Characteristic species include a variety of common Himalayan herbs, but also some endemics (*Androsace harrissii*). *Eremurus himalaicus* is the only species of this characteristic Irano-Turanian genus to extend into the western Himalayas.

(4.2) Semiarid scrub, thorn-cushion dwarf-scrub and steppe

Characteristic species: *Acantholimon lycopodioides, Aconogonon tortuosum, Astragalus lasiosemius, Carex stenophylla, Cousinia buphthalmoides, Festuca olgae, Lonicera asperifolia, Hedysarum minjanense, Nepeta paulsenii, Winklera patrinoides, Saussurea gilesii, Scorzonera codringtonii, Semenovia lasiocarpa*

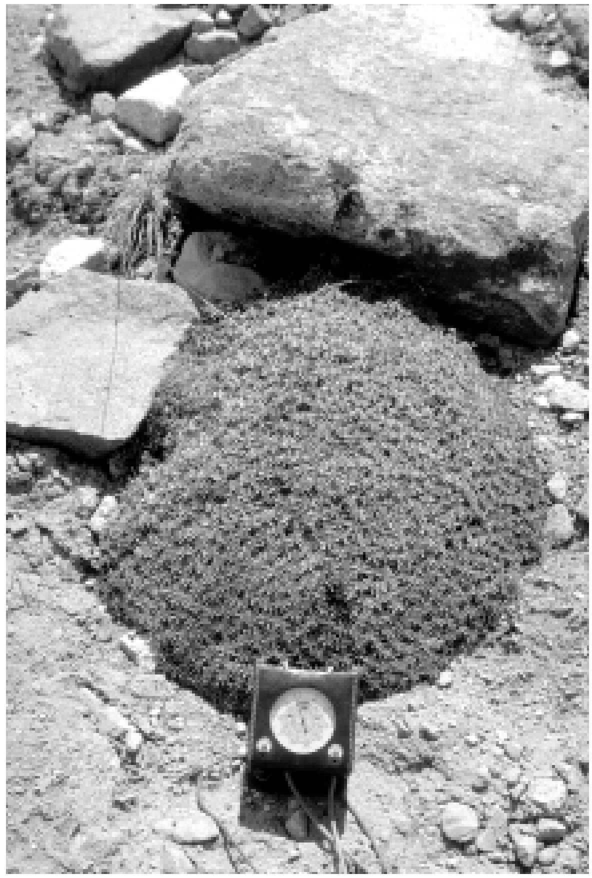
The subalpine vegetation of northern Chitral encompasses dwarf shrublands and steppe formations, which often show considerable proportions of thorn-cushions (*Acantholimon lycopodioides, Astragalus lasiosemius, A. strobiliferus)* in their life-form composition. Besides dry open turf *(Carex stenophylla)* or bunch grass 'steppes' *(Festuca olgae)*, a variety of low shrubs, subshrubs and herbs may come to local dominance. The semiarid subalpine scrub and steppe includes many taxa which are widely distributed in the inner mountains of western Central Asia and occasional endemics. The distribution of *Saussurea gilesii* is almost exclusively confined to the area covered by the vegetation map, including adjacent Wakhan and westernmost Gilgit. Several species (*Hedysarum minjanense, Nepeta paulsenii, Scorzonera codringtonii)* extend eastwards into the upper Gilgit Basin (i.e. Ghizer). The corresponding vegetation type from the southwestern Karakorum (lower Gilgit, Hunza, Baltistan) is accordingly somewhat different. Of its genus, which is prolific in the Irano-Turanian region, *Acantholimon lycopodioides* is the only species to extend eastwards through the southwestern Karakorum and inner western Himalayas to Ladakh. Thorn-cushions (*Acantholimon, Astragalus*) and other dwarf-shrubs (*Artemisia, Ephedra gerardiana*) are used for fuel (Photo 6) and thatch roofs, especially in the vicinity of seasonally inhabited pastoral settlements. Insufficient fuel-wood supply often induces the abandonment of pasture settlements (i.e. Dhaer Shal, 3620 m in Phargam Valley).

(5) Alpine belt

The alpine belt accommodates a small-scale mosaic of hemicryptophyte and chamaephyte-dominated meadow, turf and dwarf-scrub communities. Extensive areas of open rock faces and unstable scree slopes are almost devoid of vegetation or accommodate only a very thin cover of highly specialized plants. Differences in parent rock, substrate, relief position and soil moisture obviously account for local variation of plant distribution. With regard to their moisture regimes, two basic types of alpine vegetation can tentatively be distinguished.

(5.1) Humid alpine turf, and dwarf-scrub

Characteristic species: *Arnebia euchroma, Astragalus rhizocephalus, Chorispora macropoda, Cousinia thomsonii, Festuca alaica, Kobresia capillifolia, Myosotis asiatica, Oxytropis humifusa, Poa alpina, P. attenuata, P. supina, Psychrogeton andryaloides, Sibbaldia cuneata, Salix karelinii*



a)

b)

Photo 6: Thorn-cushions are a conspicuous feature in the montane and subalpine belts. Photo a) *Acantholimon lycopodioides* south of Shandur Pass, 3970 m (16.6.1997, M. Nüsser); Photo b) *Astragalus lasiosemius, Acantholimon kokandense* and other thorn-cushions are collected for fuel. Tirich Valley, 3620 m (3.7.1997, M. Nüsser)

Dornpolster bilden eine charakteristische Erscheinung der montanen und subalpinen Stufe. Photo a) *Acantholimon lycopodioides* südlich Shandur-Pass, 3970 m; Photo b) *Astragalus lasiosemius, Acantholimon kokandense* und andere Dornpolster dienen als Brennholzressource, Tirich-Tal (3620 m)

a)

b)

Photo 7: The alpine belt of northeast Chitral / Ghizer border. The subhumid alpine and subalpine meadow steppes are rich in herbs and form valuable pastures for summer grazing. Photo a) View from north above Shandur Pass across Shandur Lake, 4500 m (18.6.1997, M. NÜSSER); Photo b) The heavily grazed lower subalpine is dominated by *Artemisia brevifolia* and *Acantholimon kokandense.* View from south above Shandur Pass, 3750 m towards west (17.6. 1997, M. NÜSSER)

Die alpine Stufe im nordöstlichen Chitral an der Grenze nach Ghizer. Die krautreichen alpinen und subalpinen Wiesensteppen bilden wichtige Sommerweiden. Photo a) Standort 4500 m, oberhalb Shandur-Pass, Blick über den Shandur-See nach Süden (18.6.1997); Photo b) Die stark beweidete Vegetation der unteren subalpinen Stufe wird von *Artemisia brevifolia* und *Acantholimon kokandense* dominiert. Standort 3750 m, Blickrichtung West (17.6.1997)

The alpine regions of Nuristan, southern Chitral, Dir, Swat and Indus-Kohistan accommodate fairly closed turf and dwarf-scrub communities. The description of Chitral's humid alpine belt in general tallies with that of adjacent areas to the east (southwestern Karakorum, Nanga Parbat, Kashmir), whereas in easternmost Afghanistan this formation is apparently already on its absolute western limit. Structure and taxonomic composition on the level of genus are further quite similar to far distant mountain areas, such as the European Alps. In its over-all composition, the humid alpine belt of Chitral is transitional between the species-rich alpine vegetation of the outer Himalayas from Hazara and Kashmir eastwards and the corresponding more depauperate communities of the southwestern Karakorum and the inner western Himalayas. Besides turf and dwarf-scrub communities, the humid alpine belt accommodates a variety of specialized rock-fissure and scree slope habitats. Tall forb, meadow and scrub vegetation joins steep shady rockbases, streams and meltwater courses. Distinct 'snow valley' vegetation (TROLL 1939) is rare and local.

(5.2) Subhumid to arid steppe, dwarf-scrub and desert

Characteristic species: *Alajja rhomboide, Astragalus webbianus, Carex nivalis, Chorispora macropoda, Draba korshinskyi, D. tibetica, Kobresia karakorumensis, Lonicera semenovii, Oxytropis tatarica, Parrya stenocarpa, Poa attenuata, Psychrogeton andryaloides, Salix karelinii, Smelowskia calycina, Tanacetum pyrethroides*

Open steppe, dwarf-scrub and desert vegetation characterizes the alpine belt of northern Chitral. The respective mosaic of alpine rock and scree vegetation, including a few patches of more dense turf vegetation along bases of gravel fans, snow-fields and other water-surplus habitats, is relatively rich in species (Photo 7). Average vegetation cover of the Hindukush alpine belt is though much lower than in the preceding unit, usually far below 30 % of the surface. Floristic relations are with much of the eastern Pamirs and with the central and northern Karakorum. Characteristic species include taxa that are widely distributed through much of the Karakorum (*Carex nivalis, Kobresia karakorumensis, Lonicera semenovii, Tanacetum pyrethroides*) and the Tibetan Plateau (*Oxytropis tatarica, Poa attenuata*). Pamirean elements, which usually reach their southeastern limit of distribution approximately from the Chitral – Gilgit divide to the Khunjerab Pass (*Draba korshinskyi, Smelowskia calycina)*, are also well represented. Another group of species, which is absent from the Gilgit – Indus basin and the wider southwestern Karakorum, re-occurs disjunctively in the dry mountains of Ladakh, Zanskar and Spiti in northwest India (*Alajja rhomboidea, Parrya stenocarpa*).

(6) Subnival belt

The subnival belt extends from the upper edge of fairly closed or larger patches of alpine vegetation to the upper limit of vascular plant life. In Chitral, the subnival belt encompasses substantial areas, mainly around the Tirich Mir – Noshaq and the Buni Zom – Ghochhar Sar Massifs, from above 4400–4500 m to around 5000 m (Photo 8). Vegetation cover of the sub-

Photo 8: The subnival belt of the upper Phargam Valley. The scree-covered slopes are colonized by scattered individuals of specialized plants at the upper limit of vascular plant life (*Carex nivalis, Draba korshinskyi, Nepeta kokanica, Primula macrophylla*). Viewpoint: Phargam Pass (5123 m), towards east (23.7.1997, M. NÜSSER)

Die subnivale Stufe im oberen Phargam-Tal. Die schuttbedeckten Hänge werden von hochalpinen Arten an der oberen Grenze des Vorkommens von Gefäßpflanzen besiedelt (*Carex nivalis, Draba korshinskyi, Nepeta kokanica, Primula macrophylla*). Standort Phargam-Pass (5123 m), Blickrichtung Ost (23.7.1997)

nival belt is generally extremely low. There are no more than 20–50 plant species in the subnival belt. Most of these taxa are specialized rhizomatous scree colonizers or rock-fissure cushions, which both must be able to cope with low temperatures and mechanical stress caused by frequent freezing and thawing.

(6.1) Scree and rock desert

Characteristic species: *Christolea flabellata, Draba oreades, Nepeta kokanica, Oxytropis platonychia, Lagotis globosa, Psychrogeton olgae, Saussurea glacialis, S. gnaphalodes, Waldheimia tomentosa*

The highest altitude vegetation of Chitral comprises a single mapping unit, although regional differences are apparent throughout the wide range of subnival vegetation around the Tibetan Plateau. In Chitral, western elements, which often are restricted to the eastern Pamir, eastern Hindukush and Karakorum (*Oxytropis platonychia, Lagotis globosa, Psychrogeton olgae*) seem to outnumber the Pan-Tibetan ones *(Draba oreades, Saussurea gnaphalodes*).

(7) Cultivated areas

The altitudinal distribution of cultivated areas in Chitral ranges from the colline to the lower montane belt. As crop cultivation is almost entirely dependent on the availability of glacial and snow melt-water for irrigation, the settlement oases with agriculture are located along the streams and especially on the alluvial fans of tributary valleys. A sophisticated network of water distribution forms the precondition of irrigated agriculture (ISRAR UD-DIN 1996; KREUTZMANN 2000b). Commonly cultivated crops include rice (*Oryza sativa*) up to approximately 2300 m, maize (*Zea mays*) to 2900 m, wheat (*Triticum durum, T. aestivum*) to approximately 3300 m, and barley (*Hordeum vulgare*) to 3500 m (NAGEL 1973; HASERODT 1989; NÜSSER 1999). Cultivation of *Cannabis sativa*, often within maize fields is common in the northern tributaries, especially in Yarkhun and Laspur. Double cropping is possible in the main valley between Drosh and Buni and in the lowermost portions of Turkho Valley, with an upper limit at approximately 2500 m. Crop residues, hay, supplemented by cultivated lucerne (*Medicago sativa, M. X varia*), leaves of planted trees (*Salix* spp., *Populus* spp.) and indigenous hygrophilous bushes (*Hippophae rhamnoides*) supply winter fodder of livestock. In Sor Laspur an unidentified species of *Heracleum* is also cultivated as a winter fodder. Cultivation of fruit trees, especially mulberries (*Morus alba*), apricots (*Prunus armeniaca*), and walnuts (*Juglans regia*) is limited to a small scale and altitudes below approximately 2900 m (HASERODT 1989, 121).

Depending on the availability of water and suitable land, the general development of cultivated areas in Chitral is characterized by recent extension of irrigated fields and an increasing number of fruit and fodder trees in the village environs (NÜSSER 2001). However, in places a remarkable persistence of settlement structure can also be observed, as demonstrated by repeat photography from the Reshun Village, located in the main valley (Photo 9). Over a period of more than 110 years (1885/86 – 1997) discernible land use change almost exclusively encounters the intensification of irrigated agriculture and planting of hygrophilous deciduous trees (*Salix* spp., *Populus* spp.) along the new water channels. Due to topographical constraints, conversion of surrounding arid colline desert scrub into additional irrigated land was very limited. However, the individual fields within the irrigated area have become more fragmented into smaller plots. Another example of continuity can be found in the Tirich Valley: inhabitants of the highest permanent village in that valley, Shogram (2850–2900 m), still (1997) maintain the summer settlement Bandok (3100–3150 m) with cultivation of barley and wheat, as was in the same manner reported by SCHOMBERG (1936, 302, 304).

5 Discussion and Conclusions

Most of the previous approaches to vegetation classification and mapping in the Hindukush, Western Himalaya and Karakorum depict, in various ways, a

a)

b)

Photo 9: The Reshun Village in the main valley: one of the earliest photographic documents from Chitral; repeat photograph shows moderate change in landscape and settlement aspect. View from south of Reshun, 2100 m, towards northeast. Photo a) taken by G. M. J. GILES during the 'Gilgit Mission' (1885/86); Photo b) replicate by M. NÜSSER (14.6.1997)

Die Siedlung Reshun im Haupttal, eine der frühesten Photographien aus dem Chitral-Tal. Im Bildvergleich lassen sich nur geringe Veränderungen in den Landschafts- und Siedlungsstrukturen erkennen. Standort südlich von Reshun, 2100 m, Blickrichtung Nordost. Photo a) G. M. J. GILES im Verlauf der „Gilgit Mission" (1885/86); Photo b) Wiederholungsaufnahme (14.6.1997)

prominent altitudinal zonation, and in places tremendous horizontal variation. Our present map is thought of as a preliminary regional overview, intended to serve as a basis for further detailed studies. The following issues are to be discussed in more detail.

1) The principal division between the species-rich Sino-Himalayan region in the south and the Central Asiatic / Irano-Turanian regions to the north, evidently coincides with a physiognomically conspicuous northern limit of forest distribution. On the other hand, a west – east gradient does not show up prominently within the boundaries of our present map. The distribution of individual species and vegetation units indicate a conspicuous gradient in terms of species

turnover. Although Chitral is probably a key position regarding the transition between the Irano-Turanian and the Central Asiatic regions, this is spurious on the vegetation level and probably also due to the scale of our vegetation map.

2) Due to incomplete investigation and inherent synonymy, an approximate species inventory of Chitral is difficult to assess. Our present consensus of vascular plants recognizes 1385 species, which though still include many doubtful records. Estimates from combined floristic literature run even higher than 1800 species. Given the former figure of less than 1400 species as a realistic estimate, the area of Chitral (14,850 km^2) accommodates approximately slightly more than 1300 species per 10,000 km^2 (Evans et al. 1955).[22] However, the gradient of species richness from southern to northern Chitral encompasses narrow zones ranging between 1000–1500 to 200–500 species per 10,000 km^2 (Dickoré a. Miehe 2002). Accordingly, much of the total species inventory is expected to concentrate in southern Chitral.

3) Exact calculations of geoelements for the flora of Chitral are absent and would require a consistent classification of individual species (see Dickoré a. Nüsser 2000). A general altitudinal pattern with maximum species-richness and diversity of vegetation at middle altitudes is though apparent and probably applies to the whole area. Through central and northern Chitral, the Irano-Turanian – Central Asiatic transition comprises an apparent near equilibrium, possibly slightly shifted to the dominance of elements from the former region in terms of species numbers, and to the latter with regard of vegetation physiognomy and dominant species. On a small-scale basis, all three floristic regions seem to be intricately interlaced along the steep altitudinal gradients of Chitral. Similar altitudinal and periphery-central segregation of Sino-Himalayan and Irano-Turanian elements was observed in East Afghanistan (Breckle 1971) and the southern Karakorum (Dickoré 1995).

4) The east-west gradient along the southern declivity of the Himalayas is genuinely interpreted as to represent important migration paths of plant dispersal (Kitamura 1963). If one compares the vegetation map of the central Hindukush (Frey u. Probst 1978; 1979), which covers the adjoining areas to the west, with our present map, this horizontal gradient becomes more obvious. Besides prominent climatic gradients, there is some indication that geology, tectonic structure and orography of the area are decisive factors that widely determine plant distribution (Dickoré 1995; 2001). With regard to the transitional status of the flora of Chitral, the plate boundary system, i.e. the Shyok Suture Zone that runs through Chitral, seems to discriminate rather different floras on a larger spatial scale. The diversity of substrates resulting from the varied geology of the eastern Hindukush is also expected to exert considerable influence on local species composition. Autecology of individual species, however, needs more research. A certain degree of homogenization of surface geochemistry due to wide-spread moraines and fluvio-glacial terraces as well as generally extreme climatic conditions further hamper correlations.

5) Our approach of vegetation mapping has to face various methodical constraints, primarily resulting from the large size of the area and corresponding insufficient ground checks, especially in the Afghan areas. The tree-line ecotone through southern Chitral includes a variety of natural and anthropogenic characteristics, which are scarcely known in detail. Classification based on tree species composition, forest density and present status thus remains uncertain in many a remote location, especially of adjacent Nuristan and Kohistan. Tree species of a generally rare or scattered occurrence (*Juniperus* spp., *Pinus gerardiana*, *Quercus* spp., various deciduous trees) may sometimes have been overlooked. The proportion of the economically most important *Cedrus deodara*, which in general is confined to rather low, submontane altitudes, among the truly montane *Pinus wallichiana*, *Picea smithiana*, and *Abies pindrow* is difficult to assess at present. A rather intimate and locally variable composition of all these conifers in close neighbourhood seems to be a characteristic feature of the forests of southern Chitral as compared to a higher degree of divergence between the submontane and montane forests towards the east (Nanga Parbat region and southwestern Karakorum, Dickoré a. Nüsser 2000).

6) Consequences of increasing human impact on the natural resources and corresponding vegetation changes, notably the effects of mobile livestock keeping (Photo 10) and forest exploitation remain key issues of integrated and applied research (Nüsser 1998; Ehlers a. Kreutzmann 2000; Clemens 2001). According to the latest census data from 1998, the population of Chitral district was 317,198 with an average annual growth rate of approximately 2.5 % (Holdschlag 2001, 134). This demographic development challenges flexibility and sustainability of regional land use systems and raises questions of future human-ecological perspectives. Although the food security of a grow-

[22] $S = s * \log (N + 1) / \log (n + 1)$, where S is an estimate of the number of species expected on an area consisting of N units and s is the number of species encountered in n units selected at random.

Photo 10: Grazing by mixed herds of sheep and goats in the dry subalpine belt of northern Chitral. Viewpoint: 3500 m, Ojhor Valley, towards northeast (16.8.1997, M. NÜSSER)

Hochweidenutzung mit gemischten Schaf- und Ziegenherden in der trockenen subalpinen Stufe im nördlichen Chitral. Standort: 3500 m, Ojhor-Tal, Blickrichtung Nordost (16.8.1997)

ing mountain population strongly depends on additional supplies from the lowland economic centres of Pakistan, irrigated crop cultivation and animal husbandry still play a vital role for the subsistence of the mountain dwellers in Chitral (HASERODT 1989; NÜSSER 1999; for Kalasha: PARKES 1987; 1992). The economic importance of animal husbandry is generally more pronounced in the single cropping areas of the higher tributaries. Moreover, one can observe that herd composition and seasonal transhumance patterns vary between different areas of Chitral because of distinct utilisation rights, which mainly refer to factors of ethnic segregation and settlement processes (NÜSSER 1999). Whereas the dominant autochthonous mountain farmers (Kho population) keep sheep and goats together with cattle in the form of mixed mountain agriculture, the formerly nomadic Gujur groups, mainly concentrated in the Shishi Valley, predominantly rely on goat keeping. Yaks and yak-crossbreeds are confined to the valleys of upper Chitral, where they can be found in great numbers in the Khot Valley and around the Shandur Pass. Although the variability of pasture degradation between different valleys and altitudinal belts is certainly high in both summer and winter grazing areas, these differences do not show up prominently due to the scale of the vegetation map. Lack of fuel is generally considered to be a major problem, especially in the treeless northern parts of Chitral. Consequently, the remaining submontane and montane forest patches are under enormous pressure and exploitation of woody dwarf-shrubs as fuel-wood is a common practice. An integrated analysis of mixed mountain agriculture, forest and dwarf-shrub utilization has to encompass the agro-ecological resource potentials together with the regional resource management system.

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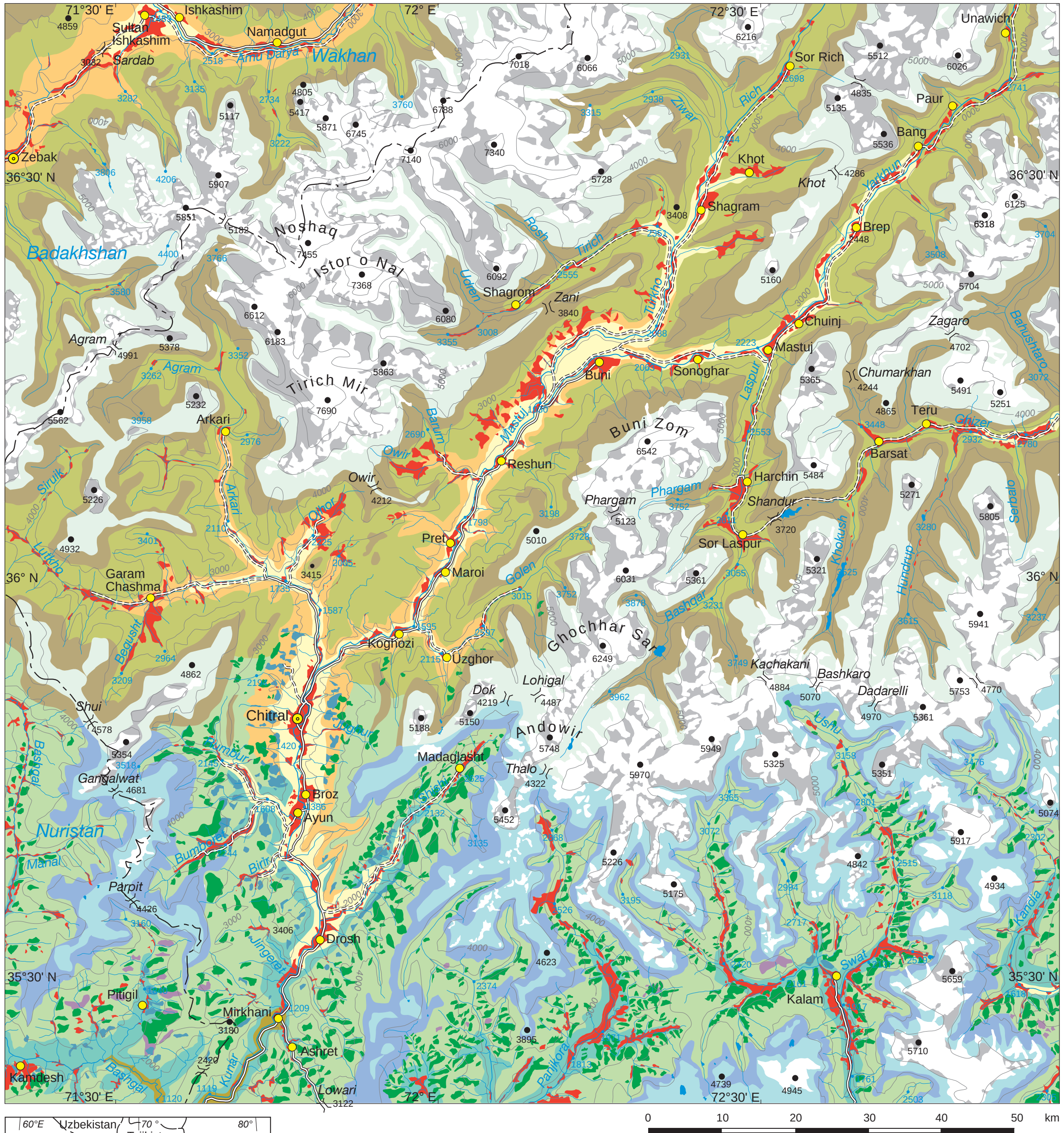
Topographical maps

Generalni Stab (1974–1985): 1:100 000. Sheets J-42-131 (Zebak), J-42-132 (Uchdrag), J-43-121 (Masdzid-Lasht), J-43-122 (Brep), J-42-143 (Sanlech), J-42-144 (Purpuni), J-43-133 (Drasan), J-43-134 (Mastuj), I-42-11 (Bargi-Matal), I-42-12 (Chitral), I-43-1 (Madaglasht), I-43-2 (Brumsa-An), I-42-23 (Kamdesh), I-42-24 (Drosh), I-43-13 (Lamutaj), I-43-14 (Kalam).

Beilage I zu ERDKUNDE 56,1 Beitrag Nüsser / Dickoré

Vegetation Map of the Eastern Hindukush (Chitral, Northern Pakistan)



Sources:

Geometrical rectified Landsat TM data (151/35), 29.8.1993, visual interpretation
Altitudes and topography according to Generalni Stab 1:100 000 (1974-1985)
Sheets: J-42-131, J-42-132, J-43-121, J-43-122, J-42-143, J-43-133, J-43-134, I-42-11, I-42-12, I-43-1, I-43-2, I-42-23, I-42-24, I-43-13, I-43-14
Toponyms in Nuristan: Edelberg and Jones (1979)
in Badakhshan, Wakhan and Yarkhun Valley: Kreutzmann (1996, 2000a)

Field surveys: 1995 (W.B. Dickoré, M. Nüsser); 1997 (M. Nüsser)
Floristic database: W.B. Dickoré, Draft and cartography: M. Nüsser

Colline belt

(1.1) Subhumid scrub
(*Dodonaea viscosa, Monotheca buxifolia, Quercus incana, Zizyphus jujuba*)

(1.2) Arid desert scrub
(*Artemisia fragrans, Pistacia khinjuk, Pulicaria salviaefolia;*
in Chitral and Wakhan: *Haloxylon griffithii, Haplophyllum dubium;*
Indus basin: *Haloxylon thomsonii, Haplophyllum gilesii*)

Submontane belt

(2.1) Subhumid sclerophyllous oak forest
(*Quercus baloot, Piptatherum vicarium, Tricholaser ovatilobum, Viburnum cotinifolium*)

(2.2) Semiarid steppe pine forest
(*Pinus gerardiana, Acantholimon kokandense, Astragalus erionotus, Onosma dichroanthum*)

(2.3) Semiarid steppe, deciduous and juniper steppe-forest groves
(*Artemisia persica, Fraxinus xanthoxyloides, Prunus kuramica, Juniperus excelsa* subsp. *polycarpos*)

Montane belt

(3.1) Humid mixed deciduous and laurophyllous oak forest
(*Quercus dilatata, Quercus semecarpifolia, Acer cappadocicum, Aesculus indica*)

(3.2) Humid coniferous forest
(*Cedrus deodara, Pinus wallichiana, Picea smithiana, Abies pindrow, Podophyllum hexandrum, Pseudomertensia parviflora*)

(3.3) Subhumid meadow steppe and scrub
(*Artemisia brevifolia, Cotoneaster nummularia, Pseudosedum lievenii, Solenanthus circinnatus*)

(3.4) Semiarid to arid steppe and scrub
(*Arenaria griffithii, Draba olgae, Juniperus semiglobosa, Krascheninnikovia ceratoides, Prangos pabularia*)

Subalpine belt

(4.1) Humid treeline forest, scrub, dwarf-scrub and meadow
(*Betula utilis* subsp. *jacquemontii, Berberis parkeriana, Juniperus squamata, Salix denticulata*)

(4.2) Semiarid scrub, thorn-cushion dwarf-scrub and steppe
(*Acantholimon lycopodioides, Carex stenophylla, Hedysarum minjanense, Nepeta paulsenii, Saussurea gilesii*)

Alpine belt

(5.1) Humid turf, dwarf-scrub and desert
(*Kobresia capillifolia, Myosotis asiatica, Poa alpina, Sibbaldia cuneata, Salix karelinii*)

(5.2) Subhumid to arid steppe, dwarf-scrub and desert
(*Astragalus webbianus, Draba korshinskyi, Kobresia karakorumensis, Lonicera semenovii, Smelowskia calycina*)

Subnival belt

(6) Scree and rock desert
(*Christolea flabellata, Lagotis globosa, Psychrogeton olgae, Saussurea gnaphalodes, Waldheimia tomentosa*)

Nival belt

Permanent ice and snow, high rock faces

Cultivated areas

(7) Cultivated fields, meadows, orchards and tree plantations predominantly irrigated

Town, village
Road, track
3135 6542 4487 Altitude [m]: river confluence, peak, pass
River, lake
Contour line [m]
International boundary