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System-scale planning to support sustainable energy systems and conservation of freshwater resources for people and nature

Nepal

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High Conservation Value Rivers of Nepal

Final Report – December 16th, 2020

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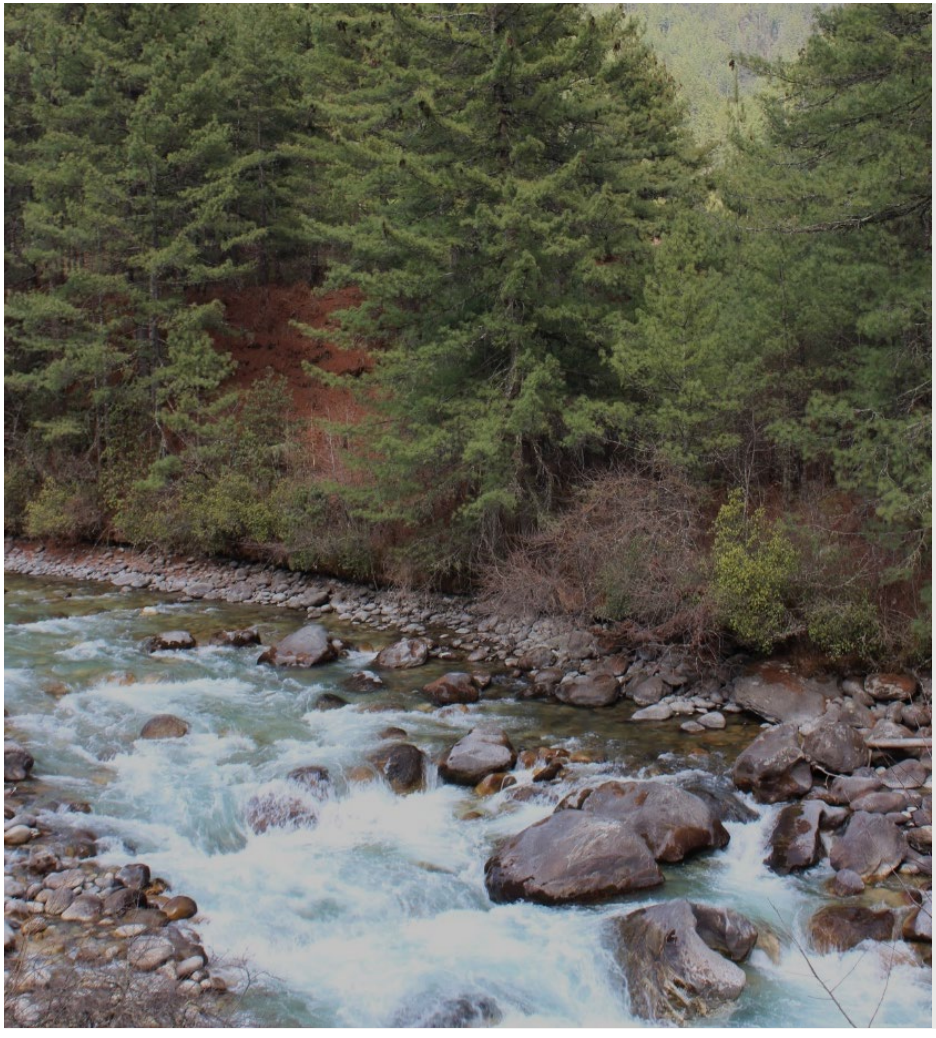
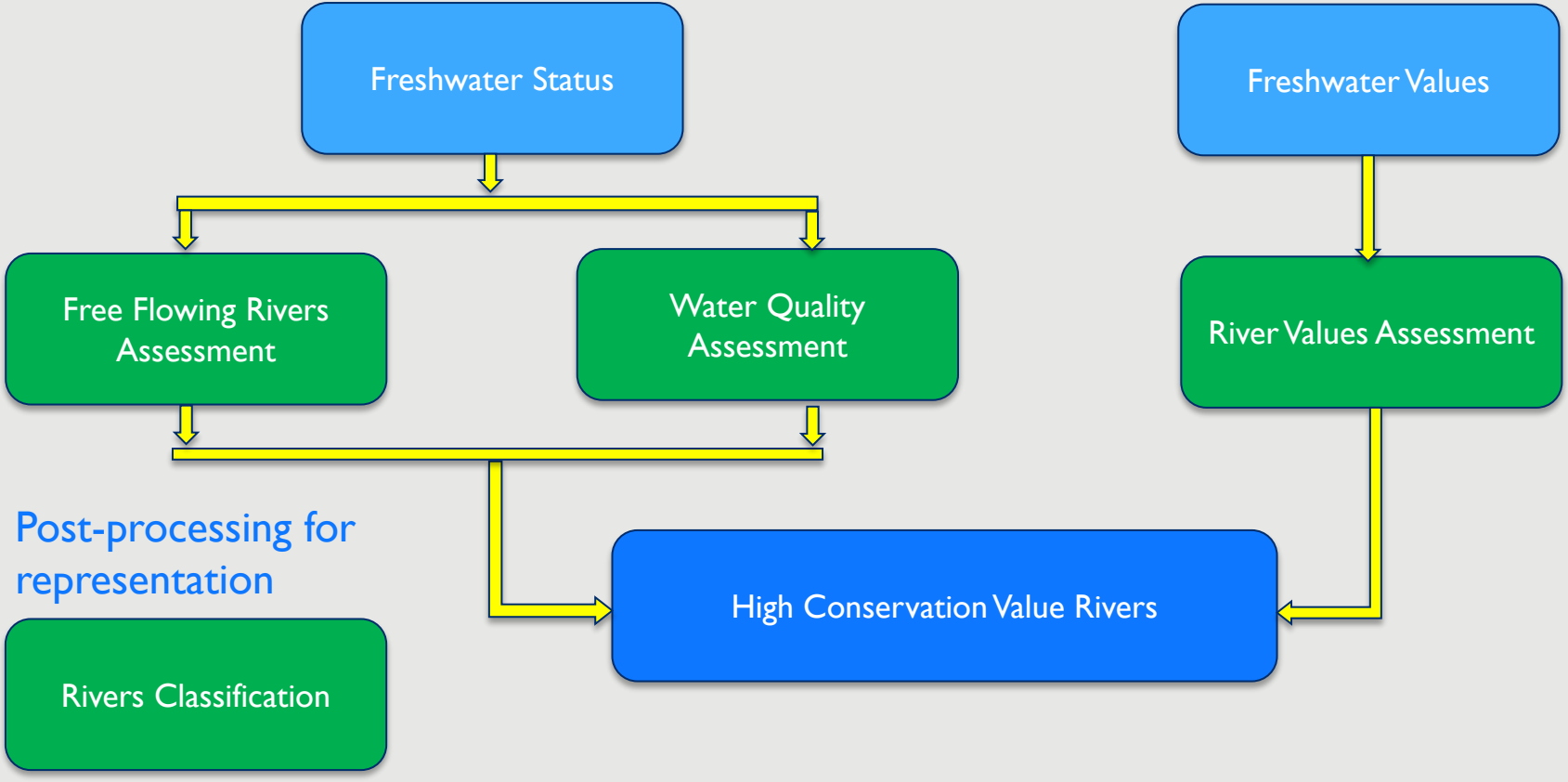


Why "High Conservation Value (HCV) Rivers" Assessment?

- Increasing degradation of rivers
- Loss of ecological, livelihood, tourism, cultural & other values
- Demand to maintain portion in "Natural" state for service delivery
- Baseline/reference rivers for understanding to compare against rivers which are being tapped for development
- Identify river or river stretches that are relatively still intact and that are providing critical ecosystem services to nature and to humankind
- Conserve freshwater integrity in selected rivers/ river stretches for current and future generations

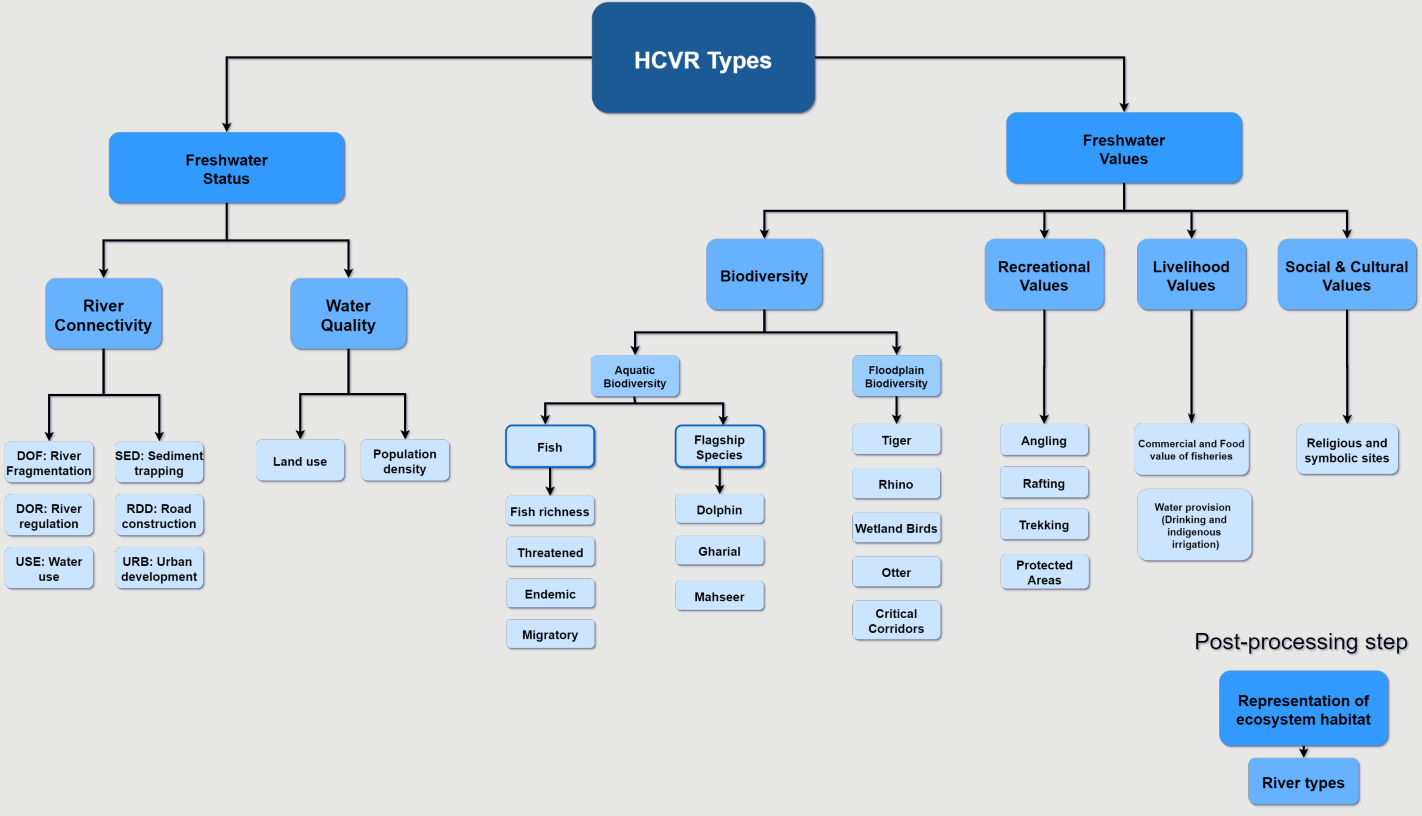
There are many components of a HCVR assessment



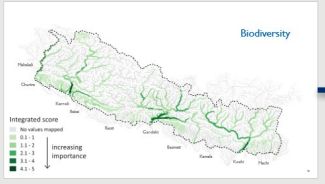
HCVR Definition within Nepalese Context

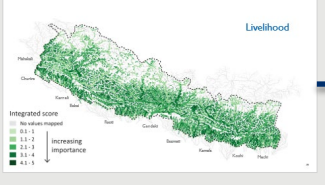
A *High Conservation Value River* is a **clean, highly connected** or **free-flowing** river or stretch that acts as **a lifeline**, maintaining **ecosystem services** for present and future generations, providing **refuge** and **habitat** for high levels of **aquatic biodiversity**, and supporting important **socio-cultural values.**

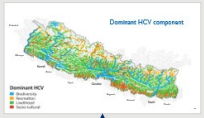
Overview of Freshwater Values and Status

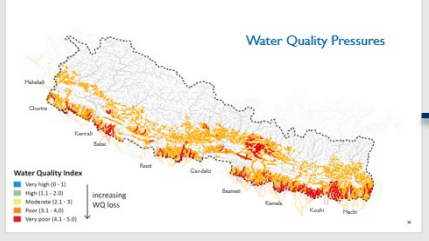


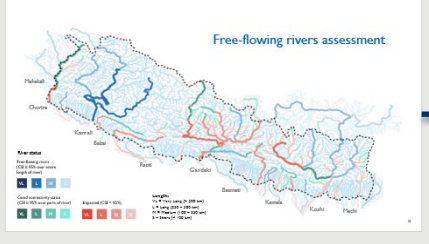
Overview of results

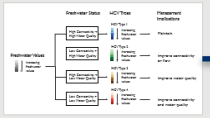


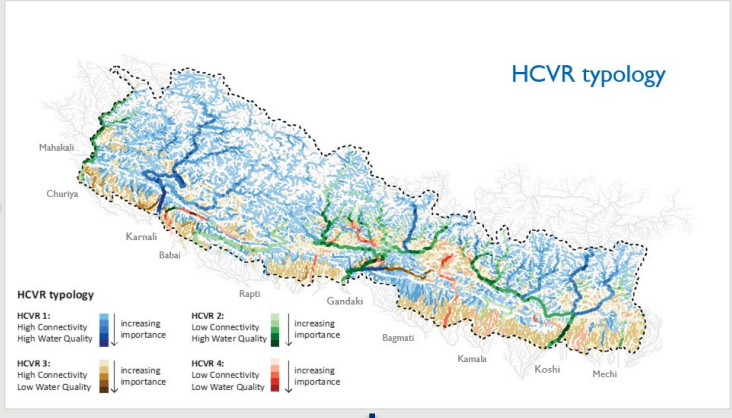


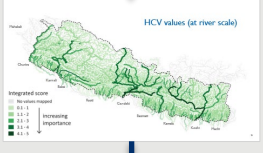


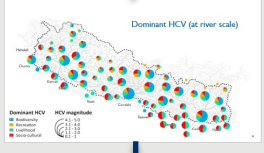


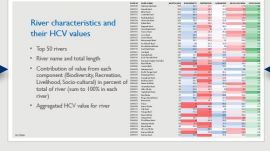




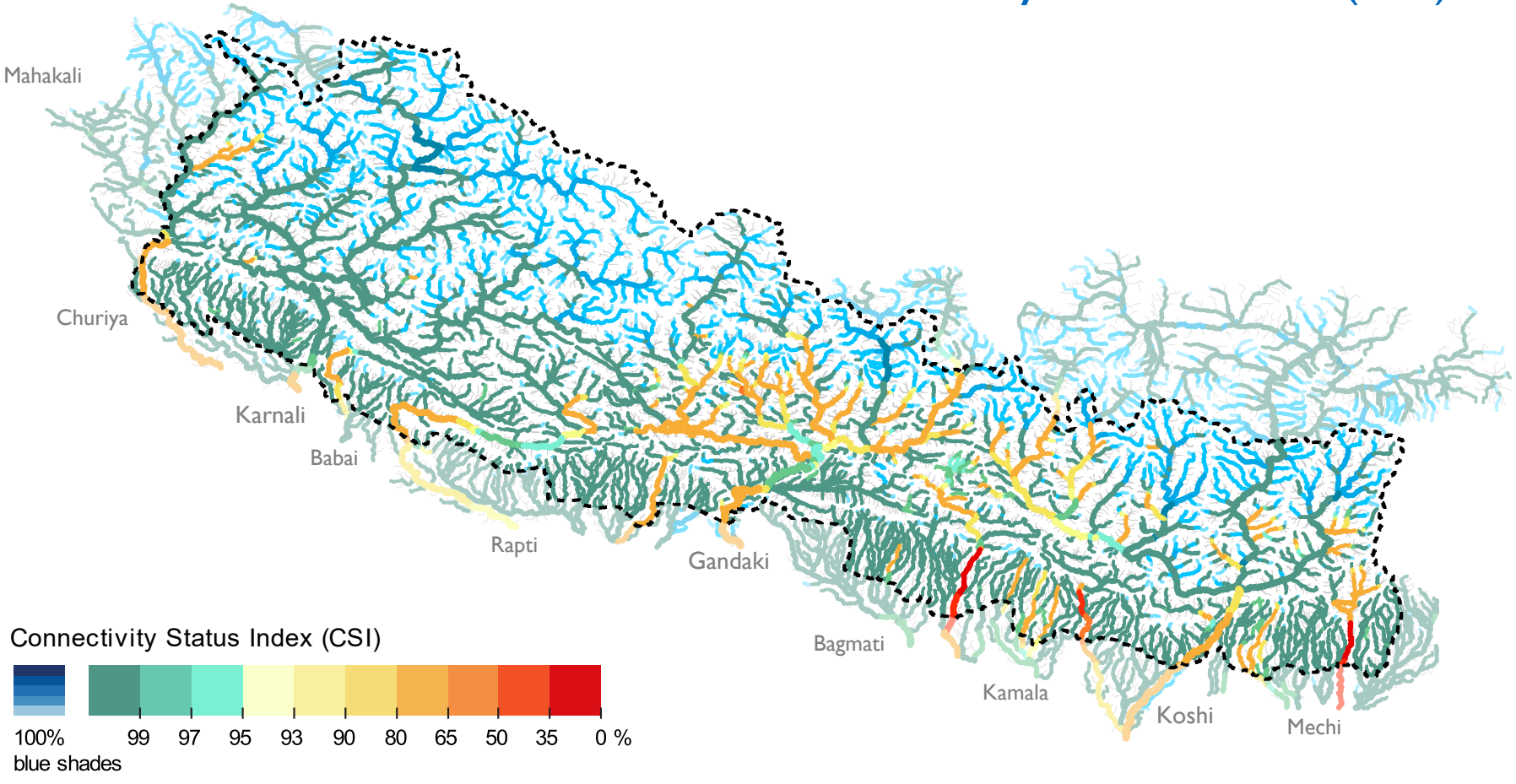




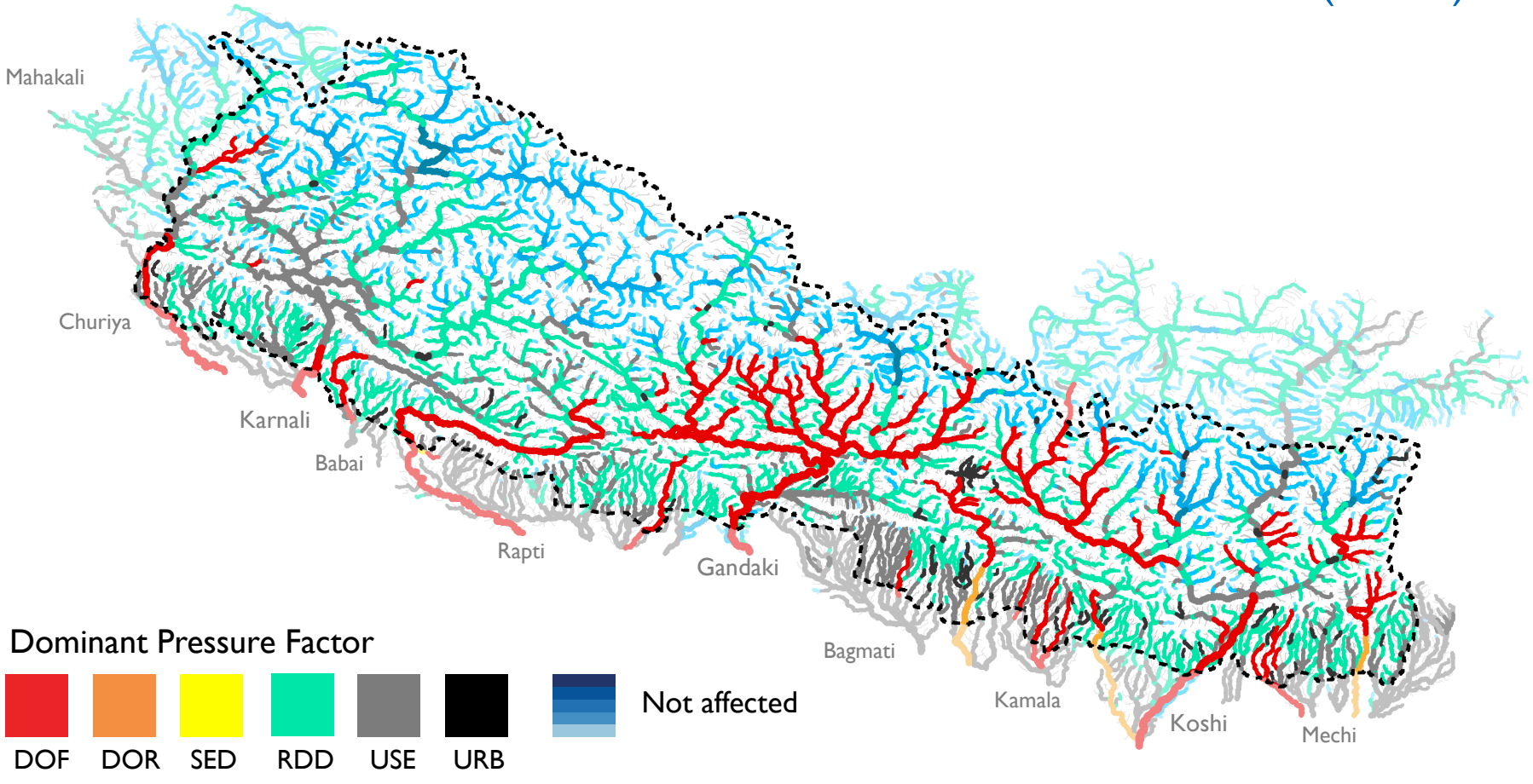




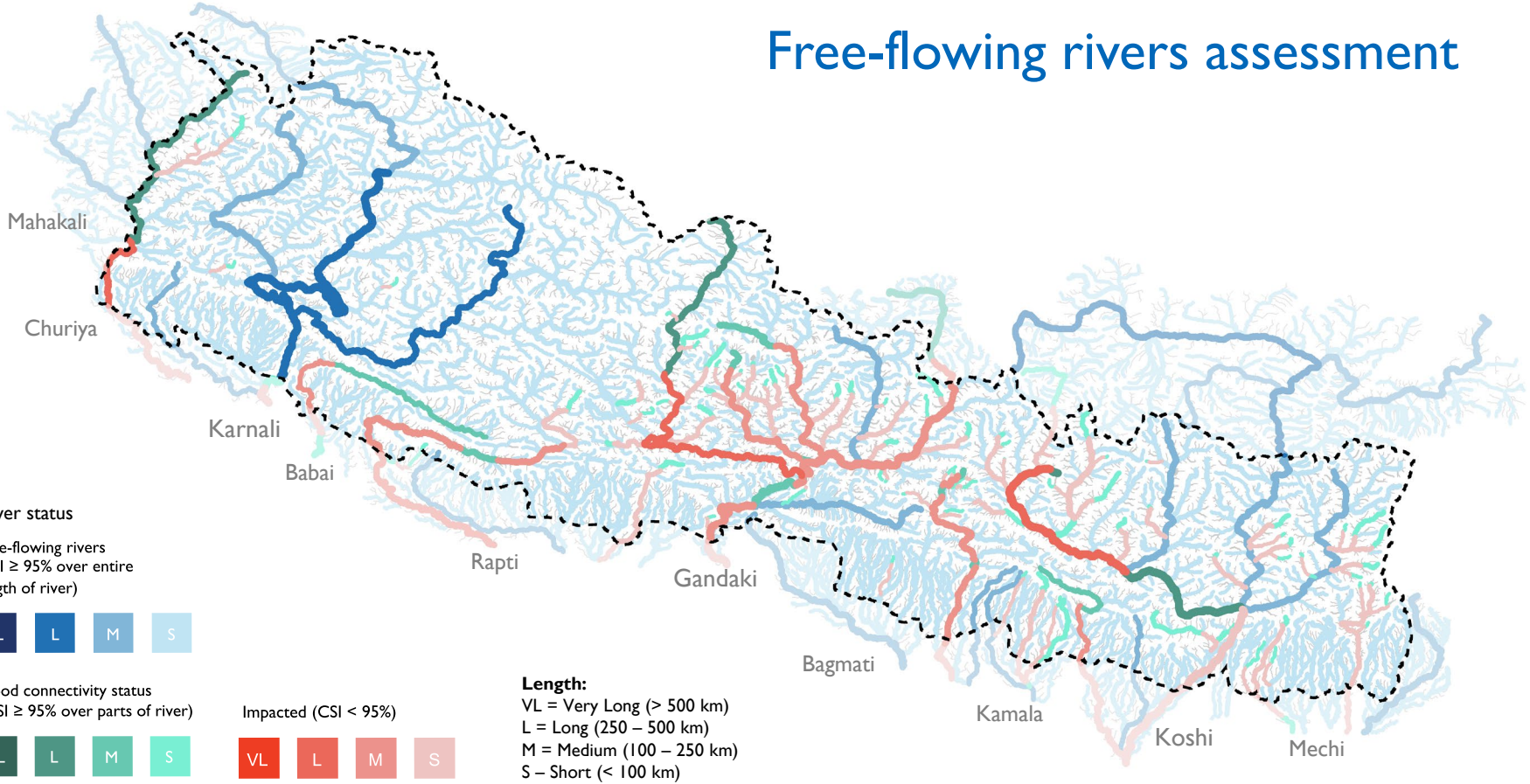
Connectivity Status Index (CSI)



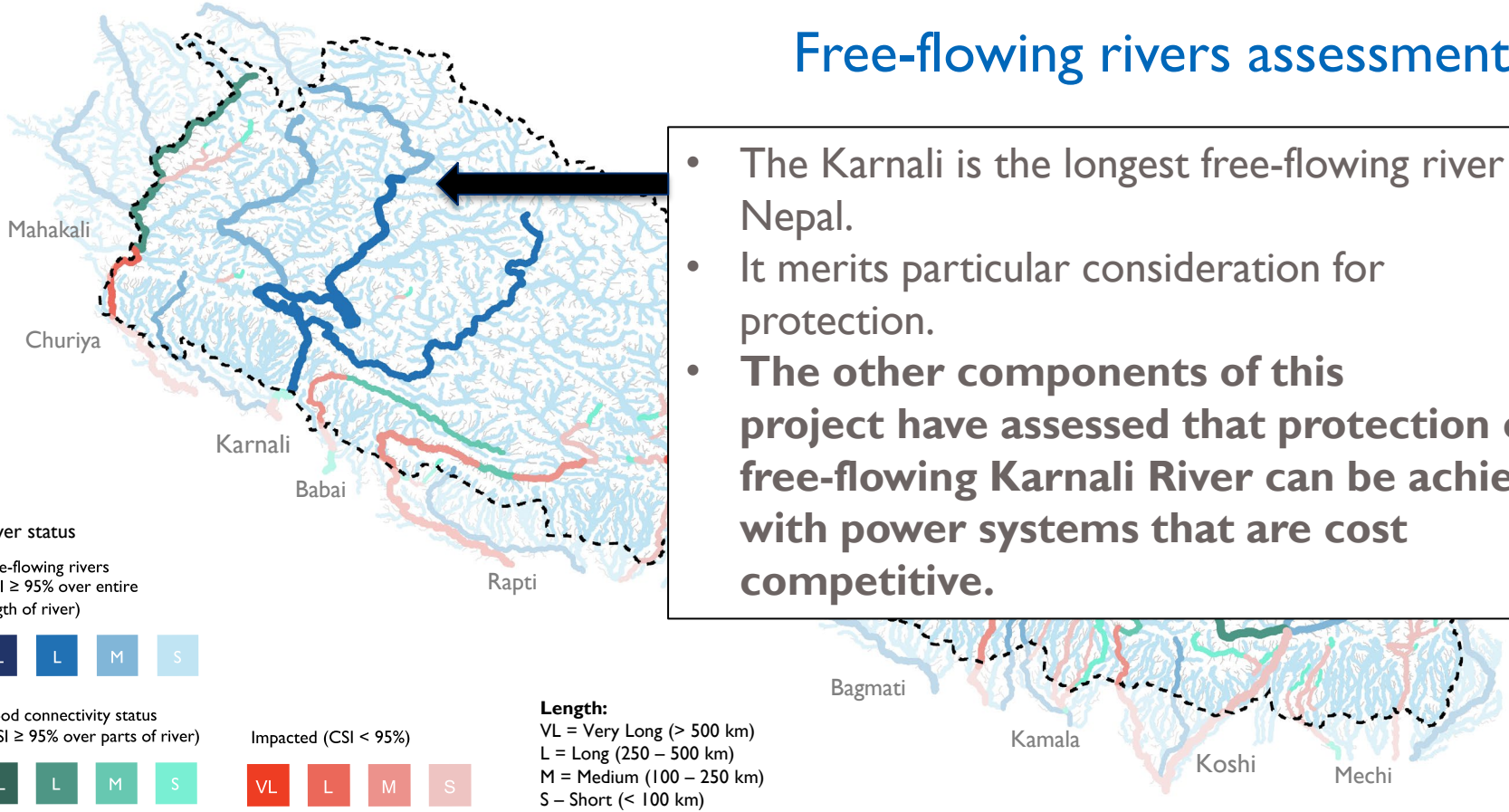
Dominant Pressure Factor (DOM)



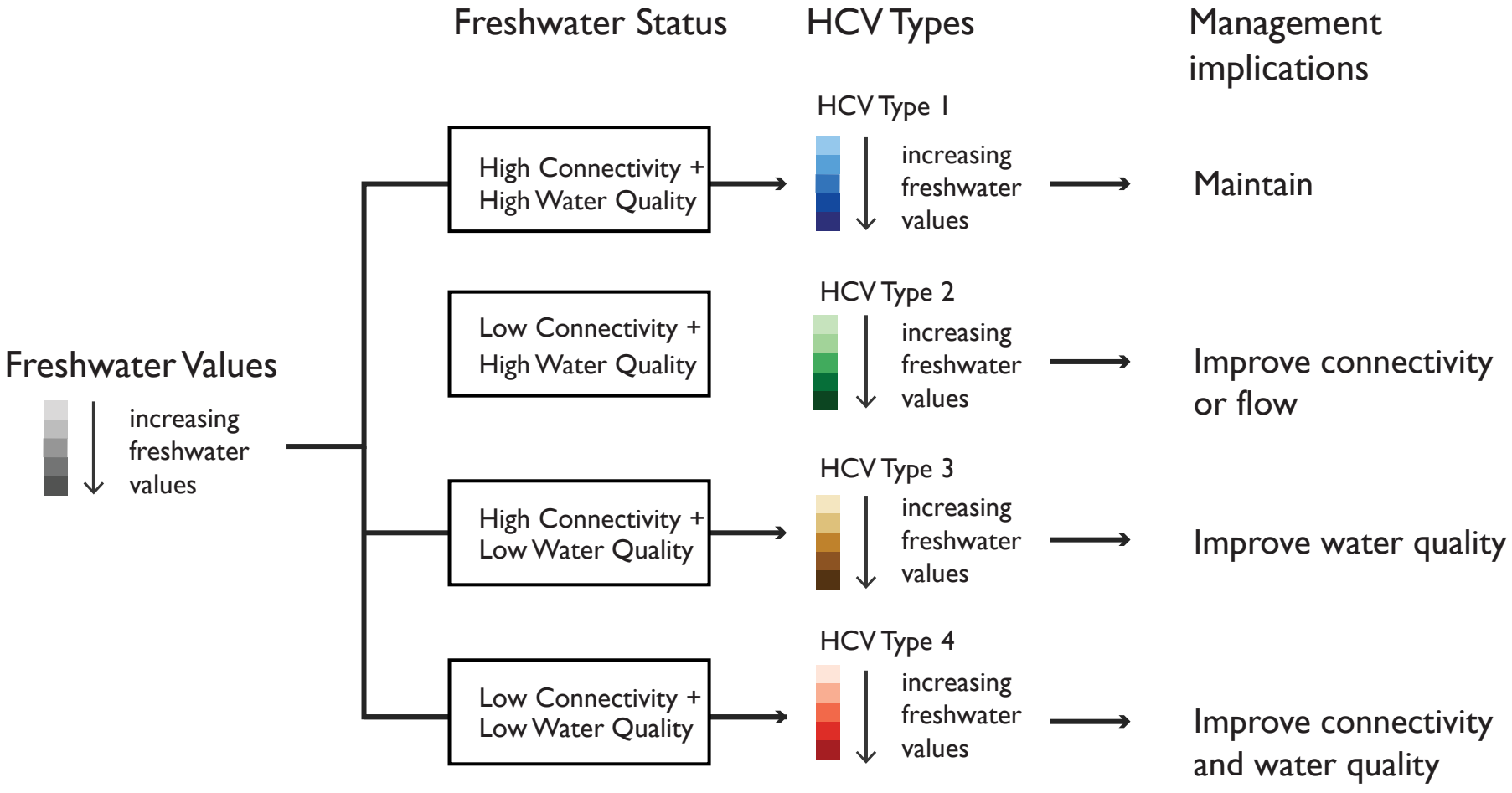
Free-flowing rivers assessment



Free-flowing rivers assessment



- The Karnali is the longest free-flowing river in Nepal.
- It merits particular consideration for protection.
- **The other components of this project have assessed that protection of a free-flowing Karnali River can be achieved with power systems that are cost competitive.**


Freshwater Status
HCV Types
Management implications
Freshwater Values
increasing freshwater values
High Connectivity + High Water Quality
Low Connectivity + High Water Quality
High Connectivity + Low Water Quality
Low Connectivity + Low Water Quality
HCV Type 1
increasing freshwater values
Maintain
HCV Type 2
increasing freshwater values
Improve connectivity or flow
HCV Type 3
increasing freshwater values
Improve water quality
HCV Type 4
increasing freshwater values
Improve connectivity and water quality

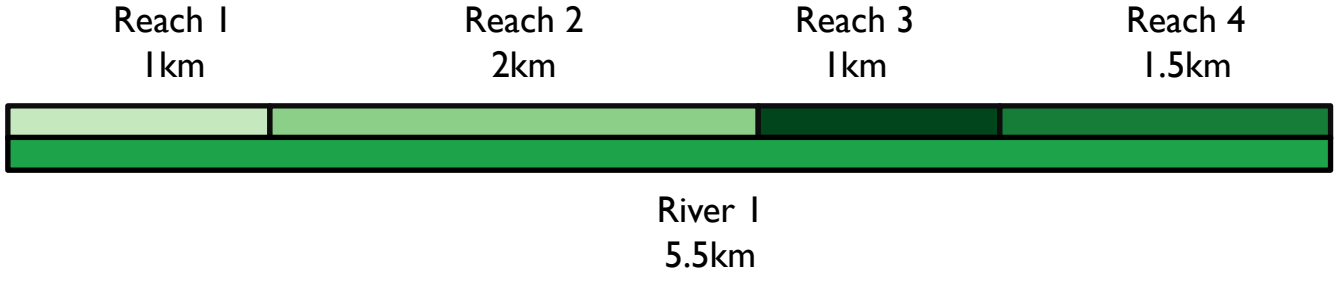
SN	Level	ID	Parent	Value_cat	Value_category	Weights_v1_Relative	Weight_v1 Global	Weights_v2_Relative	Weight_v2 Global	Weights_v3_Relative	Weight_v3 Global	Weights_v4_Relative	Weight_v4 Global
1	1	1		BIODIVERS	Biodiversity	25.0	25.0	50.0	50.0	55.0	55.0	60.0	60.0
1.1	2	2	1	AQUA_BIODIV	Aquatic Biodiversity	50.0	12.5	50.0	25.0	60.0	33.0	70.0	42.0
1.1.1	3	3	2	FISH	Fish	25.0	3.0	25.0	6.0	55.0	18.0	55.0	23.0
1.1.1.1	4	4	3	FISH_SPECIES	Fish richness	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.2	4	5	3	FISH_THRTND	Threatened	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.3	4	6	3	FISH_END	Endemic	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.4	4	7	3	FISH_MIGR	Migratory	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.4.1	5	8	7	FISH_LG_MIGR	Long Migratory	60.0	0.5	60.0	0.9	60.0	2.7	60.0	3.5
1.1.1.4.2	5	9	7	FISH_ST_MIGR	Medium and Short Migratory	40.0	0.3	40.0	0.6	40.0	1.8	40.0	2.3
1.1.2	3	10	2	MAHSEER	Mahseer	25.0	3.1	25.0	6.2	15.0	5.0	15.0	6.3
1.1.3	3	11	2	DOLPHIN	Dolphin	25.0	3.1	25.0	6.2	15.0	5.0	15.0	6.3
1.1.4	3	12	2	GHARIAL	Gharial	25.0	3.1	25.0	6.2	15.0	5.0	15.0	6.3
1.2	2	13	1	FLOOD_BIODIV	Floodplain/Wetland-Dependent Biodiv.	50.0	12.5	50.0	25.0	40.0	22.0	30.0	18.0
1.2.1	3	14	13	TIGER	Tigers	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.2	3	15	13	RHINO	Rhinos	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.3	3	16	13	BIRD	Wetland Birds	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.4	3	17	13	OTTER	Otter	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.5	3	18	13	CRITICAL_CORR	Critical Corridors	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
2	1	19		RECREATION	Recreation	25.0	25.0	16.7	16.7	15.0	15.0	15.0	15.0
2.1	2	20	19	ANGLING	Angling	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
2.2	2	21	19	RAFTING	Rafting	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
2.3	2	22	19	TREKKING	Trekking	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
2.4	2	23	19	PROTECTED	Protected Areas (large rivers)	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
3	1	24		LIVELIHOOD	Livelihood	25.0	25.0	16.7	16.7	15.0	15.0	10.0	10.0
3.1	2	25	24	FISH_COMM_FOOD	Commercial and Food value of Fisheries	50.0	12.5	50.0	8.3	50.0	7.5	50.0	5.0
3.2	2	26	24	PROVISION	Water provision	50.0	12.5	50.0	8.3	50.0	7.5	50.0	5.0
4	1	27		SOCIO_CULT	Socio-cultural	25.0	25.0	16.7	16.7	15.0	15.0	15.0	15.0
4.1	2	28	27	RELIGIOUS	Religious and Cultural Sites	100.0	25.0	100.0	16.7	100.0	15.0	100.0	15.0
						Equal Group		High Biodiversity (current)		High Biodiversity (alternative 1)		High Biodiversity (alternative 2)	

River characteristics and their HCV values

- Top 50 rivers
- River name and total length
- Contribution of value from each component (Biodiversity, Recreation, Livelihood, Socio-cultural) in percent of total of river (sum to 100% in each river)
- Aggregated HCV value for river

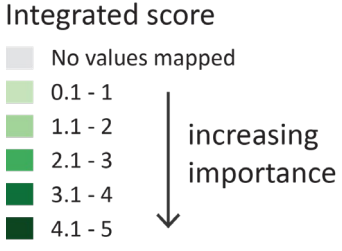
RIVER ID	RIVER NAME	LENGTH (KM)	BIODIVERSITY	RECREATION	LIVELIHOOD	SOCIO-CULTURAL	HCVR VALUE
2085930	Kali Gandaki Nadi	365	42.7	17.1	22.7	17.4	3.2
2085921	Karnali Nadi	334	56.3	13.6	21.5	8.5	3.9
2086024	Bheri Nadi	311	31.1	27.3	22.7	19	1.9
2085791	Sunkoshi Nadi	263	56.3	13.2	22.2	8.3	4.1
2085881	Mahakali Nadi	262	51.4	13.9	21.4	13.4	3.0
2085758	West Seti Nadi	210	24.2	25.8	27.8	22.2	1.4
2086043	Babai Nadi	194	54	16.5	20.1	9.4	3.6
2086037	Bagmati Nadi	188	43.9	7.8	25.9	22.5	3.5
2085825	West Rapti Nadi	182	37.8	13	31	18.2	2.2
2085781	Tamur Nadi	175	49	18.3	25.4	7.4	2.6
2086047	Arun Nadi	158	46.3	21.5	21.3	10.9	3.3
2085762	Trishuli Nadi	156	45.6	14.1	21.7	18.5	3.8
2085875	Marsyangdi Nadi	156	28.1	26.4	19	26.5	2.4
2085980	Dudhkoshi Nadi	140	33	24.9	24.6	17.5	2.0
2085953	Humla Karnali Nadi	139	40.3	21.5	26	12.1	1.7
2085978	East Rapti Nadi	138	61.1	10.9	17.6	10.4	5.0
2085801	Seti Nadi	132	49	13.6	18.5	18.9	3.4
2085929	Kamala Nadi	127	21.5	0	43.5	35	1.6
2086016	Budi Gandaki Nadi	126	48.7	17.3	23.3	10.7	3.1
2085860	Narayani (Sapta Gandaki)	108	66.6	11.4	15.6	6.4	4.8
2040810	Madi Khola	96	0	10.4	56.7	32.9	1.0
2085806	Sarada Nadi	95	37.3	0	37.7	25	1.7
2086033	Bakaiya Nadi	92	0	0	39	61	1.3
2086017	Budhi Ganga Nadi	90	41	10.5	26.1	22.4	2.0
2086029	Banganga River	86	6.3	0	45.8	47.9	1.6
2085784	Tamakoshi Nadi	86	46.9	12.8	17.3	22.9	3.2
2085868	Mohana Nadi	85	32.9	0	33.9	33.2	1.9
2085945	Jhimruk Khola	84	35.6	12.6	45.9	5.9	1.7
2086008	Chameliya Nadi	83	47.7	11.5	22.9	17.9	2.7
2085891	Likhu Khola	80	46.4	16.9	28	8.7	2.0
2085807	Saptakoshi Nadi	77	58.6	9.3	17.4	14.8	4.7
2085877	Mai Khola	77	25.9	0	50.5	23.6	1.2
2085866	Mugu Karnali Nadi	75	50.2	11	29.9	8.9	2.0
2085882	Madi Nadi	75	40	18.7	21.7	19.6	3.4
2085847	Panar	67	0	0	55.3	44.7	1.5
2086028	Barun Khola	65	0	43.8	30.5	25.7	0.7
2085771	Tila Nadi	64	37.4	2.5	26	34.2	2.6
2085764	Trijuga Nadi	64	37.4	1.3	42.9	18.5	2.0
2085876	Marin Khola	64	0	0	64.8	35.2	0.9
2085974	Ganga Nadi	63	33.4	17.6	42.4	6.6	1.4
2086056	Thuli Bheri Nadi	62	0	40.3	39.3	20.4	1.1
2085823	Ratmata Khola	62	9.8	0	39.5	50.7	1.7
2085873	Mechi Nadi	62	25.3	4.8	35.1	34.8	1.7
2085966	Ghunse Khola	61	11	53.8	24.1	11.1	1.0
2085988	Daraudi Khola	61	0	29.9	57.9	12.3	0.8
2085927	Kandra Nadi	61	50.8	0	28.5	20.7	2.2

Summarizing HCV at the scale of rivers (vs. river reach)



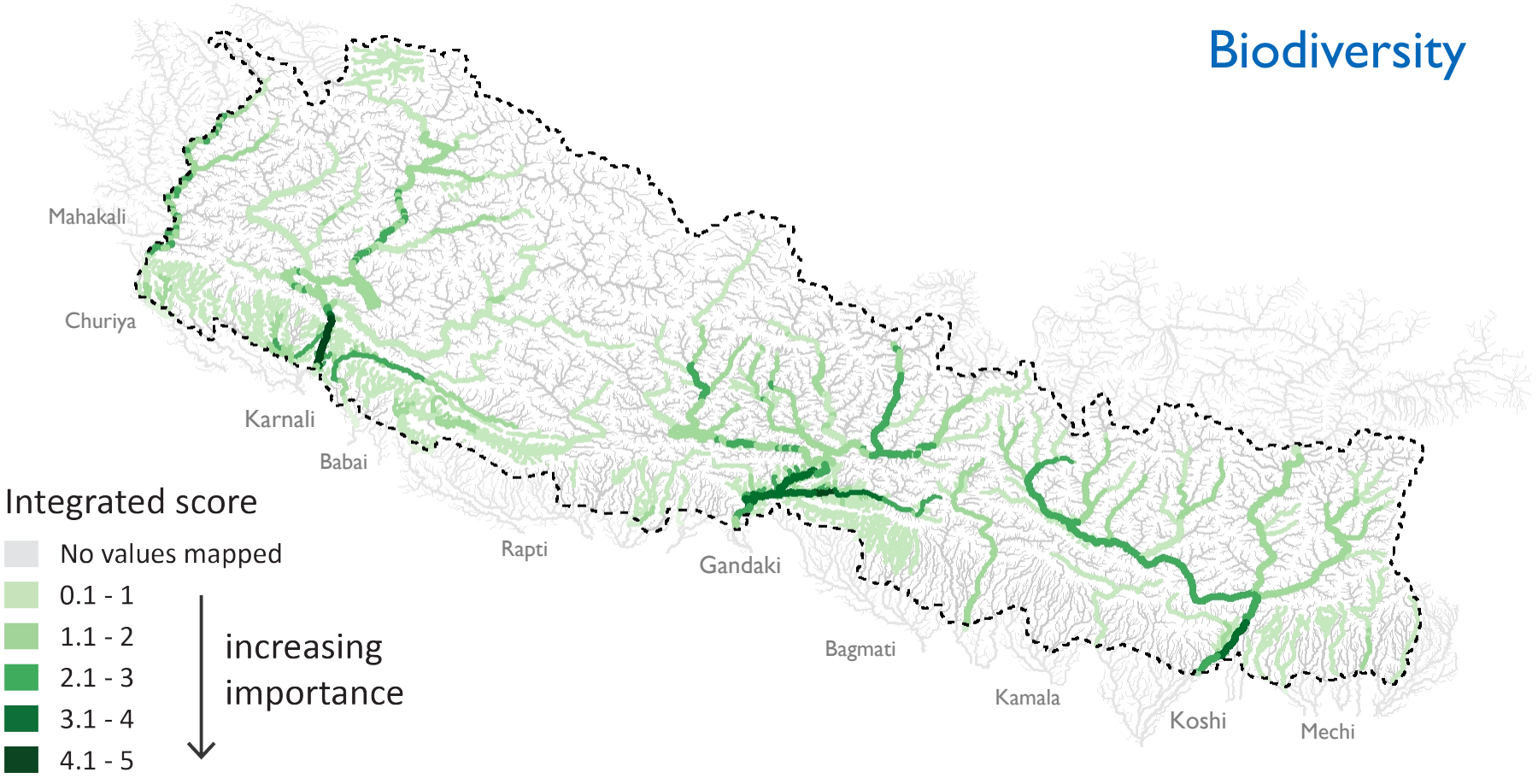
The length-weighted HCV for a river is calculated as:

$$HCV_R = \frac{\sum_{i=1} HCV_i * l_i}{\sum_{i=1} l_i}$$

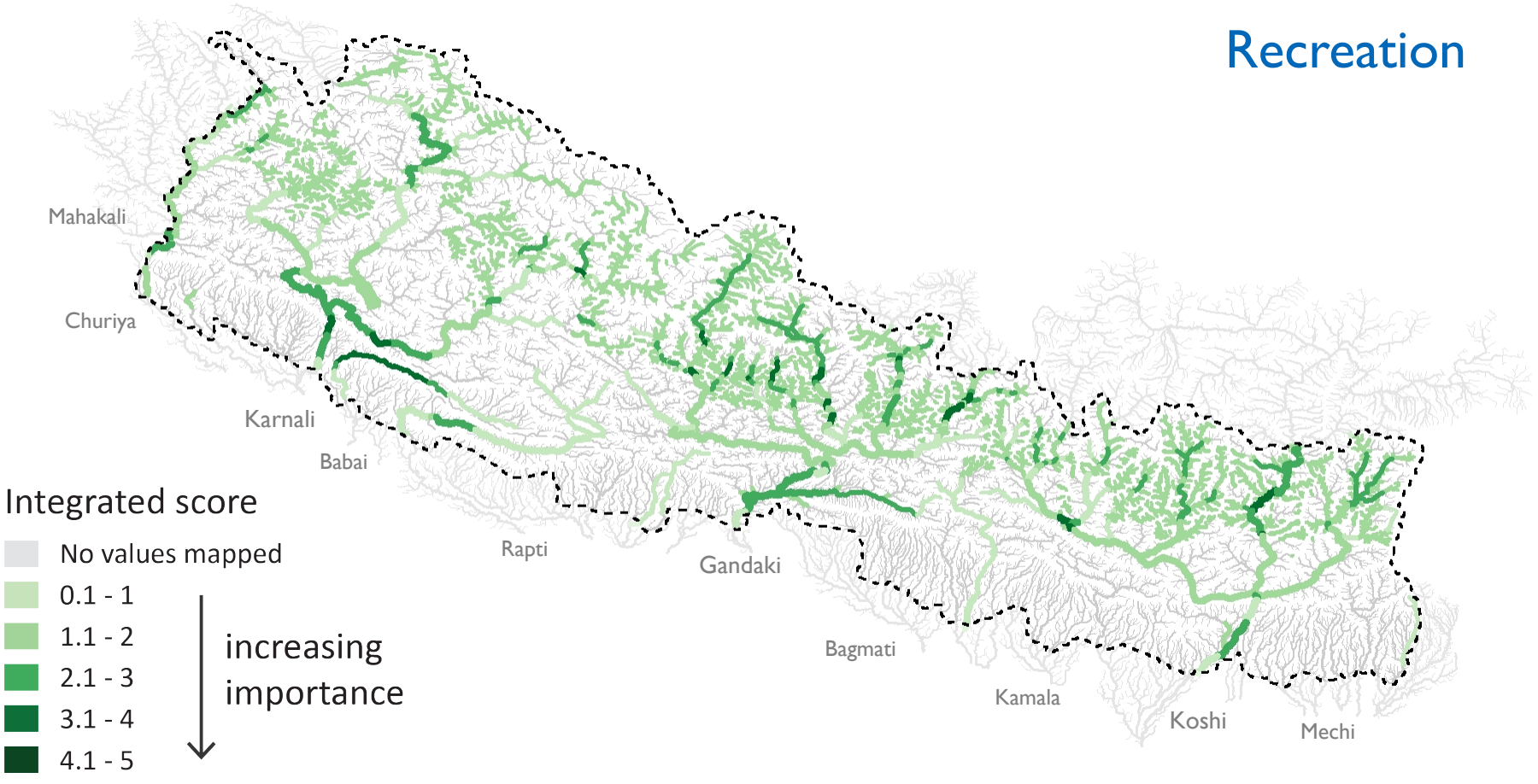


where HCV_R is the HCV in park *R*; HCV_i is the HCV value of the river reach *i* and *l* is the length of river reach *i*.
The resulting aggregated HCV values can range from 0 (no value mapped) to 5 (maximum value of all components)

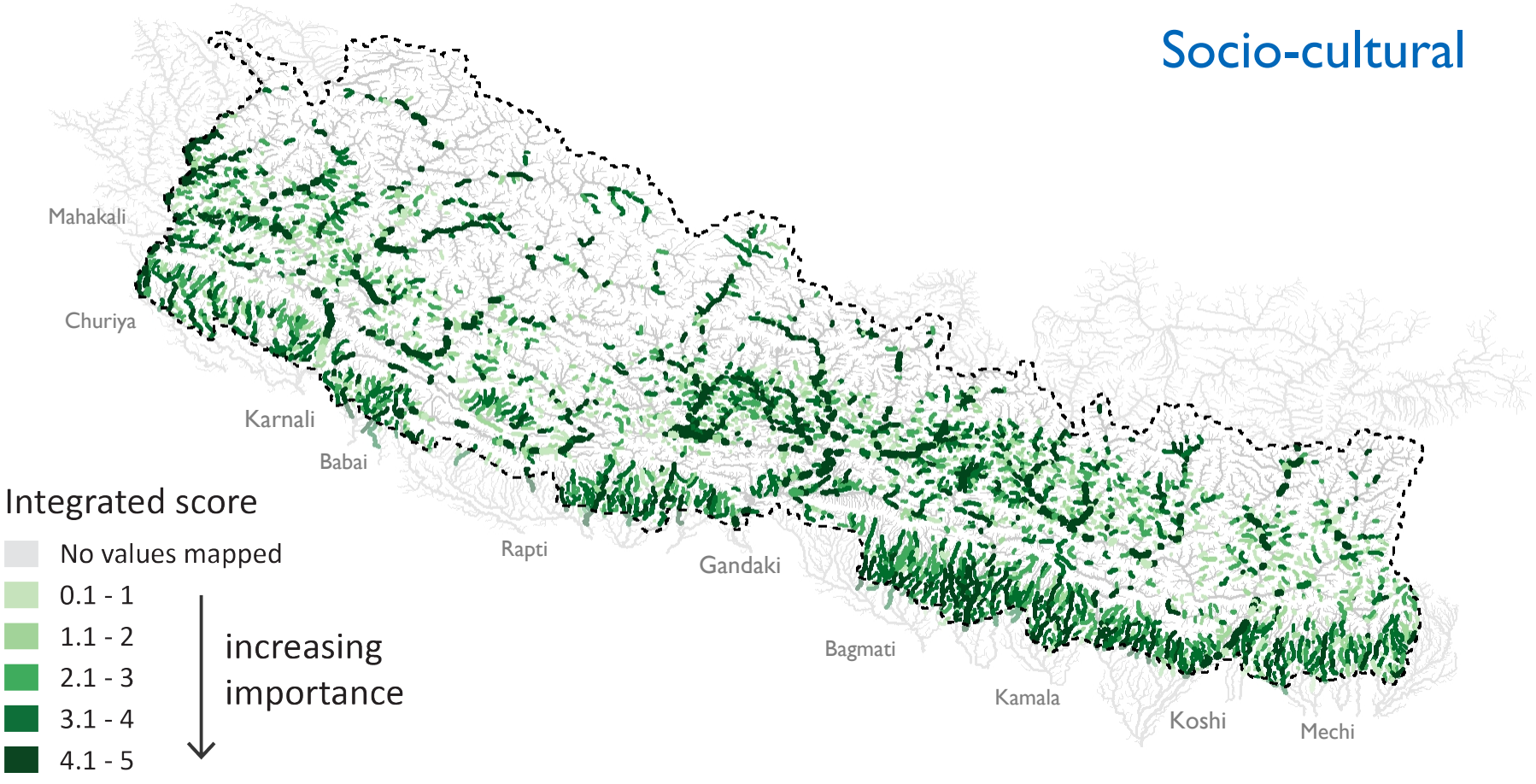
Biodiversity



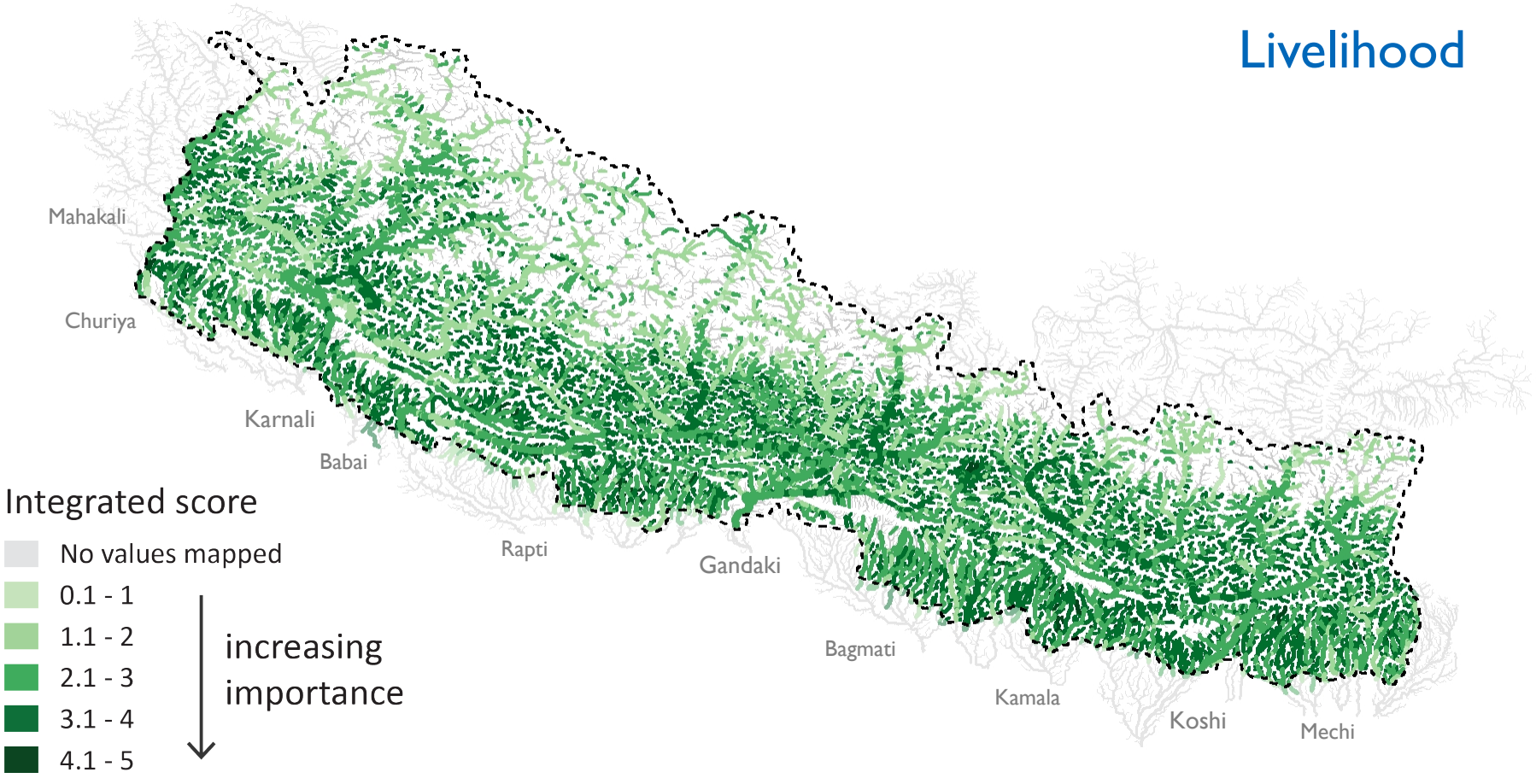
Recreation


Mahakali
Churiya
Karnali
Babai
Rapti
Gandaki
Bagmati
Kamala
Koshi
Mechi
Integrated score
No values mapped
0.1 - 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
increasing importance

Socio-cultural



Livelihood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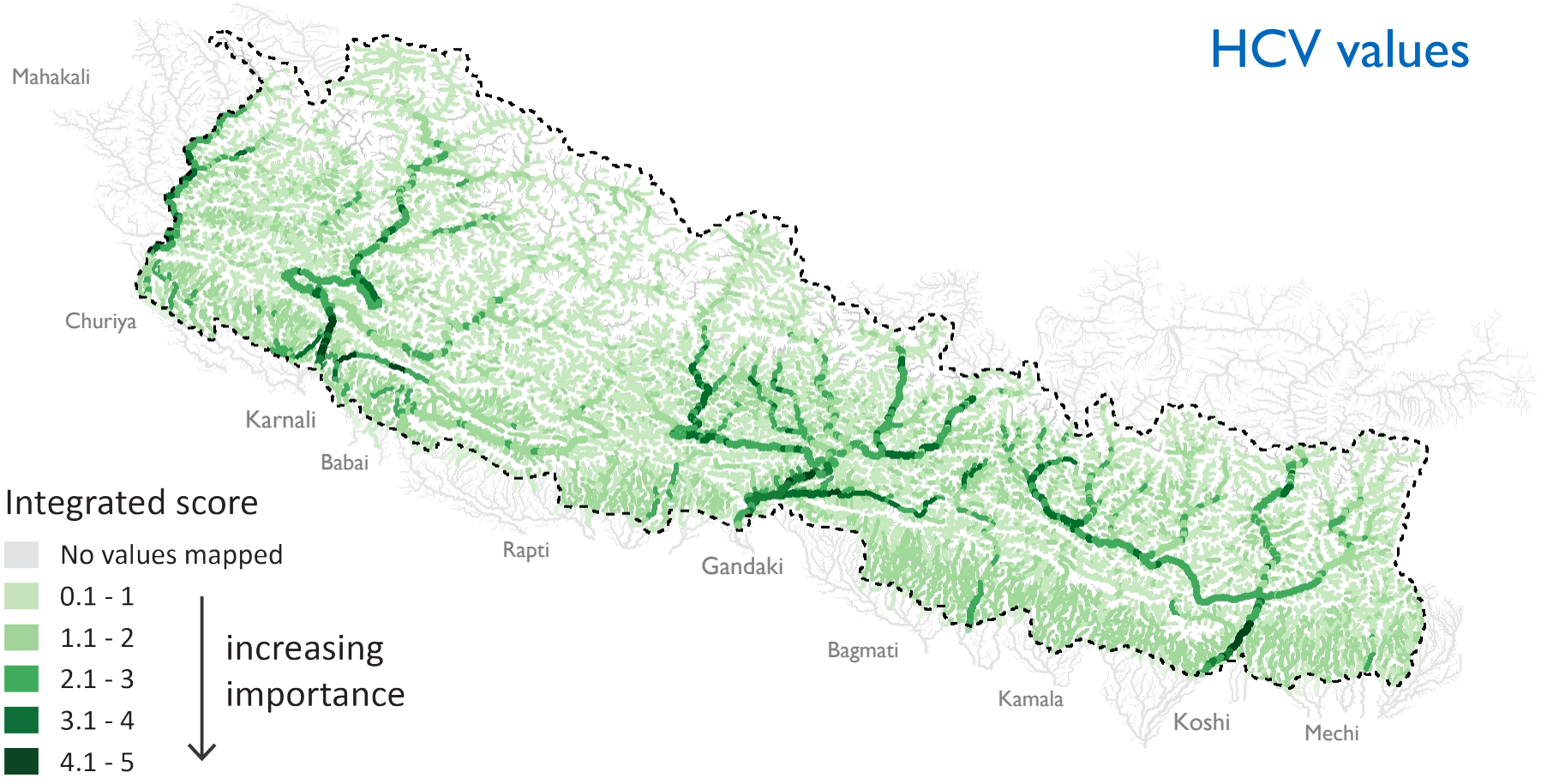
Mechi
Integrated score
No values mapped
0.1 - 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
increasing importance

HCV values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Integrated score
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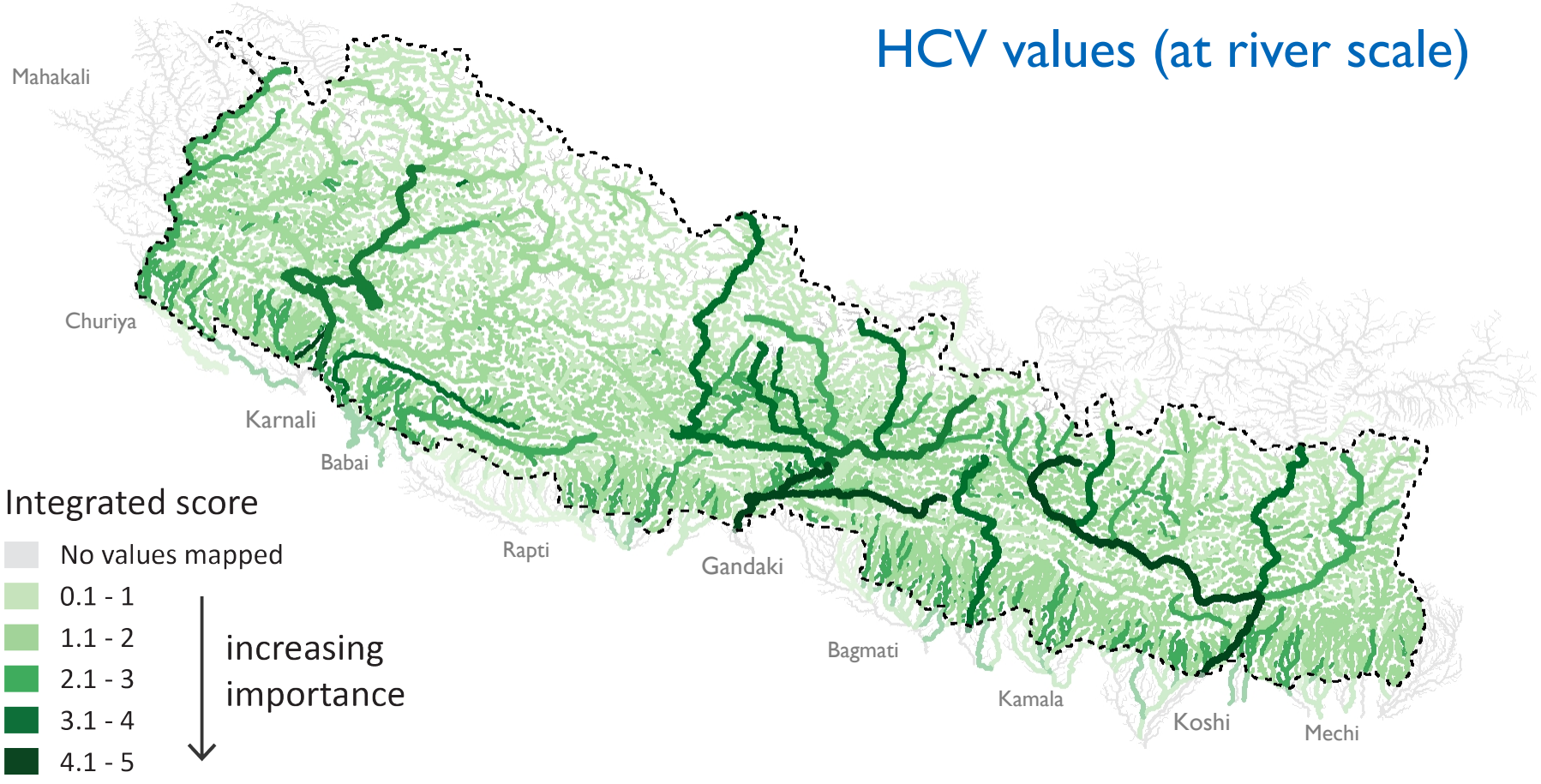
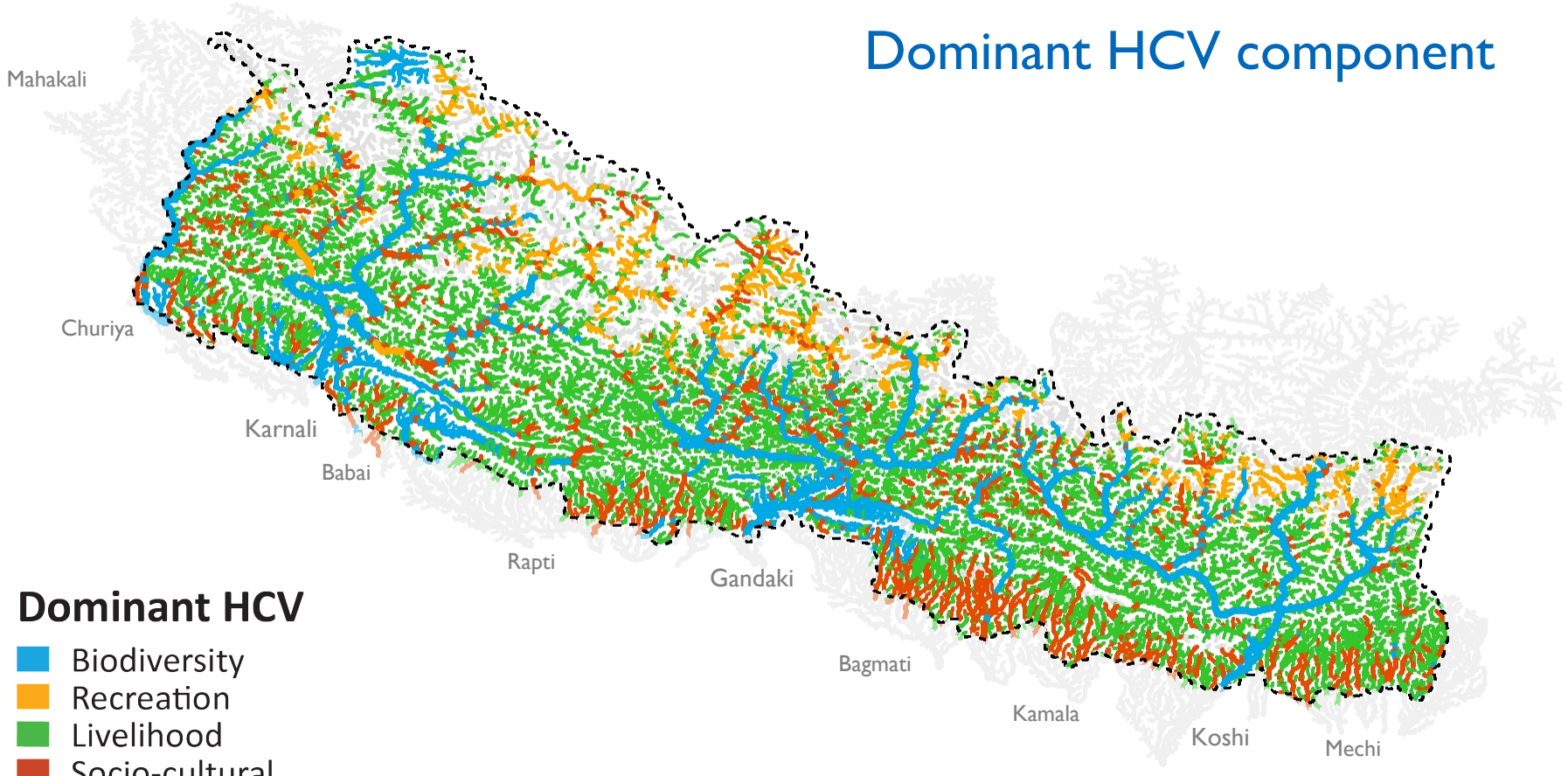
0.1 - 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
increasing importance

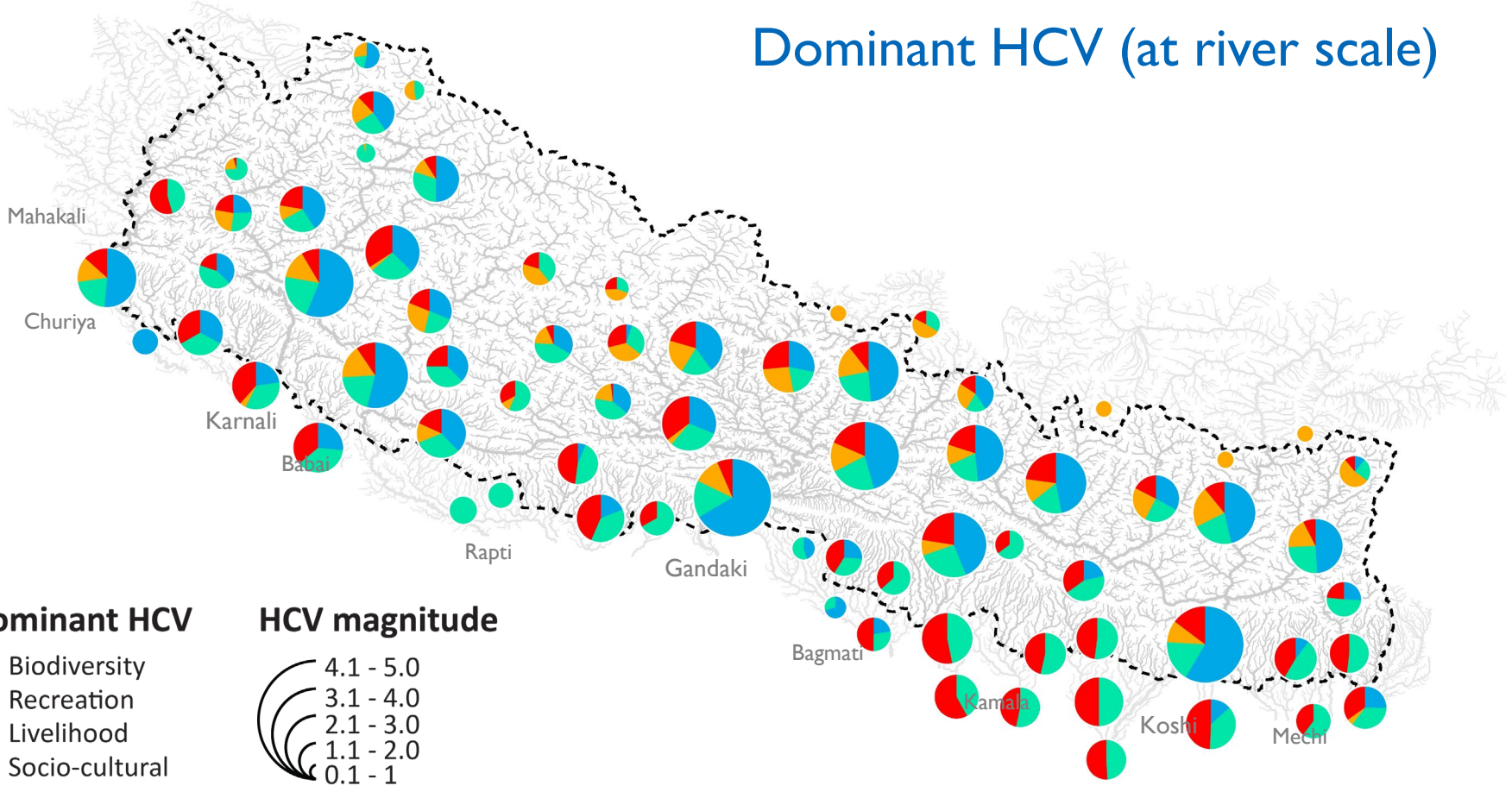
HCV values (at river scale)



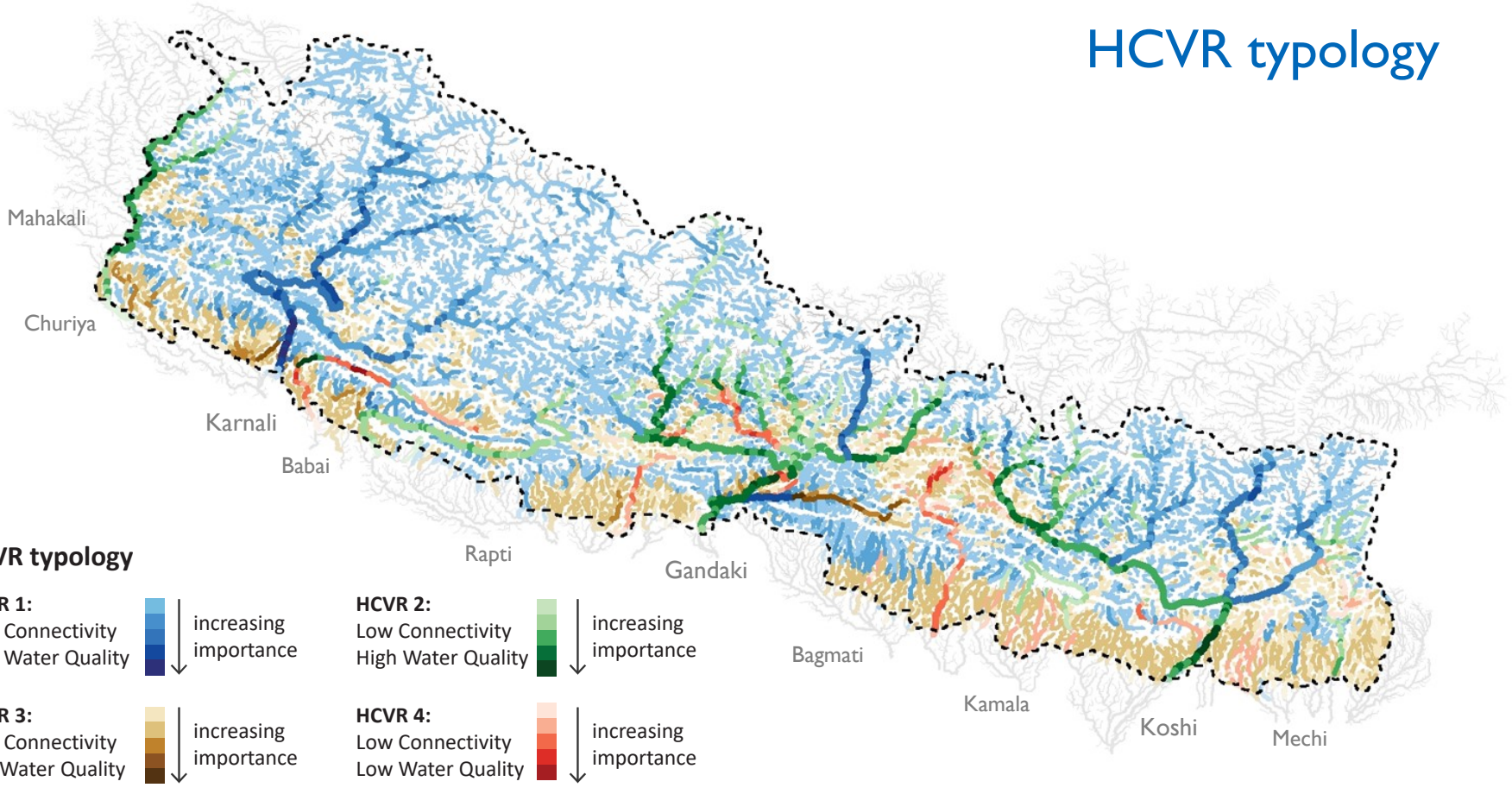
Dominant HCV component



Dominant HCV (at river scale)



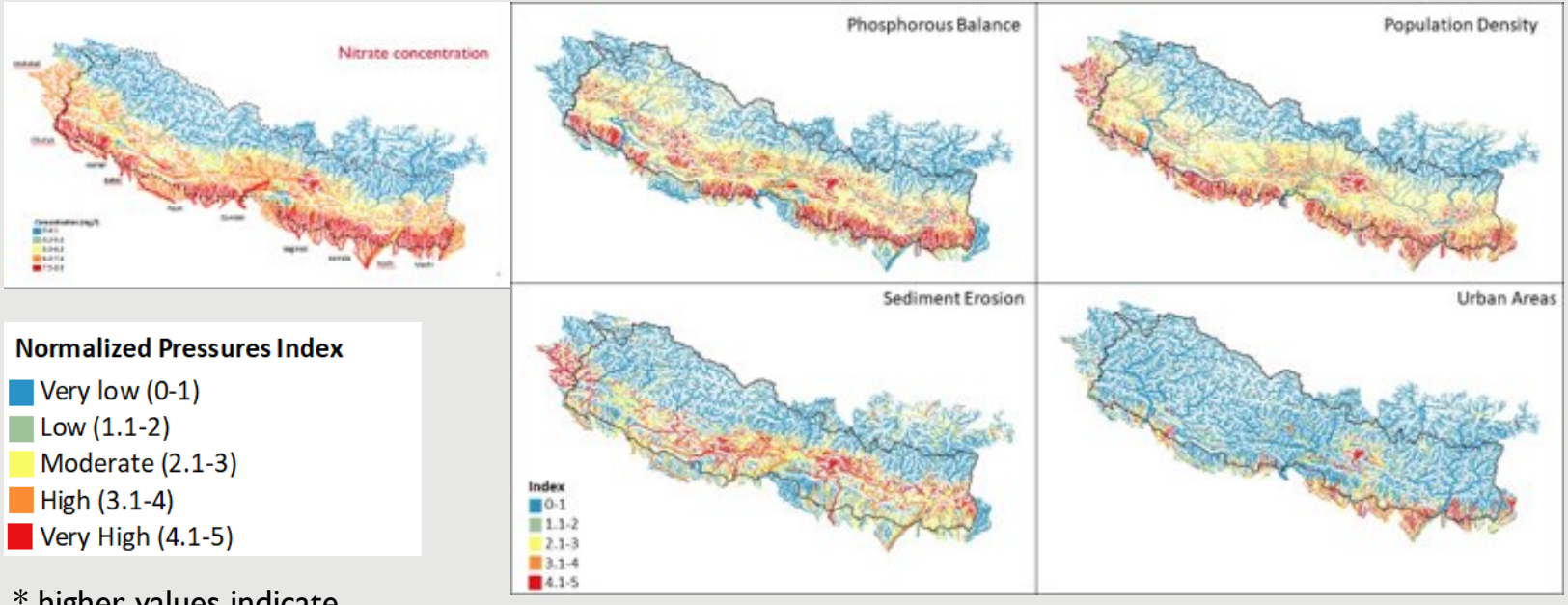
HCVR typology



Water Quality Datasets

Proxy Indicator	Rationale	Source	Resolution	Method
Urban areas	Urban areas are a source of industrial and manufacturing pollutants	Global Urban Footprint; Esch et al. (2014)	0.4 arcsec (~12 m)	Spatial accumulation
Phosphorous application	Phosphorus fertilizer is an important source of Phosphate pollution	West et al. (2014) (link)	5 arcmin	Spatial accumulation
Sediment pollution from road construction	Sediment from road construction increases the sediment load, and constitutes are constant source of sediment delivery through ongoing erosion	World Bank study (Vogl, Schmitt, et al. 2019); own calculations using OpenStreetMap	Calculated on river-reach scale	Spatial accumulation
Population density	Human settlements introduce Nitrate and Phosphate via waste and waste-water streams	WorldPop 2020; Gaughan et al. (2013)	30 arcsec	Spatial accumulation
Nitrate	Nitrate is important source of water pollution with impacts on humans and aquatic organisms	Training data (Nitrate observations): PAANI Covariates: global river and nutrient data sets	Variable	Machine learning model

Results - Proxy indicators for Water Quality

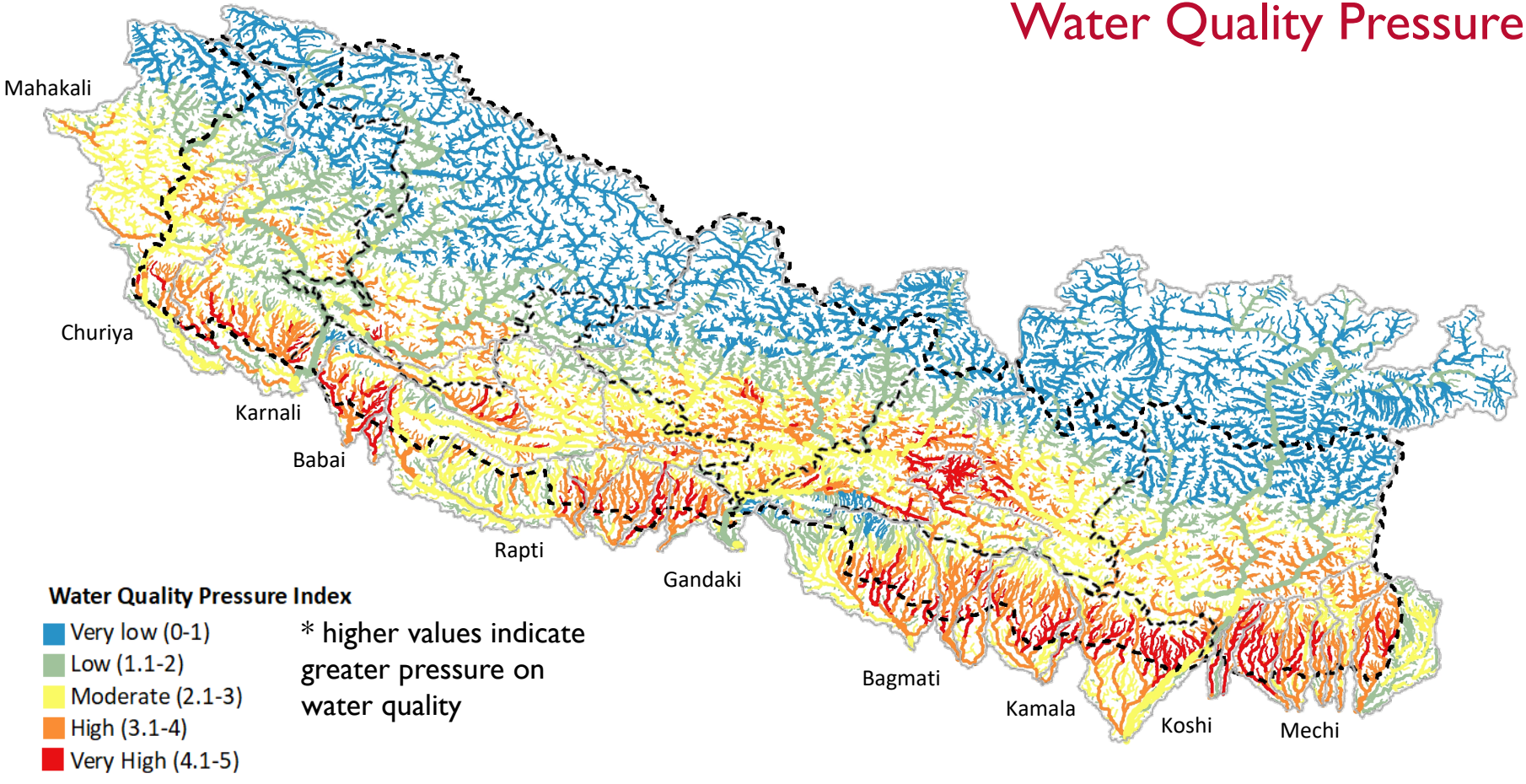


Normalized Pressures Index

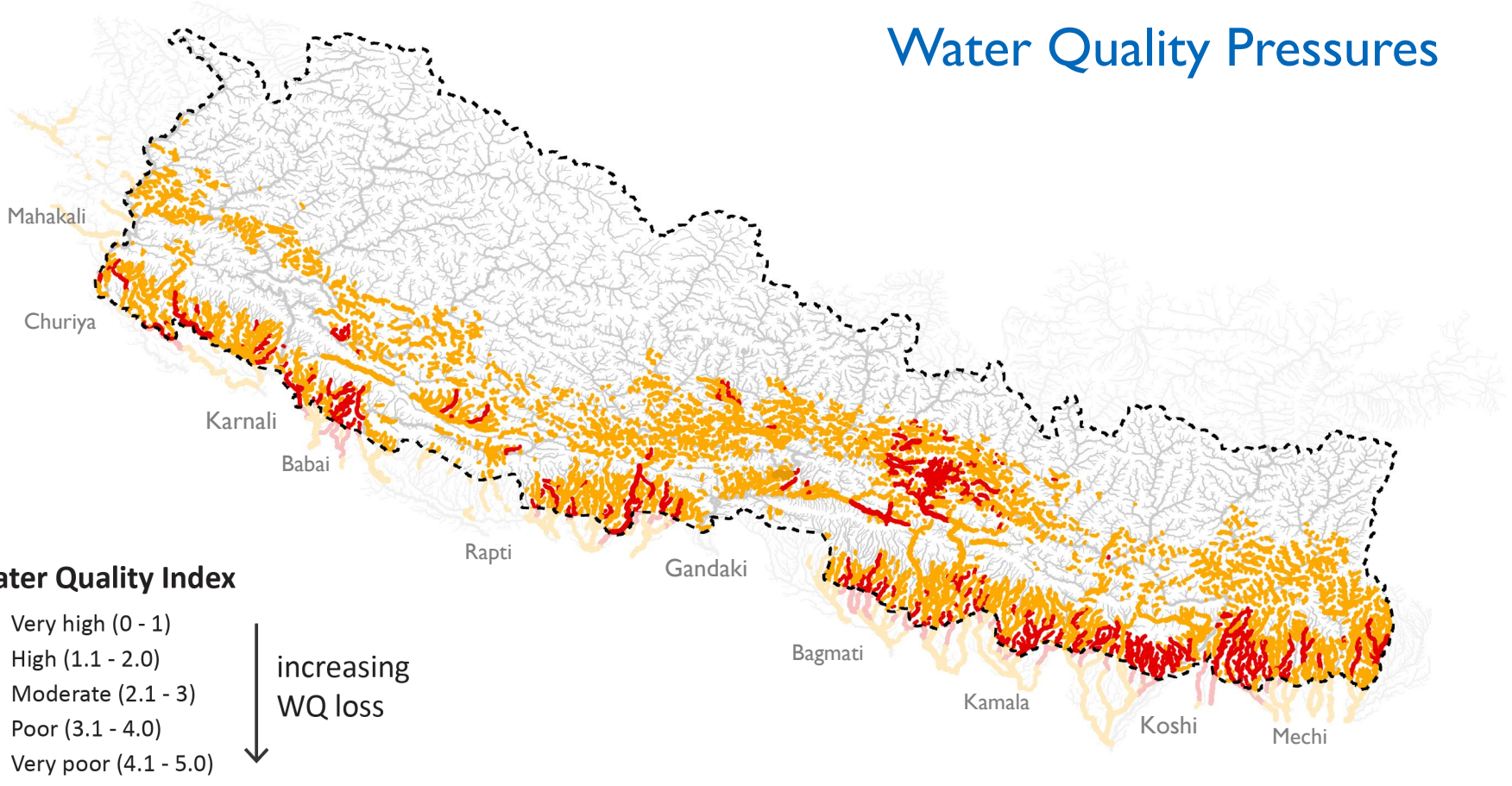
- Very low (0-1)
- Low (1.1-2)
- Moderate (2.1-3)
- High (3.1-4)
- Very High (4.1-5)

* higher values indicate greater pressure on water quality

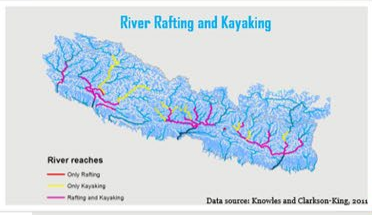
Water Quality Pressures

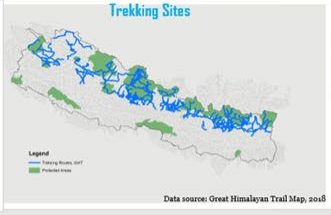


Water Quality Pressures

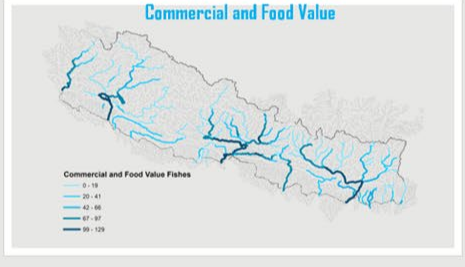


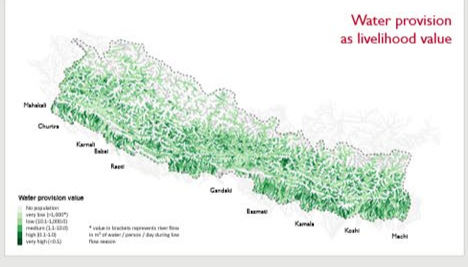
Recreation Values

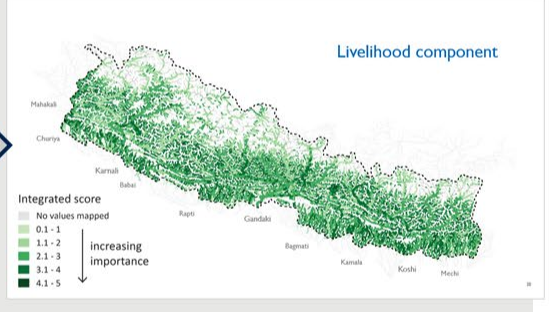




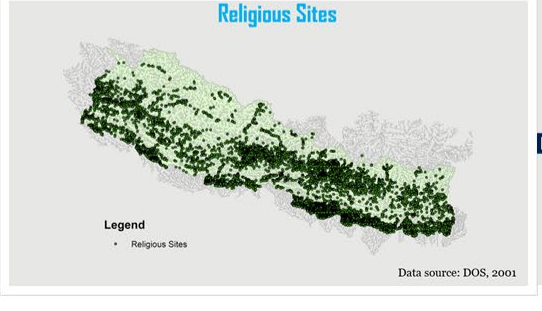
Livelihood Values

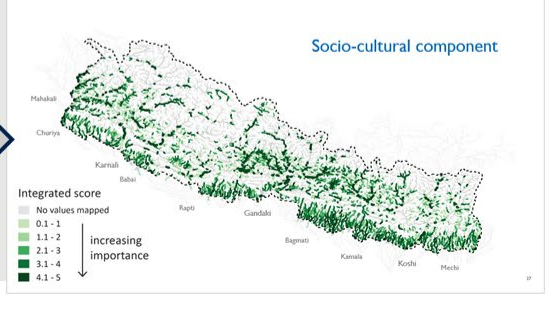






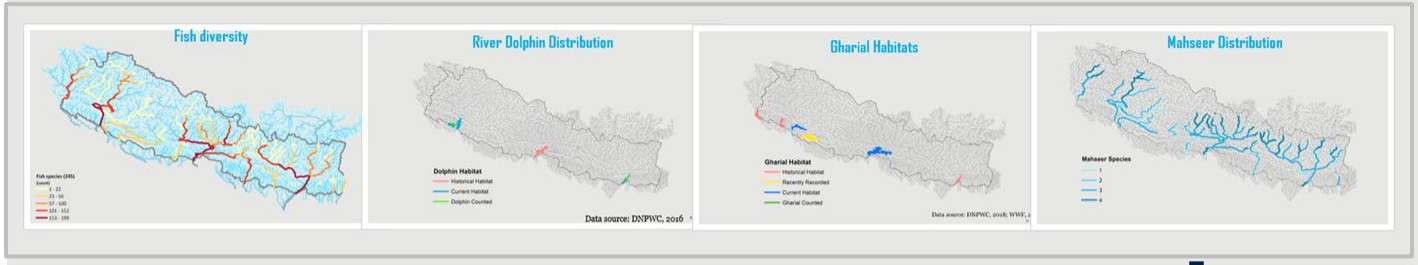
Cultural and Religious Values

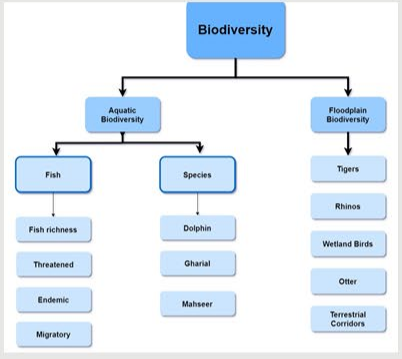




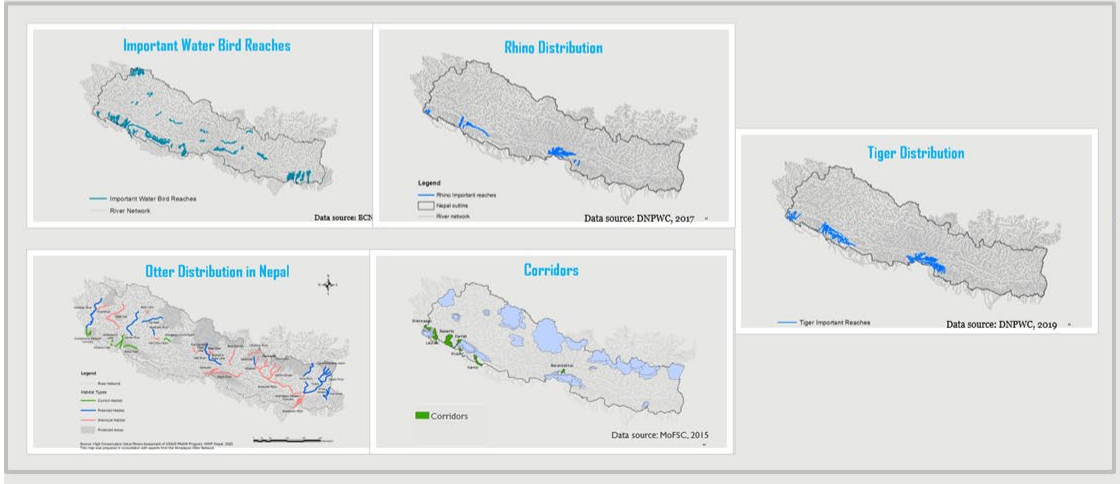
Biodiversity

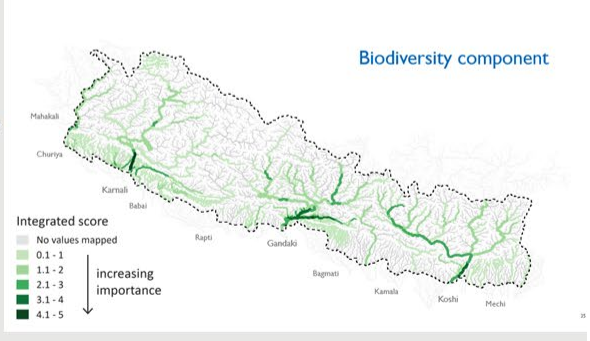
Aquatic Biodiversity



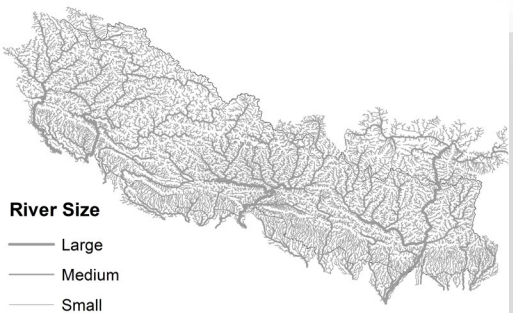


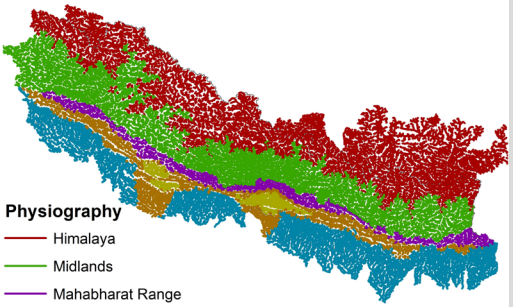
Floodplain and Riverine Biodiversity

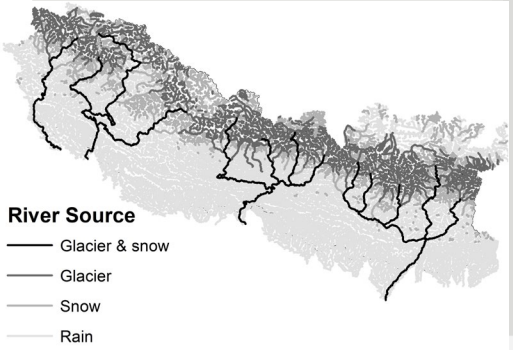


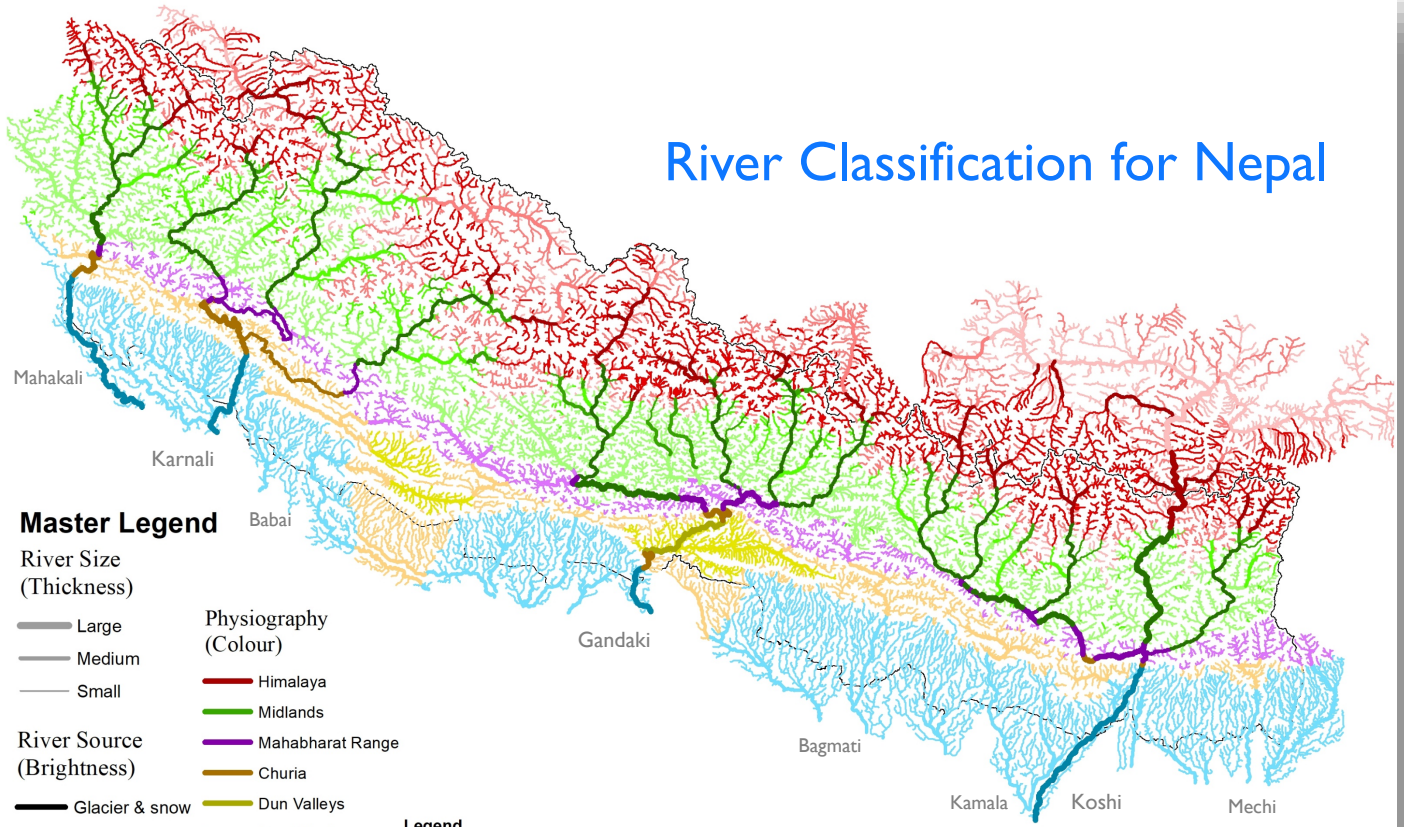


River Classification for Nepal









Master Legend

River Size (Thickness)
- Large
- Medium
- Small

River Source (Brightness)
- Glacier & snow
- Glacier
- Snow
- Rain

Physiography (Colour)
- Himalaya
- Midlands
- Mahabharat Range
- Churia
- Dun Valleys
- Terai Region

Legend

River Types (31 types)

River size, Source, Physiography

- Large, Glacier & snow, Himalaya (27)
- Large, Glacier & snow, Midlands (128)
- Large, Glacier & snow, Mahabharat Range (88)
- Large, Glacier & snow, Churia (67)
- Large, Glacier & snow, Dun Valleys (27)
- Large, Glacier & snow, Terai Region (110)
- Large, Rain, Himalaya (26)
- Medium, Glacier & snow, Himalaya (93)
- Medium, Glacier & snow, Midlands (636)
- Medium, Glacier & snow, Mahabharat Range (63)
- Medium, Glacier & snow, Churia (39)
- Medium, Glacier, Himalaya (294)
- Medium, Glacier, Midlands (230)
- Medium, Snow, Himalaya (135)
- Medium, Snow, Midlands (221)
- Medium, Rain, Himalaya (142)
- Medium, Rain, Midlands (204)
- Medium, Rain, Churia (209)
- Medium, Rain, Dun Valleys (97)
- Medium, Rain, Mahabharat Range (101)
- Medium, Rain, Terai Region (412)
- Small, Glacier, Himalaya (3,636)
- Small, Glacier, Midlands (176)
- Small, Snow, Himalaya (2,712)
- Small, Snow, Midlands (1,071)
- Small, Rain, Himalaya (1,145)
- Small, Rain, Midlands (5,355)
- Small, Rain, Mahabharat Range (1,509)
- Small, Rain, Churia (1,681)
- Small, Rain, Dun Valleys (499)
- Small, Rain, Terai Region (3,114)

River Types Representation on HCV categories

- All 29 river types within Nepal are represented across different HCV value categories
- Large, Glacier & Snow, Dun; Large, Glacier & Snow, Terai; Large Glacier & Snow, Churia; Medium, Rain, Dun; and Medium, Glacier & Snow, Midland rivers have been well represented in high HCV value categories (M to VH)
- Thus, the results show that most river types are well represented in the results of the HCV assessment

	Number of River Reaches	HCV Value Categories (HCV Value range)						Total
SN	River Types	No Value mapped (0)	Very low (<1)	low (1-2)	medium (2-3)	high (3-4)	very high (4-5)	
1	Large, Glacier/snow, Himalaya			7	7			14
2	Large, Glacier/snow, Dun Valleys					20	7	27
3	Large, Glacier/snow, Terai Region				6	22	9	37
4	Medium, Glacier/snow, Churia			38	1			39
5	Large, Glacier/snow, Churia				2	56	4	62
6	Medium, Glacier/snow, Mahabharat Range			21	18	24		63
7	Medium, Snow, Himalaya	19	44	1				64
8	Medium, Glacier/snow, Himalaya	3	24	42	5			74
9	Large, Glacier/snow, Mahabharat Range				9	73	4	86
10	Medium, Rain, Mahabharat Range	28	38	5	18	8		97
11	Medium, Rain, Dun Valleys	2	2	11	34	14	34	97
12	Large, Glacier/snow, Midlands				34	70	18	122
13	Medium, Rain, Terai Region	33	2	31	45	10	2	123
14	Small, Glacier, Midlands	51	71	11	12	2		147
15	Medium, Rain, Midlands	46	55	27	10	15	1	154
16	Medium, Glacier, Himalaya	18	98	44	9			169
17	Medium, Rain, Churia	50	25	33	48	16		172
18	Medium, Glacier, Midlands	14	95	25	35	15	2	186
19	Medium, Snow, Midlands	38	74	58	42	4		216
20	Small, Rain, Himalaya	211	152	1	9			373
21	Small, Rain, Dun Valleys	147	4	121	139	88		499
22	Medium, Glacier/snow, Midlands		37	162	223	169	15	606
23	Small, Snow, Midlands	495	402	39	11			947
24	Small, Rain, Churia	1157	28	126	49	10		1370
25	Small, Rain, Mahabharat Range	1354	58	40	8	3		1463
26	Small, Rain, Terai Region	1146	54	279	94	154	5	1732
27	Small, Snow, Himalaya	1103	645	31	23			1802
28	Small, Glacier, Himalaya	1516	707	117	30			2370
29	Small, Rain, Midlands	3461	1340	69	36	3		4909
	Grand Total	**10892**	**3955**	**1339**	**957**	**776**	**101**	**18020**

Products and assessments

- Freshwater status
  - Free-flowing river analysis
  - Water Quality pressures assessment
- Freshwater values
  - Created 20 novel data layers of freshwater values from four categories: Biodiversity, Recreation, Livelihood, and Socio-cultural
- High-Conservation Value River Maps for Nepal
  - Combination of Freshwater status and freshwater values into HCVR types and recommendations for management

Conclusions & Recommendations

Maps of High Conservation Value Rivers of Nepal provide critical information for:

- Natural resources, energy and spatial planning such as:
  - ongoing hydropower and basin planning processes under the leadership of the Water and Energy Commission Secretariat and the Ministry of Forest and the Environment.
- Policy implementation, such as:
  - delivery of international and national commitments to Nepal's National Biodiversity Strategy and Action Plan (2014-2020) under the Convention on Biodiversity
  - and National Strategic Framework for Sustainable Development (2015-2030)
- Insights into opportunities for mitigation of development impacts

Machapuchare mountain, Nepal. Photo by Benjamin Grant on Unsplash

For questions, please get in touch
with Günther Grill (guenther.grill@confluvio.com)

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Policy Brief 1: Why is it important to identify HCVR in Nepal?

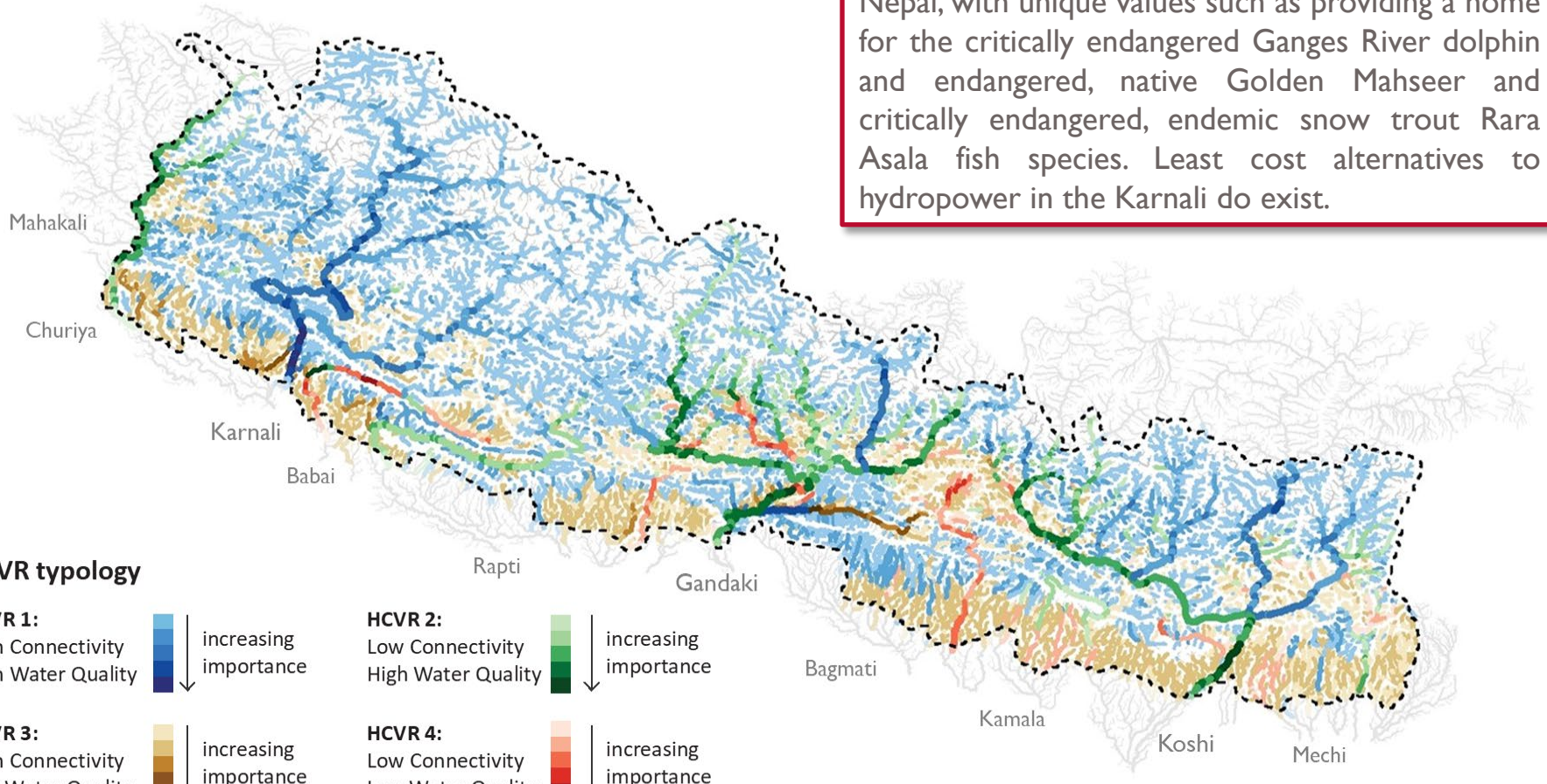
A *High Conservation Value River* (HCVR) is a **clean, highly connected** or **free flowing** river or stretch that acts as **a lifeline**, maintaining **ecosystem services** for present and future generations, providing **refuge** and **habitat** for high levels of **aquatic biodiversity**, and supporting important **socio-cultural values.**

Identification of HCVRs can:

- provide critical information for planning at different levels through quantitative evaluation and spatial mapping of the values that rivers provide to society.
- help the country in meetings its national and international commitments including Nepal's National Biodiversity Strategy and Action Plan (2014-2020) and National Strategic Framework for Sustainable Development (2015-2030).
- provide insights into opportunities for mitigation of development impacts.

The HCVR outputs will guide development and contribute to a set of ongoing hydropower planning processes under the leadership of the Water and Energy Commission Secretariat (WECS).

The Karnali is one of the last free-flowing rivers in Nepal, with unique values such as providing a home for the critically endangered Ganges River dolphin and endangered, native Golden Mahseer and critically endangered, endemic snow trout Rara Asala fish species. Least cost alternatives to hydropower in the Karnali do exist.



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System-scale planning to support sustainable energy systems and conservation of freshwater resources for people and nature

Nepal