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Description of a simple operative top down stream typology for the HKH region

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1. INTRODUCTION

1.1 Introduction to stream typology

The classification of rivers in general is based on three approaches such as, the longitudinal zonation approach, catchment based approach and the regional (geographic, physiographic) approach, which is comparatively a new approach in aquatic sciences. The regional classification of rivers (i. e. 'river typology') is a trans-disciplinary and applied approach, which is based on integrated hydro-biological, geological, geographical and hydrological sciences.

For developing assessment systems, river typologies based on near-natural reference conditions is an essential basis. The comparison of impaired sites with undisturbed sites allows the definition and classification of different stages of degradation. This must be done river type specific.

It is not surprising that the abiotic conditions of slow-flowing lowland rivers with their finer substrates and higher temperature regimes support completely different biological assemblages (bio-coenoses) compared to the fast-flowing mountain rivers with rough substrates and generally lower water temperature. Similarly, the stages of deterioration are also river type specific. For example, the effects of channel bed alteration (scouring, straightening, and artificial bed fixation) lead to complete different results in lowland rivers in comparison to Mountain Rivers.

A river type is a constructed ecological entity with limited internal variation in its biotic and abiotic components, which shows a minimal and constant biotic and abiotic discontinuity in comparison to other entities. Such river types might serve as 'units', for which an assessment system can be applied. A river type should always be defined on the basis of natural or near-natural reference sites. The comparison with undisturbed sites of a certain river type allows defining and classifying different stages of degradation. Biological assessment requires sufficiently stable, integrated river typologies, which consider both abiotic and biotic criteria. The most prominent abiotic factors are river morphology, geochemistry, altitude, river size and hydrology. Generally, river typologies can be designed following either 'top-down' or 'bottom up' approaches. The major difference between a top-down and a bottom-up approach is the reliability of criteria (either environmental parameters or organism groups). In a top-down approach parameters are chosen on the basis of knowledge and human prejudice. For example, the division of the large-scale units of the eco-regions top-down into 'sub-ecoregions' is a helpful base for further differentiation of river types.

In a bottom-up approach the types are the direct results of ecological analysis (e.g. analysing the similarity of biotic assemblages by multivariate statistics). The latter includes only those parameters, which are actually ecologically relevant. Research on the importance of scale and ecological relevancy of parameters shows that even small-scale landscape units may only partially explain the distribution of species and communities.

1.2 Introduction to the eco-region approach

Thirty years ago it was stated that there are recognizable regions within which we observe particular patterns (Frey 1977). These regions generally exhibit similarities in the mosaic of environmental resources, ecosystems, biota and effects of humans, and can therefore be termed "ecological regions" or "eco-regions". In recent years there has been an increasing awareness that these eco-regions exist and that effective management of environmental resources must be undertaken with an ecosystem perspective (Omernik 1995).

Ecological regions are defined as **areas of relative homogeneity in ecological systems and relationships between organisms and their environment** (Glenn *et al.,* 1994). From the perspective of water quality assessment it is to be seen as a great advantage for developing and applying a methodology that within these areas, natural variability will be comparatively low and ecological expectations will be relatively uniform. Thus ecoregions are regarded as a basic element of river typology.

The objective of working package 2 is to define a classification system for streams (typology) e.g. based on ecoregions (or sub-entities like sub-ecoregions, bioregions etc.), conditions of climate and geology, catchment size, altitude etc. for the HKH region that leads to;

- the description of reference site criteria (necessary for the assessment of environmental pressures and impacts)
- an overview of (common and/or individual) stream types that will be sampled during the project

As no common practicable stream typology exists in the HKH region evident from the Kick Off meeting in Brno, Czech Republic, the HKH typology will be based on the collection of existing information applying criteria that are used internationally. Existing (abiotic) typologies or typological elements will be included in a general top down typological scheme for the HKH countries, which may be later validated (bottom up) using collected field data.

As our proposed assessment method is based on the reference approach, the stream types serve as a unit for defining reference conditions and, in a second step in defining impact classes of selected pressures.

As mentioned in the technical annex of project document, task 2.1, a set of two or three stream types per country is currently planned for further investigation under the WP2.

- Streams in the Eastern Himalayan broadleaf forests from Bhutan and Nepal
- Streams in the Himalayan subtropical pine forests from Bhutan, Nepal, India and Pakistan
- Streams in the Western Himalayan broadleaf forests from India and Pakistan
- Streams in the Lower Gangetic Plains moist deciduous forests from Bangladesh, Nepal and India.

Fig. 1. Roshi khola, Nepal (RQ-II, Alt. 1482m) Fig. 2. Thimphu chhu, Bhutan (RQ II, Alt. 2300m)

Few examples of stream types in the Eastern Himalayan broadleaf forests (IMO 401) are illustrated above and stream types in the Himalayan subtropical pine forests (IMO301) as below.

Fig. 3. Yamdi, Nepal (RQ- II, Alt. 1100 m) Fig. 4. Kalsa, India (RQ- II ALt. 1250 m) Fig. 5. Lubichhu, Bhutan (RQ- II, Alt 1380m)

Some examples of stream types in the Lower Gangetic Plains (IMO102) are illustrated below;

Fig.6. Barahwa, Nepal (RQ-III, Alt. 80m) *Fig.7. Sutia Kaoraid, Bangladesh (RQ-III, Alt. 75m)*

1.3 Review of the existing knowledge on eco-regions and Rationale behind selection of WWF 200 based eco-region for the Hindu Kush-Himalaya

A literature survey clearly showed that a couple of 'regions' and 'zones' have already been outlined for Asian countries based on forests type (FRA 2000), fish type (Petr 1999) and physiographic regions (Hagen 1959, Norbu et al. 2003).

Bangladesh is divided into two eco-regions with emphasis on forestry such as tropical moist deciduous forests and tropical rainforests (FRA 2000). Rashid (1991) identified 24 physiographic regions in Bangladesh [http://www.sos-arsenic.net/english/intro/physio.html]. Zoning of water systems of the Chittagong region has been done (Pramanik MAH, in Rahman AA (edited), 2000). Bangladesh has three major river systems, the Ganges-Padma, the Brahmaputra – Jamuna, and the Meghna system covering about 15,000 miles (24, 000 km) of rivers, streams and canals (Rahman et al., 2000). Land use in Bangladesh is primarily for irrigation. The cropping patterns are very much dependent on the availability of water. Bangladesh has some of the world's best tropical forests.

Bhutan is a country of dramatic contrasts, rising almost vertically from the warm, tropical plains of India to the crisp, rarefied atmosphere of the Himalayas. Bhutan has six Agro-ecological zones (Gyamthso, 1996), as reflected in the table 1 below. The wet sub-tropical zone is from 150 to 600 m, followed by the humid sub-tropical zone to 1,200 m. The dry sub-tropical zone starts at 1,200 m and extends to 1,800 m, followed by the warm temperate zone, which reaches 2, 600 m. The cool temperate zone lies between 2 600 and 3 600 m and finally the alpine zone at a height of 4 600 m.

Table 1. Agro-ecological zones of Bhutan (Source: Gyamthso, 1996)

Agro-ecological Zones	**Altitudinal range (m a.s.l)**	**Annual rainfall (mm)**	**Max. annual temperature (^{0}C)**	**Min. annual temperature (^{0}C)**	**Annual mean temperature (^{0}C)**
Alpine	3,600-4,600	< 650	12.0	-0.9	5.5
Cool Temperate	2,600-3,600	650-850	22.3	0.1	9.9
Warm Temperate	1,800-2,600	650-850	26.3	0.1	12.5
Dry Subtropical	1,200-1,800	1,200-1,800	28.7	3.0	17.2
Humid Subtropical	600-1,200	1,200-2,500	33.0	4.6	19.5
Wet Subtropical	150-600	2,500-5,500	34.6	11.6	23.6

The concept of physiographic zonation in Bhutan integrates all of the main components of the natural environment, such as bedrock, surface drift deposits, landform, soils, climate, water, and plants and animals (Chencho Norbu et al., 2003). This paper has divided Bhutan into some physiographic zones based on soil survey.

Nepal is divided into six ecological zones with an emphasis on forestry as shown on the FAO global map of ecological zones produced as part of the FRA 2000. There are six well defined topographic regions in Nepal, classified by Hagen in 1959 viz., Terai plain, Churia hill, Mahabharat Mountain, Midland, The Himalayas, and Inner Himalayas. The following cold water fish zones have been described for Nepal (J. Shrestha. in T. Petr, 1999) for the Bagmati River, which is based on the presence of the dominant fish species.

Snow trout zone (1875 m - 3125 m): It is characterised by fast flowing cold snow-fed water dominated by *Schizothorax plagiostomus* and *S. spp*.

Stone carp zone (1250 m - 1875 m): Stone carp (*Psilorhynchus pseudecheneis*), stone roller (*Garra gotyla*), loach (*Noemacheilus spp*) and sucker catfish (*Glyptothorax spp*) dominate the fast flowing waters in this zone.

Hill barbel zone (625 m - 1250 m): This zone, with fairly slow water current, is dominated by mahseer (*Tor tor, T. putitora*) and Katle (*Neolissocheilus hexagonolepis*).

The River Gandaki system drains the central part of Nepal, and forms the deepest gorge in the world, as it flows through the Himalayas on its way from its headwaters on the Tibetan Plateau to lowlands, where it merges with the Ganges (Edds, 1989). Thirty-five cold water species have been identified from the River Kali Gandaki alone. Edds (1989) gives the following species zonation for the Kali Gandaki/Narayani rivers:

Schizothorax richardsonii zone (850 m - 2810 m): This stretch of the river includes both mountain and Trans-Himalayan regions.

Schizothorax progastus zone (300 m - 850 m): In this high hill region *S. richardsonii* is gradually replaced by *S. progastus*.

Barilius zone (50 m - 300 m): The low hill region is named for the presence of its most common fish *Barilius vagra*.

The other rivers of the Gandaki system such as Seti, Madi, Marsyandi and Trisuli are important from the cold water fisheries point of view. The important fish species in these rivers are *Tor putitora, T. tor, Neolissocheilus hexagonolepis, Semiplotus semiplotus, Garra annandalei, G. gotyla, Glyptothorax pectinopterus* and *Channa gachua*. The River Karnali arises on the Tibetan Plateau and enters Nepal, to become the major river system in Western Nepal. Menon (1954) recorded *Noemacheilus spp* as the dominant genus in this river, and Jha and Shrestha (1986) found *S. plagiostomus* in the upper reaches of this river.

The Indian Himalayas are drained by 19 major rivers, of which the Indus and the Brahmaputra are the longest, each having a mountain catchment of about 160,000 km^2. Of the remaining 17 rivers five belong to the Indus system, of which the Beas and the Sutlej have a total catchment area of 80,000 km^2; nine (Ganga, Yamuna, Ram Ganga, Kali-Sharda, Karnali, Rapti, Gandak, Bhagmati, Kosi) belong to the Ganga system, draining nearly 150,000 km^2; and three (Tista, Raidak, Manas) belong to the Brahmaputra system, draining another 110,000 km^2. Most of these rivers flow in deep valleys until they exit the mountains (K.L. Sehgal in T. Petr 1999).
The fish species distribution in the Himalayan streams depends on the flow rate, nature of substratum, water temperature; and the availability of food. In torrential streams Sehgal (1988) identified several zones on the basis of dominant fish species and the hydrographical features:
headwater zone inhabited by rheophilic species of loaches and catfishes (*Noemacheilus gracilis*, *N. stoliczkae* and *Glyptosternum reticulatum*); large stream zone, formed by the joining of headwater streams, inhabited by *Diptychus maculatus* and *Noemacheilus spp*. In the upper reaches or the most torrential reaches of this zone, rheophilic species of the snow trouts *Schizothoraichthys esocinus*, *S. progastus*, *Schizothorax richardsonii* and *Schizopygopsis stoliczkae* occur. The intermediate reaches of the large stream zones are frequented by *Schizothorax longipinnis*, *S. planifrons* and *S. micropogon*. The least rapid reaches of this zone are occupied by *Garra gotyla*, *Crossocheilus diplochilus*, *Labeo dero* and *L. dyocheilus*; slow moving meandering zone inhabited by a large number of cold- to eurythermal species such as *Barilius spp*., *Tor spp*. cat fishes, homalopterid fish (*Homaloptera spp*.) and snakeheads (*Channa spp*.).

Pakistan is classified into six ecological zones (based on FRO 2000), with subtropical and temperate mountain forests covering the Hindu Kush – Himalaya. Based on the type of landscape, one can distinguish four physiographic regions in Pakistan (according to: T. Petr: “Fish and fisheries at higher altitudes: Asia”, FAO, Rome, 1999.). Cold water fishes in Pakistan are limited to the higher latitudes of the northern half of Pakistan, where three mountain systems extend from the west to the east: the Hindu Kush, Karakoram and Himalayas. In the northern mountains of Pakistan the Indus River, which itself originates in Tibet (China), receives a number of tributaries, viz. Gilgit, Swat, Kunhar, Neelum and Jhelum. Further downstream, already in the plains, the rivers Chenab, Ravi and Sutlej, all of which arise from the Indian Himalayas, join the Indus River from the east. There are no Coldwater fish zones classified for Pakistan.

None of the above mentioned factors such as forests, fish types and physiographic regions have been used collectively for ecological zone classification of rivers as river typology. A further differentiation of river types can be developed by using criteria that are easily accessed in each HKH partner country. Adopting a proven procedure that has been outlined in the European Water Framework Directive (WFD) it is hereby proposed that the characterization of river types in HKH should be done using fixed categories of parameters to classify rivers *viz.*, altitude range, catchment size ranges, and three geological categories. The FRO 2000 based eco-regions were found insufficient for the comparison of eco-regions in the whole of HKH region leading towards classification of river types. Hence, as an alternative method of classifying eco-regions based also on forests type but with a broader coverage was explored (source: WWF Global 200 Eco-regions). The river types within each eco-region should then be differentiated according to the description set out in the following table 2.

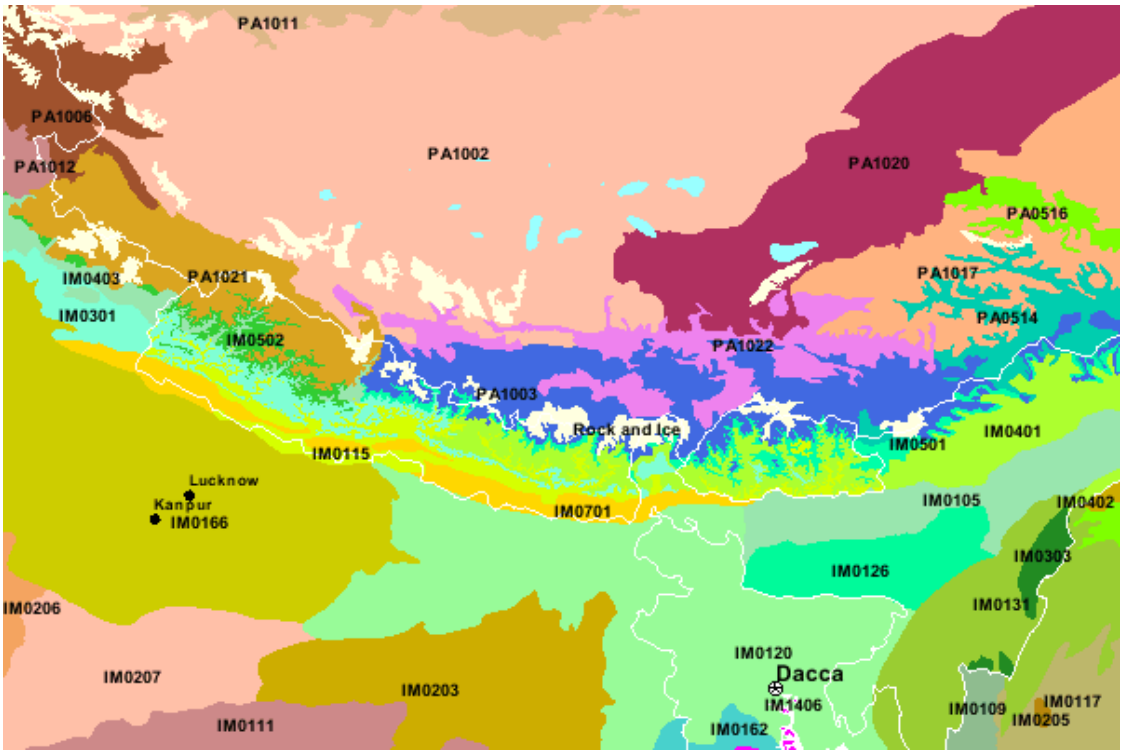
Table 2. Proposed range of descriptive features for differentiating the ecoregions using three criteria.

Fixed Typology	Description
Type	1. Altitude typology Very high land >3200 High land 1600-3200 Upland 800 –1600 m Midland 200 to 800 m Lowland < 200 m 2. Size typology based on catchment area small 10 – 100 km² medium > 100 to 1000 km² large > 1000 to 10000 km² very large > 10000 km² 3. Geology calcareous siliceous organic

2. SHORT DESCRIPTION OF SELECTED ECOREGIONS

2.1. Lower Gangetic Plains moist deciduous forests (IM0120)

The Lower Gangetic Plains Moist Deciduous Forests [IM0120] lie along the confluence of two of Asia's largest rivers, the Ganges and Brahmaputra Rivers, which run the length of the Himalayan foothills and drain its breadth. The ecoregion supports one of the dense human populations on Earth, and the fertile alluvial plains have been cleared and intensely cultivated. The human activities that date back thousands of years have taken a very heavy toll on the natural biodiversity of the ecoregion, and many of these species have disappeared from the ecoregion.



The tropical moist deciduous forests represented by this ecoregion once stretched along the lower reaches of the Ganges and Brahmaputra river plains across the Indian states of Bihar, West Bengal, Assam, Uttar Pradesh, and Orissa, and most of Bangladesh. The southwest monsoon that sweeps in from the Bay of Bengal deluges the ecoregion with more than 3,500 mm of rainfall during the four months from June to September. Devastating cyclones sweep in from the Bay of Bengal, causing widespread flooding.

The alluvial substrate deposited by the rivers is clayey and drains poorly, but on the more stable but flood-prone riverine flats the soil tends to be more sandy, with only local clay patches.

2.2. Himalayan subtropical pine forests (IM0301)

The Himalayan Subtropical Pine Forests [IM0301] are the largest in the Indo-Pacific region. They stretch throughout most of the 3,000-km length of this the world's youngest and highest mountain range. It is believed that climate change and human disturbance are causing the lower-elevation oak forests to be gradually degraded and invaded by the drought-resistant Chir pine (*Pinus roxburghii*), the dominant species in these subtropical pine forests. Biologically, the ecoregion does not harbor exceptionally high levels of species richness or endemism, but it is a distinct facet of the region's biodiversity that should be represented in a comprehensive conservation portfolio.

The subtropical pine forests represented by this ecoregion extend as a long, disjunct strip from Pakistan in the west, through the states of Jammu and Kashmir, Himachal Pradesh, and Uttar Pradesh in northern India, into Nepal and Bhutan. Although Champion and Seth (1968) indicate the presence of large areas of Chir pine in Arunachal Pradesh, the easternmost extent of large areas of Chir pine is in Bhutan.

The world's deepest river valley, the Kali Gandaki, bisects the ecoregion in Nepal, dividing it into a drier, western conifer forest and a wetter and richer eastern conifer forest. However, the species assemblages, community structure, and ecosystem dynamics are not sufficiently different to separate this pine forest into eastern and western ecoregions, as was done for the broadleaf forest ecoregions.

Most of the rainfall is brought by the southwestern monsoon from the Bay of Bengal. The monsoon rains are intercepted and expended in the eastern Himalayas, which are closer to the Bay of Bengal; therefore, the western region receives less precipitation. The climatic gradient influences the vegetation in the Himalayas. For instance, the treeline in the western Himalayas is more than 500 m lower than in the east (Kendrick 1989).

2.3. Eastern Himalayan broadleaf forests (IM0401)

The Eastern Himalayan Broadleaf Forests [IM0401] is one of the few Indo-Pacific ecoregions that is globally outstanding for both species richness and levels of endemism. In addition to the outstanding levels of species diversity and endemism, the ecoregion also plays an important role in maintaining altitudinal connectivity between the habitat types that make up the larger Himalayan ecosystem.

This ecoregion represents the band of temperate broadleaf forest between 2,000 and 3,000 m, stretching from the deep Kali Gandaki River gorge in central Nepal, eastward through Bhutan,

into India's eastern states of Arunachal Pradesh and Nagaland. Champion and Seth (1968) identified a number of broadleaf forest types across the mid-elevations (1,500-3,000 m) of the Himalayas.

The monsoon rains provide about 2,000 mm of precipitation from May to September. Because these monsoons are funnelled in from the Bay of Bengal, the eastern Himalayas receive the greatest rainfall, with a progressively drier trend toward the west. Thus, precipitation, topography, and temperature combine to influence the vegetation across this ecoregion.

The Eastern Himalayan Broadleaf Forests [IM0401] is globally outstanding for both species richness and endemism, especially for its flora. It contains several localized areas of floral richness and endemism-floral hotspots-which are especially rich in rhododendrons and oaks.

2.4. Western Himalayan broadleaf forests (IM0403)

Because the western Himalayas are drier than the eastern extent, the Western Himalayan Broadleaf Forests [IM0403] are less species-rich than their eastern counterpart. This ecoregion is nevertheless of regional conservation importance for its biodiversity and for its role as a critical link in the chain of Himalayan ecosystems that are layered along the steep south-facing slopes.

This ecoregion represents the temperate broadleaf forests of the western Himalayas, to the west of the Kali Gandaki River gorge in Nepal, through northern India's states of Uttar Pradesh and Himachal Pradesh, and into Jammu and Kashmir, with small sections extending into Pakistan. These temperate forests form a narrow east-west-directed band between 1,500 and 2,600 m.

The Himalayan Range receives most of its moisture from the southwestern monsoon that originates in the Bay of Bengal. The moisture-laden monsoon winds are funneled through the Gangetic Plains toward the mountain range, where most of the precipitation is intercepted by the eastern Himalayas. The western extent therefore receives less precipitation. The drier climate in the west influences the vegetation. For instance, the treeline declines from 4,000 m in the east to about 3,500 m in the west (Kendrick 1989).

3. AIMS & SCOPE

The main aim of this report is to document the different geo-morphological characteristics of the Hindu Kush - Himalayan (HKH) Rivers leading to the development of a simple and operative classification system called as STREAM TYPOLOGY.

The stream typology is based on the collection of existing data. All partners participated in contributing to this.

4. METHODOLOGY

The process of stream classification was based on the following steps:

- A general questionnaire was circulated to each partner countries before the Kick-Off meeting in Brno, Czech Republic.
- On the kick-off meeting in June 2005 the participants presented the state of the art in stream classification at partner countries.
- At the end of Kick-Off the Workpackage leader compiled a comparative chart of the geo-morphological description of the streams in the partner countries.
- Based on the experiences with the first phase of the site selection process, the information given by partner countries were validated leading to a circular by the Workpackage leader to the Asian partners.
- Based on the above mentioned guidelines the partners selected their sampling sites and provided the Workpackage leader with the necessary information.
- The Workpackage leader prepared the report as deliverable 4

Simultaneously, an intensive discussion concerning the stream typology was performed. This was mainly done through the discussion forum on the project homepage. The above mentioned discussion lead to a number of alterations in describing stream types based on ecoregion, conditions of geology, catchments, altitude etc.

5. RESULTS

5.1. The ASSESS-HKH stream types

a) Present status on stream typology

A questionnaire was circulated to all partners (See Annex) to collect information regarding river typology in partner countries. Rivers type classification based on macroinvertebrates as bio-indicators is not known from the region (Table 3). Although immense knowledge on macroinvertebrates taxonomy is available from HKH, criteria describing stream types based on macroinvertebrates has not yet been performed. The ecoregion or bioregion approach exists in some countries but its use for water management is not known from the region. Criteria used to delineate ecoregions/bioregions in these countries are mostly based on forests type. However, so far as hydrological and hydro-morphological information on river systems is concerned, data are available at government and non governmental agencies. Special permission is needed to procure such information from the government due to socio-political sensitivity of the region. Information are available on ecological zones with emphasize on forestry (FRO 2000) and physiographic regions (Rashid 1991) in Bangladesh and Bhutan. Additionally, river systems in Nepal and India are classified based on fish fauna as coldwater fish zones.

Table 3. State of art about stream typology in partner countries

Partner countries	Yes	No	Under Development
Pakistan			X
India			X
Nepal		X	
Bhutan		X	
Bangladesh		X	

In torrential streams of India, Sehgal (1988) identified several zones on the basis of dominant fish species and the hydrographical features reaches or the most torrential reaches of this zone. J. Shrestha described the Coldwater fish zones for Nepal (in T. Petr (1999): "Fish and fisheries at higher altitudes: Asia", FAO , Rome). Similarly, zoning for the Bagmati River is also based on the presence of the dominant fish species. Thirty-five cold water species have been identified from the River Kali Gandaki alone. Edds (1989) gives species zonation for the Kali Gandaki/Narayani rivers. The River Karnali arises on the Tibetan Plateau and enters Nepal, to become the major river system in Western Nepal. Menon (1954) recorded *Noemacheilus* spp as the dominant genus in this river, and Jha and Shrestha (1986) found *S. plagiostomus* in the upper reaches of it.

b) Strategy for the selection of stream types

In ASSESS-HKH, four different kinds of stream types were proposed for investigation (Table 4). Streams' flowing through the Himalayan subtropical pine forests were considered as "core" for this ecoregion was shared by all countries except Bangladesh. In Bhutan this ecoregion covered the Southern Mountain and Gorges, which is equivalent in Nepal as Middle Mountains. In India, Kulu valley formed by river Beas is selected as similar ecoregion. The other alternative ecoregions would have been Yamuna valley in Garhwal-Kumaon Himalaya.

Table 4. Ecoregions based stream classification in the Hindu Kush-Himalayan region.

Ecoregions*	Bd	Bh	Np	Id	Pk
1. Eastern Himalayan broadleaf forests (IMO401)					
• Inner Valleys and Passes in Western and Central Bhutan		x			
• Midhills and Mahabharata range			x		
2. Himalayan subtropical pine forests (IMO301)					
• Southern mountain and gorges		x			
• Middle mountains and valleys			x		
• Kulu valley (River Beas Basin)				x	
• The Salt Ranges (Indus River basin)					x
3. Western Himalayan broadleaf forests (IMO403)					
• Almora hills in the Kumaon Himalaya				x	
• Muree hills in the Kala Chitta Range					x
4. Lower Gangetic Plains moist deciduous forests (IMO120)					
• Padma and Meghna river basin	x				
• Terai			x	x	

** WWF Global 200 ecoregions*

The Eastern Himalayan broadleaf forests spread from Bhutan to Nepal. In Bhutan it covers the region with Inner Valleys and Passes in Western and Central Bhutan and in Nepal it covers the Midland Valleys and Mahabharata ranges. India shares Himalayan subtropical pine forests and Western Himalayan broadleaf forests with Pakistan.

Bangladesh is predominantly in the Lower Gangetic plains. It covers nearly whole of Bangaldesh. Bangladesh has five major networks. The fifth network unconnected to the other four is the Karnaphuli, which is flowing through the region of Chittagong and the Chittagong Hills. This may be considered the mid-sized river for consideration in ASSESS-HKH. The *Terai* in Nepal and India is lowland area extending east-west similar to Lower Gangetic plains in Bangladesh. They occupy a position which is more or less parallel to the lower Himalaya.

Core stream type:

- To be sampled in: Bhutan, Nepal, India, and Pakistan
- Characterization:
    - catchment area of 50 - 500 km^2
    - altitude range of 1000 - 3000 m
    - ecoregion of Himalayan subtropical pine forests
    - Predominantly silicious catchment geology

Other stream types:

- To be sampled in: Bhutan and Nepal

  Characterization:
    - catchment area of 50-500 km^2
    - altitude range of 800-2000
    - ecoregion of Eastern Himalayan broadleaf forests
    - Predominantly calcareous catchment geology

- To be sampled in: India and Pakistan

  Characterization:
    - catchment area of 50-500 km^2
    - altitude range of 800-2500m
    - ecoregion of Western Himalayan broadleaf forests
    - Predominantly calcareous catchment geology

- To be sampled in: Bangladesh, India and Nepal

  Characterization:
    - catchment area of 500-1000 km^2
    - altitude range of 45-250 m
    - ecoregion of Lower Gangetic Plains moist decidious forests
    - Predominantly alluvial deposits catchment geology

5.2. The ASSESS-HKH stressors

In ASSESS-HKH, four different kinds of stressors are selected (Table 5):

- Organic pollution (op)
- Effect of water abstraction in the river channel upstream the weir (Rd1)
- Effect of water abstraction in the river channel downstream the weir with residual flow (Rd2)
- Effects of River Engineering (re)

Table 3. Region specific stream types and selection of stressors

	Bd					Bh					Np					Id					Pk				
	Rf	op	Rd1	Rd2	re	Rf	op	Rd1	Rd2	re	Rf	op	Rd1	Rd2	re	Rf	op	Rd1	Rd2	re	Rf	op	Rd1	Rd2	re
IMO401											4	6	2	4	1										
IMO301																									
IMO403																									
IMO120																									

note: numbers in table indicate sites selected.

Organic pollution and water abstraction are considered as main stressors. Only in cases of un-availability of category classes in the sequence of 4 as I, 4 as II, 3 as III, 3 as IV, and 3 as V or inaccessibility of the sites in the specified ecoregions, inclusion of river engineering such as pavements and river straightening shall be considered.

6. SUMMARY

- Based on all available literature relating to ecoregion delineation, it was decided that unless we have our own HKH bioregions, following four ecoregions and ten bioregions will be accepted for our study.

  1. Eastern Himalayan broadleaf forests (IMO401) ecoregion
     - Inner Valleys and Passes in Western and Central Bhutan
     - Midhills and Mahabharata range
  2. Himalayan subtropical pine forests (IMO301) ecoregion
     - Southern mountain and gorges
     - Middle mountains and valleys
     - Kulu valley (River Beas Basin)
     - The Salt Ranges (Indus River basin)
  3. Western Himalayan broadleaf forests (IMO403) ecoregion
     - Almora hills in the Kumaon Himalaya
     - Muree hills in the Kala Chitta Range
  4. Lower Gangetic Plains moist deciduous forests (IMO120) ecoregion
     - Padma and Meghna river basin
     - Terai
- The above described basis of ecoregion delineation shows that it would be wise to define our own HKH bioregions because so many different ecoregion scales exist. We suggest to give it a name "HKH aquatic bioregions".
- The HKH aquatic bioregions will serve as the geographical basis of our river typology.
- For continuing the river typology we need to collect data on altitude ranges, catchment size, and existing chemical data of our targeted stream types. In deciding which stream type(s) per bioregion to be investigated a stream type based on combination of all three criteria is suggested.
- After having determined the stream types to be studied, the impacts to be studied were fixed as organic load and water abstraction.
- After having decided which impacts we want to document the number of sampling sites to be considered under each stresses were decided. Different partner countries will have different numbers of total sites to be considered, which again will be based on state of the river to be investigated (Table 6):

Table 6. Total number of unstressed or reference (R) and stressed or degraded (D) sites in HKH

Country	Bd		Bh		Np		Id		Pk	
Ecoregions/Status	R	D	R	D	R	D	R	D	R	D
1. Eastern Himalayan broadleaf forests (IMO401)										
i. Inner Valleys and Passes in Western and Central Bhutan			4	13						
ii. Midhills and Mahabharata range					4	13				
2. Himalayan subtropical pine forests (IMO301)										
i. Southern mountain and gorges			4	13						
ii. Middle mountains and valleys					4	13				
iii. Kulu valley (River Beas Basin)							4	13		
iv. The Salt Ranges (Indus River basin)									4	13
3. Western Himalayan broadleaf forests (IMO403)										
i. Almora hills in the Kumaon Himalaya							4	13		
ii. Muree hills in the Kala Chitta Range									4	13
4. Lower Gangetic Plains moist deciduous forests (IMO120)										
i. Brahmaputra-Jamuna Basin	8	26								
ii. Terai					4	13	4	13		
Total sites considered:	8	26	8	26	12	39	12	39	8	26

6. ANNEXURE

Annex 1: Questionnaire on stream typology

1. Does a stream typology exist in your Country?

   ☐ yes

   ☐ under development (To be finished in which month/year?)

   ☐ no

   If **yes**, or **under development** please answer question 2.

   If **no**, please proceed with question 5.

2. What criteria are used to describe stream types for your Country? Additional to your answer please give the source of information (references, reports, position papers etc.).

3. Is the ecoregion or bioregion approach used as a tool for water management in your Country?

   ☐ yes

   ☐ under development (To be finished in which month/year?)

   ☐ no

   If **yes**, or **under development** please answer question 4.

   If **no**, please proceed with question 5.

4. What criteria are used to delineate ecoregions/bioregions for your Country? Additional to your answer please give the source (of information (references, reports, position papers etc.).

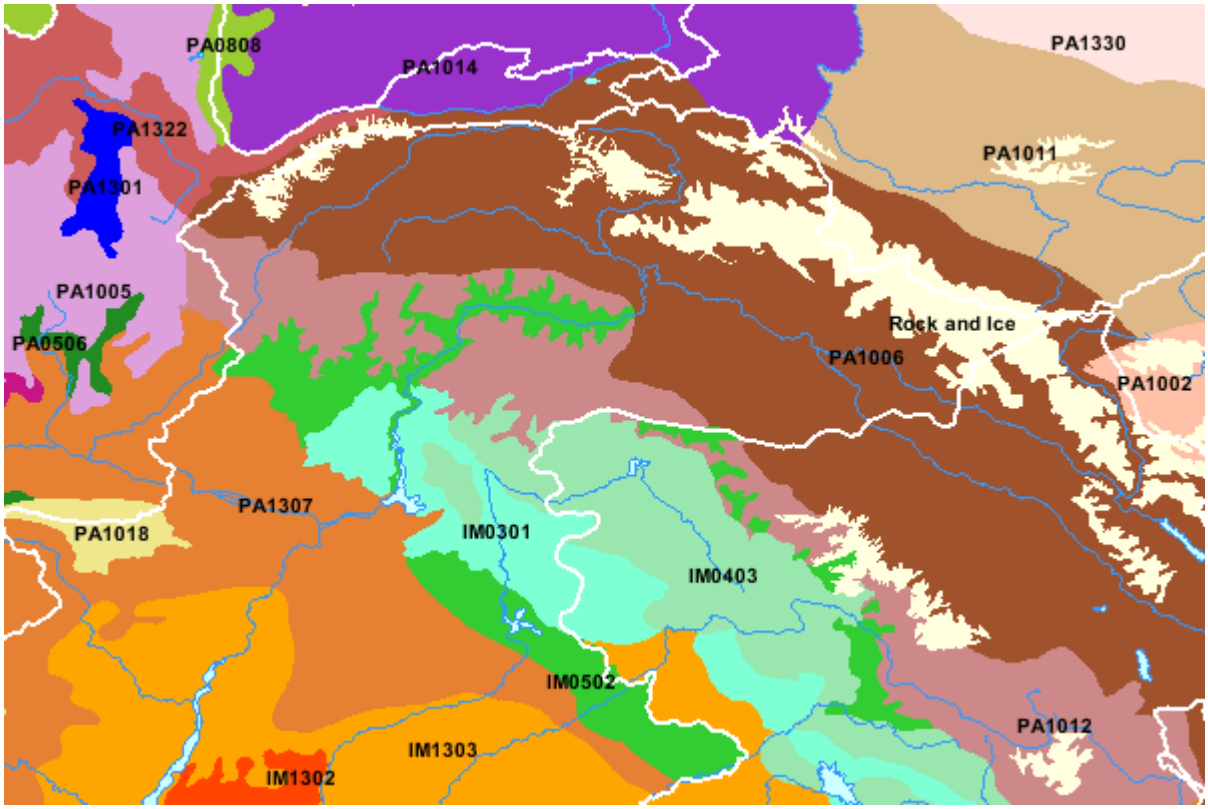
5. Please add information about “typologies”, “regions” and “zone” in country that can finally serve as input for the development of a common HKH stream typology.

Please send the filled questionnaires to the WP leader, Subodh Sharma (KU) latest till May 25. Don’t forget that we need the information before the kick-off meeting to be able to make the first decisions at the meeting.

Otto Moog
(co-ordinator)

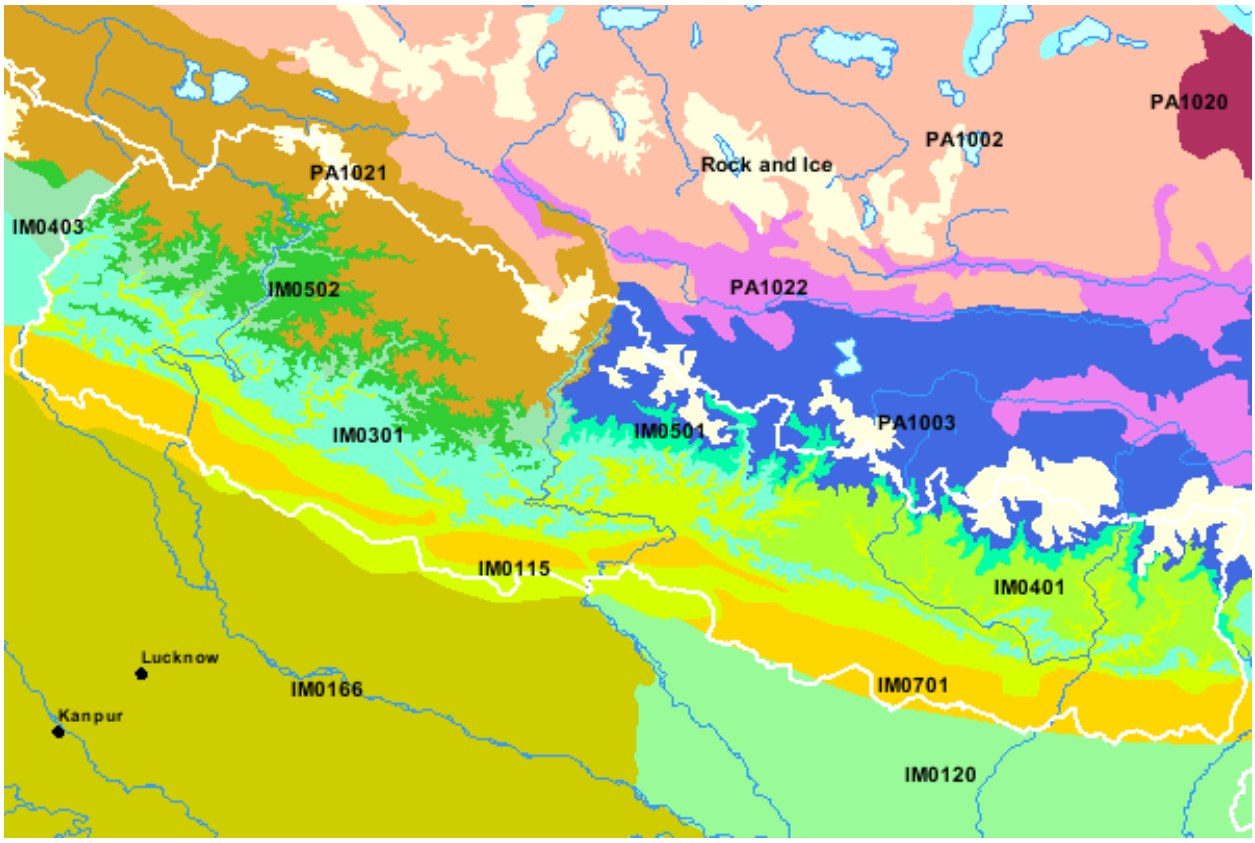
Subodh Sharma
(WP-leader)

Annex 2: Maps showing ecoregions of North-Pakistan (Source: WWF Global 200 Ecoregions)



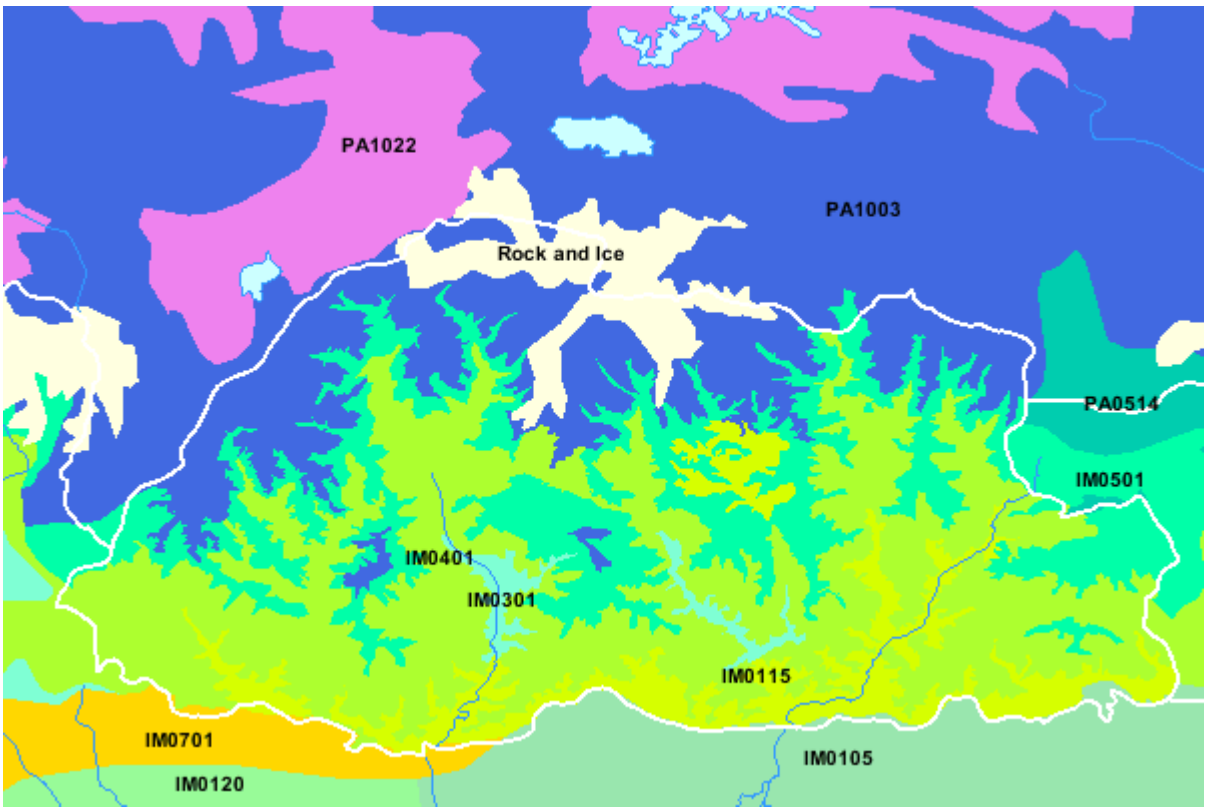
IM0301	**Himalayan subtropical pine forests**
IM0403	**Western Himalayan broadleaf forests**
IM0502	**Western Himalayan subalpine conifer forests**
IM1302	***Indus Valley desert***
IM1303	**Northwestern thorn scrub forests**
PA1006	**Karakoram-West Tibetan Plateau alpine steppe**
PA1012	**Northwestern Himalayan alpine shrub and meadows**
PA1018	**Sulaiman Range alpine meadows**
PA1307	**Baluchistan xeric woodlands**

Annex 3: Maps showing ecoregions covering Nepal (source: WWF Global 200 Ecoregions)



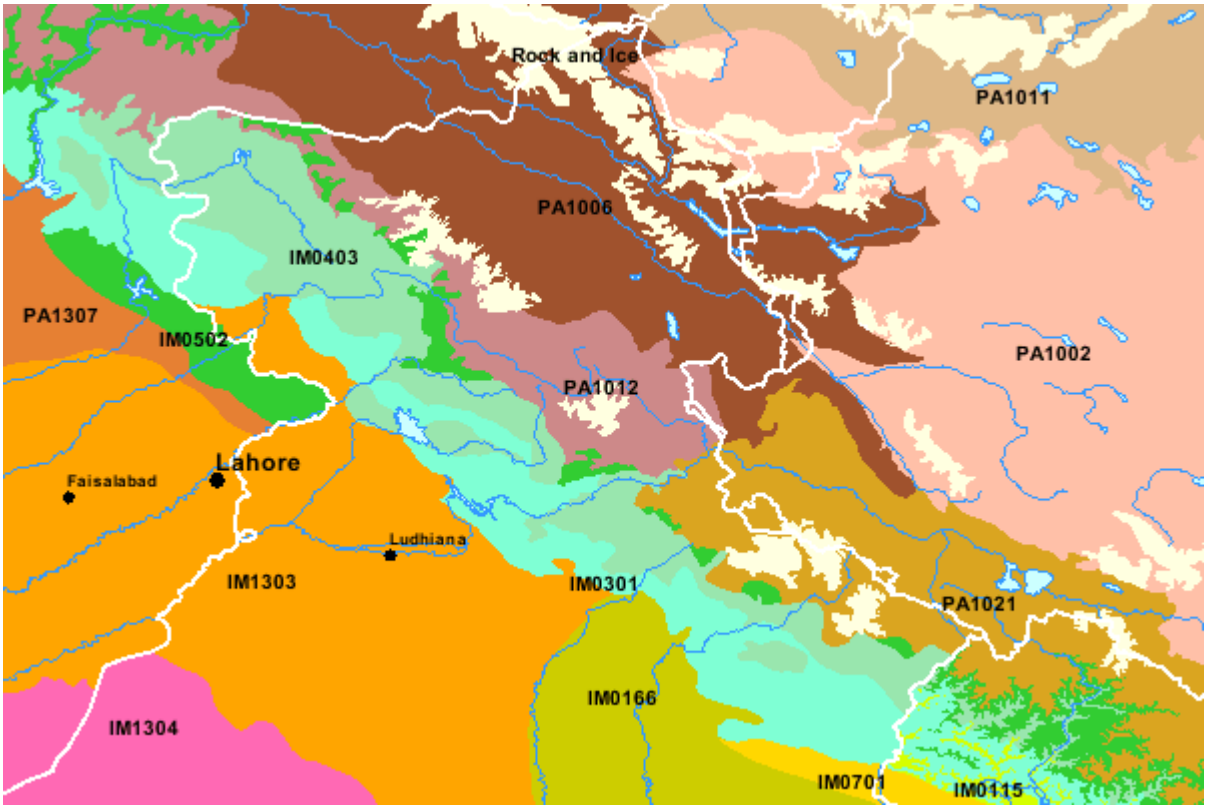
IM0115	**Himalayan subtropical broadleaf forests**
IM0120	**Lower Gangetic Plains moist deciduous forests**
IM0301	***Himalayan subtropical pine forests***
IM0401	**Eastern Himalayan broadleaf forests**
IM0403	**Western Himalayan broadleaf forests**
IM0501	**Eastern Himalayan subalpine conifer forests**
IM0502	**Western Himalayan subalpine conifer forests**
IM0701	**Terai-Duar savanna and grasslands**
PA1003	**Eastern Himalayan alpine shrub and meadows**
PA1021	**Western Himalayan alpine shrub and meadows**

Annex 4: Maps showing ecoregions covering Bhutan (source: WWF Global 200 Ecoregions)



IM0105	**Brahmaputra Valley semi-evergreen forests**
IM0115	**Himalayan subtropical broadleaf forests**
IM0301	***Himalayan subtropical pine forests***
IM0401	**Eastern Himalayan broadleaf forests**
IM0501	**Eastern Himalayan subalpine conifer forests**
IM0701	**Terai-Duar savanna and grasslands**
PA1003	**Eastern Himalayan alpine shrub and meadows**

Annex 5: Maps showing ecoregions covering North-India (source: WWF Global 200 Ecoregions)



IM0166	**Upper Gangetic Plains moist deciduous forests**
IM0301	**Himalayan subtropical pine forests**
IM0403	**Western Himalayan broadleaf forests**
IM0502	**Western Himalayan subalpine conifer forests**
IM1303	**Northwestern thorn scrub forests**
IM1304	***Thar desert***
PA1006	**Karakoram-West Tibetan Plateau alpine steppe**
PA1012	**Northwestern Himalayan alpine shrub and meadows**
PA1021	**Western Himalayan alpine shrub and meadows**

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