Received: 31 October 2021 | Revised: 11 July 2022 | Accepted: 22 July 2022

DOI: 10.1111/csp2.12793

SCIENTIFIC IMPACT PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access

WILEY

Protected areas in the Hindu Kush Himalaya: A regional assessment of the status, distribution, and gaps

Sunita Chaudhary[1,2] | **Kabir Uddin**[1] | **Nakul Chettri**[1] | **Rajesh Thapa**[3] | **Eklabya Sharma**[1]

[1]International Centre for Integrated Mountain Development, Kathmandu, Nepal

[2]Macquarie University, Sydney, New South Wales, Australia

[3]University of New England, Armidale, New South Wales, Australia

Correspondence
Sunita Chaudhary, International Centre for Integrated Mountain Development, GPO Box 3226, Kathmandu, Nepal.
Email: sunita.chaudhary@icimod.org

Abstract

Protected areas (PAs) are a key strategy for conserving areas of outstanding biodiversity value and promoting sustainable development. Significant efforts have been made toward establishing PAs over the last few decades across the globe. However, an assessment of PAs in mountain regions, including in the biodiversity rich Hindu Kush Himalaya (HKH), is lacking. We assessed the status, trend, and distribution of PAs and the ecological representativeness in the PA network. Our analysis showed the HKH has a total of 575 PAs covering 40.17% of the region, accounting for 8.49% of global PA coverage. The HKH hosts 335 Important Bird and Biodiversity Areas (IBAs), 348 Key Biodiversity Areas (KBAs), 12 Global 200 Ecoregions, and 4 Global Biodiversity Hotspots. However, the study showed limited ecological representation in the current PA system as 67% of ecoregions, 39% of hotspots, 69% of KBAs, and 76% of IBAs are still outside of the PA system. About 47% of the PAs are small (<250 sq. km) with no connectivity to other PAs and the majority are distributed in the lower reaches of the HKH. These findings suggest the need to assess and demarcate potential corridors to improve connectivity between PAs and integrate PAs into wider conservation landscapes at national and regional scale beyond country boundaries through regional cooperation. There is also a need to assess and strengthen PA management effectiveness and governance and consider other effective area-based conservation measures especially in the higher elevations and with a specific focus on ecological representation.

KEYWORDS

biodiversity hotspots, corridors and connectivity, global 200 ecoregions, landscapes, other effective area-based conservation measure (OECM)

The views and interpretations in this publication are those of the authors. They are not necessarily attributable to ICIMOD and do not imply the expression of any opinion by ICIMOD concerning the legal status of any country, territory, city or area of its authority, or concerning the delimitation of its frontiers or boundaries, or the endorsement of any product.

1 | INTRODUCTION

A Protected Area (PA) is a "geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives" (CBD, 1992). The creation of PAs is one of the greatest conservation efforts in human history dating back over 2000 years when the royals in India set aside special areas for protection (Holdgate & Phillips, 1999). Today, there are 251,947 terrestrial PAs covering 15.73% of the global land area (UNEP-WCMC, 2021). PAs are also one of the core tools for conservation and sustainable development, managing key habitats, ensuring the maintenance of natural processes, and directly supporting the livelihoods of about 1.1 billion people (CBD, 2019). More importantly, PAs are considered critical to help address the "biodiversity crisis" (Hoekstra et al., 2005) and halt species extinction (IUCN, 2016).

PAs have gained substantial policy attention globally. The CBD adopted the Programme of Work on Protected Areas (PoWPAs) in 2004 as a guiding framework for creating and developing a comprehensive, effectively managed, and sustainably funded national and global PA system (CBD, 2006). In 2010, the Strategic Plan for Biodiversity (2011–2020) with 20 Aichi Biodiversity Targets was adopted by the Parties to the CBD to address biodiversity loss, ensure sustainable use of natural resources, and equitable sharing of benefits (CBD, 2010). Aichi Target 11 states that "by 2020 at least 17% of terrestrial areas and inland water especially areas of particular importance for biodiversity and ecosystem services are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes" (CBD, 2020). This target comprises both quantitative and qualitative elements (see Table 1). Its quantitative elements focus on area coverage, and its qualitative element on the performance of PAs and aspects such as ecological representation, areas of particular importance for biodiversity and ecosystem services are equitably and effectively managed. The last subcomponents of Aichi Target 11 focus on well-connected system of PAs and integration of PAs into wider landscapes and seascapes (see Table 1), functional linkages of ecosystems, and strengthening of regional networks and transboundary PAs (CBD, 2008). PAs have gained further attention in the draft post-2020 global biodiversity framework. Action Target 3 of the framework proposes to conserve at least 30% of the world's terrestrial and marine habitats by 2030, known informally as "30 × 30." The target is considered critical for halting biodiversity loss and conserving areas, especially areas of particular importance for biodiversity and livelihoods (CBD, 2022).

TABLE 1 Quantitative targets and qualitative elements of Aichi Target 11 (adapted from Rees et al., 2018)

A. Quantitative targets	A.1. 17% terrestrial
B. Qualitative elements	B.1. Ecologically representative B.2. Areas of particular importance for biodiversity and ecosystem services B.3. Management equity and effectiveness B.4. Well-connected B.5. Integration into wider landscape and seascape

Note: Means of conservation: protected areas (PA), and/or other effective area-based conservation measures (OECM).

Ecological representation is often considered for global conservation priority setting and planning purposes (Dinerstein et al., 2017; Mittermeier et al., 2011; Sayre et al., 2020). CBD considers ecological representation as the "need for PAs to represent the full variety of biodiversity for different biological realms, in all ecoregions such as freshwater, terrestrial, and marine, and at different biological scales (ecosystems, species, and within species variations)" (CBD, 2016). Similarly, areas of particular importance for biodiversity are areas important for the rich diversity of life at the genetic, species, and ecosystem levels, which have the capacity to provide immense services for both humans and nonhumans. Some examples are: Global 200 Ecoregions, Key Biodiversity Areas (KBAs), Important Bird and Biodiversity Areas (IBAs), and Biodiversity Hotspots (Kullberg et al., 2019).

Global 200 Ecoregions are "relatively large units of land or water containing a characteristic set of natural communities that share a large majority of their species dynamics, and environmental conditions" (Olson & Dinerstein, 2002). The 200 Global Ecoregions, identified based on the threats (current and future) and conservation status of areas, are for conserving the Earth's most biologically valuable ecoregions. KBAs are the most important places globally for conserving species and their habitats, and their conservation helps to safeguard the most critical sites for nature on our planet (BirdLife, 2020). IBAs are sites of international significance identified using an internationally agreed criteria for bird conservation. Biodiversity hotspots are biologically rich conservation priority areas deeply threatened by human activities. A biodiversity hotspot must have at least 1500 endemic vascular plants and must have lost ≥70% of its primary vegetation. There are 36 such hotspots around the world, which represent about 2.4% of the Earth's land surface, but support more than half of the world's endemic plant species, and nearly 43% of endemic bird, mammal, reptile, and amphibian species (Mittermeier et al., 2011).

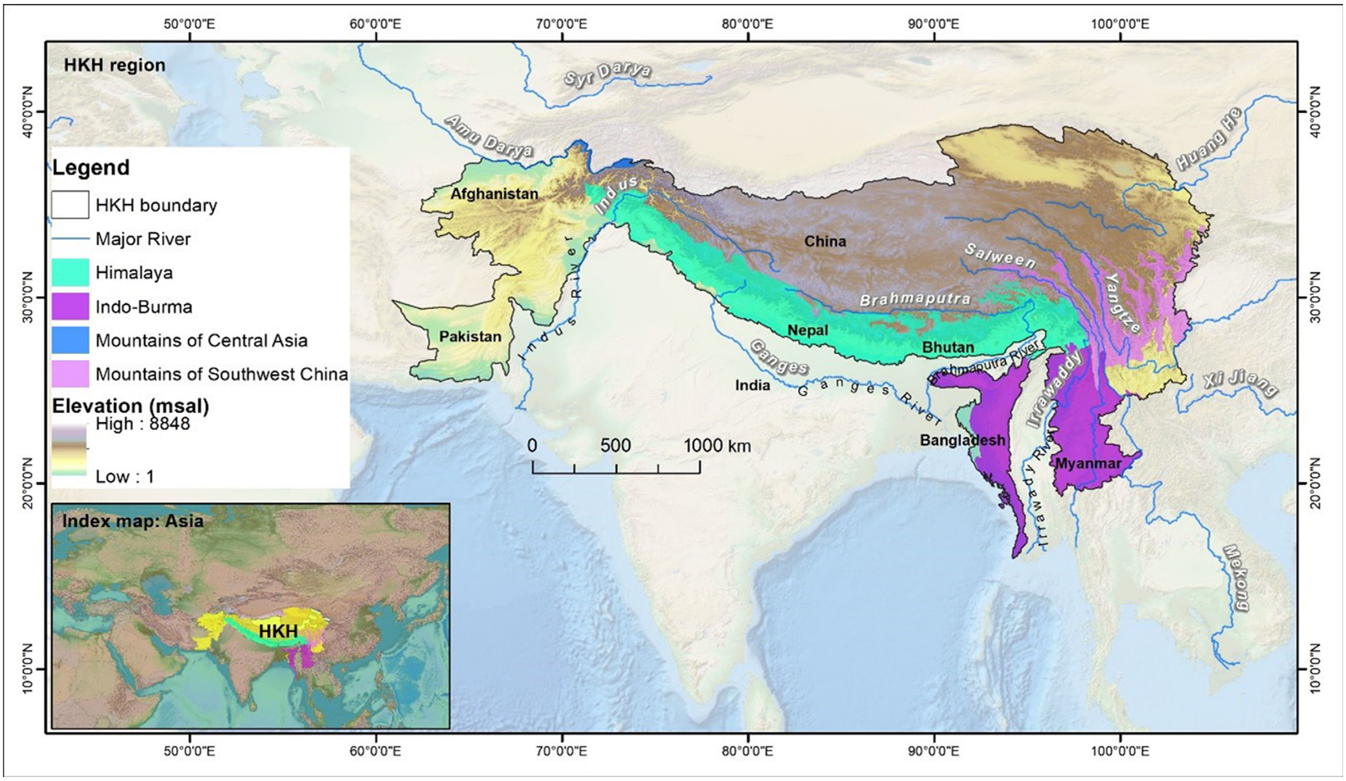

FIGURE 1 Elevation map of Hindu Kush Himalaya showing four Global Biodiversity Hotspots. (i). Himalaya, (ii). Indo-Burma, (iii). Mountains of Central Asia, and (iv). Mountains of Southwest China)

There have been efforts to evaluate the progress of PAs (Zafra-Calvo et al., 2019) but there is very limited understanding of ecological representation, and "areas of important biodiversity" such as IBAs, KBAs, and so on at regional scale (Sayre et al., 2020). Sayre et al. (2020) analyzed ecological representation and biogeographical biomes at the global scale showing inadequate representation in PAs. They recommended representation analysis for different regions for conservation priority setting and for conservation planning at the transboundary scale (Tantipisanuh et al., 2016). This is particularly important for mountain regions, which are exceptionally rich in biodiversity but highly susceptible to various drivers of change, including climate change.

The Hindu Kush Himalaya (HKH), one of the major mountain regions of the world, is extraordinarily rich in diversity of ecosystems, species, and cultures and highly vulnerable to risks and changes (Wang et al., 2019). The region is spread over an area of 4.2 million square kilometers (sq. km) covering Bhutan and Nepal in their entirety, and the mountainous parts of Afghanistan, Bangladesh, Bhutan, India, Nepal, Myanmar, and Pakistan (Bajracharya et al., 2015; Wang et al., 2019). It encompasses a wide elevation range from tropical (<500 meters above sea level, masl) in the lowlands to alpine and areas of permanent ice and snow (>6000 masl) upto the Mount Everest (8848.86 masl; Figure 1). The region is variously referred to as the "Third Pole" and the "Water Tower" of Asia (Wester et al., 2019) as it has the world's 10 highest mountain peaks and over 760,000 sq. km of snow cover (Bolch et al., 2019). Together with the Tien Shan mountains, the HKH forms the largest area of permanent ice cover outside of the North and South Poles, with an estimated 6000 km^3 of ice volume (Wester et al., 2019). It contains the headwaters of 10 important large river systems of Asia including the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze, and Yellow (Messerli & Ives, 1997).

The HKH is biodiverse and comprises tropical and subtropical rainforest, temperate broadleaf, deciduous and temperate coniferous forest, and high-altitude cold shrub or steppe, and cold desert (Guangwei, 2002). The heterogeneity in altitude, latitude, geography, and climate supports diverse ecosystems and species (Sharma et al., 2010). As such, the HKH is often regarded as a key region of biodiversity (Hoekstra et al., 2005; Mittermeier et al., 2011; Olson & Dinerstein, 2002). The region includes all or part of four global biodiversity hotspots—the Himalaya, Indo-Burma, mountains of Southwest China, and mountains of Central Asia—with a rich variety of species with high endemism and novel ecosystems (Mittermeier et al., 2011), and is among the Global 200 Ecoregions (Olson & Dinerstein, 2002). The Indo-Burma hotspot alone supports 7000 endemic plants and 1.9% of global endemic vertebrates (Myers et al., 2000). Similarly, more than 7000 plant species, 175 mammal species, and over 500 bird species have been reported in the Eastern Himalaya alone (WWF & ICIMOD, 2001). This highest mountain biome provides immense goods and services in terms of food, water, habitat, pollination, and climate regulation that sustain the livelihoods of 1.9 billion people within the region and in the river basins downstream (Molden et al., 2014; Sharma et al., 2015).

However, the HKH is highly vulnerable to risks and different drivers of change. It is geo-physically fragile and prone to erosion and landslides. Land cover change, unplanned development, and invasive species are prominent drivers of change with significant impacts on biodiversity, ecosystem services, and human wellbeing (Chettri & Sharma, 2016; Xu et al., 2019). Climate change is further impacting the region with observed changes in plant phenology and productivity (Bawa & Seidler, 2015). With increased impacts of various drivers of change including land cover change and climate change, the HKH, especially the Indo-Burma and the mountains of southwest China hotspots, have been identified as an "area of imminent extinction," (Ricketts et al., 2005). The region is on the list of crisis ecoregions (Brooks et al., 2006). Jantz et al. (2015) predicted that the HKH could lose 80%–86% of its original habitat by 2100, underlining the urgency for conservation in the region.

PA management in the HKH has been reported to have contributed to conservation over the last few decades (Chettri et al., 2008). The regional member countries, which are parties to the CBD, have recently doubled their efforts to increase the number and coverage of PAs as part of their commitment to achieving Aichi Target 11 (ICIMOD, 2020). However, a regional assessment of PAs is lacking. In 2008, Chettri et al. (2008) conducted a comprehensive analysis of the region's PAs. It showed a total of 488 PAs covering 39% of the HKH, with 25% of the global biodiversity hotspots, and 40% of the Global 200 Ecoregions included in the PAs network (Chettri et al., 2008). Since then, no study has been conducted to update the status of PAs in the HKH and assess their ecological representation (Chettri et al., 2010; Xu et al., 2019). Therefore, this study was aimed at updating the status of PAs in the HKH, with a focus on number, area coverage, and ecological representativeness. It was guided by the following research questions:

1. What is the status of PAs in terms of number, area, distribution, and trend over the last century and decade (2010–2020) at the country and HKH levels?
2. What is the status of areas of particular importance for biodiversity and their representation in the PA system?
3. How ecologically representative are the PAs of the HKH?
4. What are the conservation gaps?

In doing so, we aim to recommend actions for better conservation planning and outcomes. With this, the study responds to many calls for assessing the status and representativeness of PAs (Buchanan et al., 2020; Saura et al., 2019; Sayre et al., 2020) with a particular focus on mountain PAs (Rodríguez-Rodríguez et al., 2011). The outcomes would also contribute to post-2020 agenda setting and preparing National Biodiversity Strategy and Action Plan (NBSAP) of the regional member countries of the HKH. This would consequently contribute to the conservation of mountain ecosystems and sustainable development goals.

2 | METHODS

2.1 | Data collection

We used six different datasets to assess the status and analyze ecological representation in HKH PAs (see Table 2). They are: (i) Information on PAs from World Database on Protected Areas (WDPA), which is considered the most comprehensive global database on terrestrial and marine PAs (UNEP-WCMC, 2021); (ii) Global Biodiversity Hotspots (Mittermeier et al., 2011); (iii) Important Bird and Biodiversity Areas (IBA; BirdLife, 2014); (iv) Global 200 Ecoregions (Olson & Dinerstein, 2002); (v) Shuttle Radar Topography Mission (SRTM) elevation data (Becker et al., 2009; USGS & EROS, 2017); and (vi) Key Biodiversity Areas (Birdlife., 2020).

2.2 | Data analysis

The information on PAs from the WDPA datasets was collected, screened, cleaned, and analyzed. During screening, only PAs inside the HKH were selected by overlaying the HKH boundary shapefile over WDPA datasets using "Select by Location Tool" in ArcGIS. The selected points and polygons of all PAs were then cleaned by cross-checking double or multiple placements of points and polygons and deleting the repeated placements for the same PA. We also removed PAs with different designations and status, also noted by You et al. (2018). For instance, Chitwan National Park was repeated three times as its name and designation changed from National Park to World Heritage Site (WHS), and from *Royal* Chitwan National Park to Chitwan National Park. Despite these shortcomings, we used the datasets for analyzing the status of PAs in the region as WDPA is a major conservation dataset developed over the last 60 years (Bingham et al., 2019).

For analysis, all the cleaned spatial data (vector and raster) were converted from World Geodetic System 1984

TABLE 2 List of datasets considered for protected area and ecological representation analysis

S. no.	Dataset description	Dates and links
1.	WDPA, a global PA database, has been compiling information on protected areas and making this available to the public since 1981 (Bingham et al., 2019). Updates on PAs are submitted by the respective government organizations, or nongovernmental organizations in collaboration with governments. The national targets related to Aichi Target 11 are often measured using WDPA (Smallhorn-West & Govan, 2018)	Data for 1970–2020 collected in April 2020 for eight countries of the Hindu Kush Himalaya https://www.protectedplanet.net/
2.	There are 36 global biodiversity hotspots, which represent about 2.4% of Earth's land surface, but support more than half of the world's endemic plant species, and nearly 43% of endemic bird, mammal, reptile, and amphibian species (Mittermeier et al., 2011).	GIS data was downloaded in April 2020 from the official website of Conservation International (https://www.conservation.org/priorities/biodiversity-hotspots).
3.	Important bird and biodiversity areas: There are over 12,000 IBAs worldwide identified by BirdLife International Partnership using standardized data-driven selection criteria based on threats and irreplaceability (Birdlife, 2014).	The data was accessed in April 2020 https://www.birdlife.org/worldwide/programme-additional-info/important-bird-and-biodiversity-areas-ibas
4.	Global 200 Ecoregions are "relatively large unit of land or water containing a characteristic set of natural communities that share a large majority of their species dynamics, and environmental conditions" (Olson & Dinerstein, 2002)	The data was retrieved in April 2020 from: http://maps.tnc.org/files/metadata/ERA_STEWARD_tnc_terr_ecoregi.xml
5.	Shuttle Radar Topography Mission (SRTM) provides for the first time a near-global high-resolution digital elevation model (DEM) with significant advantages of homogeneous quality and free availability.	SERTM version 3.0 1 arc second data was retrieved in April 2020 from (Becker et al., 2009; USGS & EROS, 2017): https://urs.earthdata.nasa.gov/
6.	Key Biodiversity Areas (KBAs)	Birdlife. (2020) Key Biodiversity Areas (KBAs)—Nature's Hotspots. https://www.birdlife.org.au/. Accessed August 26, 2020

(WGS84) reference coordinate systems into Asia_North_Albers_Equal_Area_Conic projection system using ArcGIS 10.4 projection tool.

The cleaned PA dataset was then analyzed with respect to date of establishment, size, and elevation for each country. Using the global datasets, all the IBAs, ecoregions, hotspots, and KBAs for the HKH were listed. Then, the polygons of all listed IBAs were overlaid with the polygons of PAs to analyze representation of ecosystems and biodiversity areas in PAs network. The overlay process was repeated for ecoregion, hotspots, and KBAs to identify representation, and conservation gaps in the PA network.

3 | RESULTS

3.1 | Status and distribution of PAs

The HKH has a total of 575 PAs, covering an area of 1,721,894 sq. km. This represents 40.17% of the whole HKH geographical area (see Figure 2) and about 8.49% of the global PA coverage. By country-wise, China contributes the most with 45% to the total PA coverage of the HKH, followed by Pakistan (35%), India (11%), Nepal (3%), Myanmar (2%), Afghanistan (1.83%), Bhutan (1.7%), and Bangladesh (0.11%).

3.2 | Management category of PAs

The region has eight different management categories of PAs (see Figure 3). Of the total PAs in the HKH, around 454 PAs fall under IUCN category (I–VI), while 30 PAs are WHSs and Ramsar sites of international importance. The remaining 91 PAs do not have a category and are categorized as "not reported" in WDPA. Within IUCN category, around 32% PAs are managed as "protected landscape (category V)," 28% of PAs are managed under category IV (Habitat/Species Management Area), 10% PAs are under II (National Park) and 8% are managed under category VI (PAs with sustainable use of natural resources). There is only one PA under Ib (wilderness area) and four PAs are Ia (strict nature reserve).

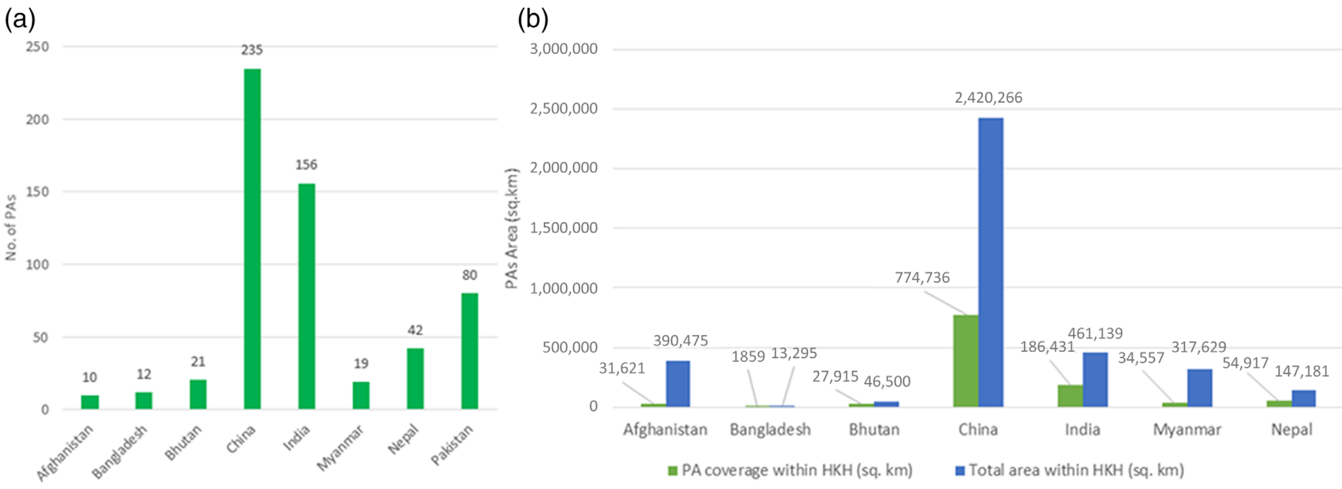

FIGURE 2 (a) Total number of protected areas (PAs) in the eight Hindu Kush Himalaya countries. (b). Total PA coverage with respect to the total area of the eight countries

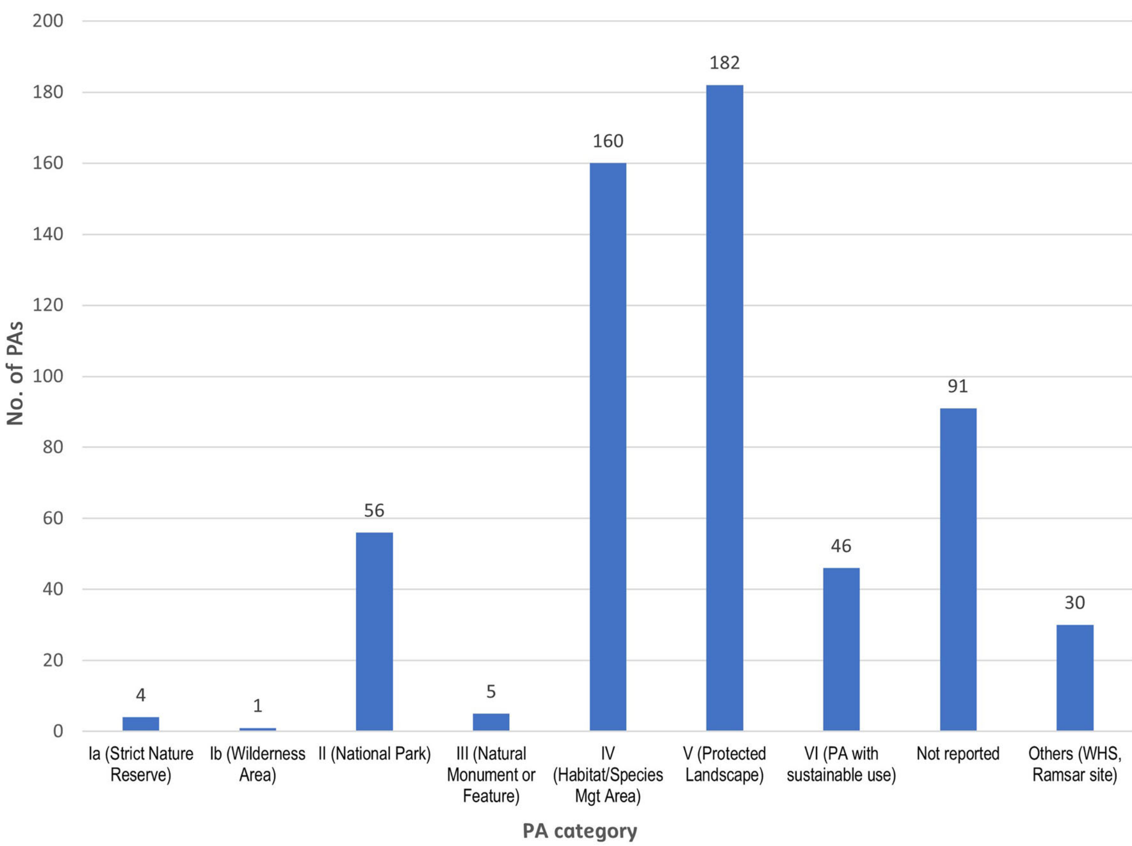

FIGURE 3 Management category of protected areas in the Hindu Kush Himalaya. *Source*: WDPA (2020)

3.3 | Size and proximity of PAs across the HKH

PAs in the HKH differ in size (Figure 4). The largest PA has an area of 4940, 76 sq. km, while the smallest one has an area of 0.02 sq. km. There are around 115 PAs less than 50 sq. km in size that cover an area of 2456 sq. km; 49 PAs between 51 and 100 sq. km covering an area of 3748 sq. km; 109 PAs between 101 and 250 sq. km covering an area of 18,243 sq. km; and 89 PAs between 251 and 500 sq. km covering an area of 33,397 sq. km (Figure 4). The 30 PAs with an area larger than 5000 sq. km cover 1,354,263 sq. km, while the105 PAs ranging from 1001 to 5000 sq. km cover 254,119 sq. km.

Conservation Science and Practice
A Journal of the Society for Conservation Biology
Open Access
WILEY

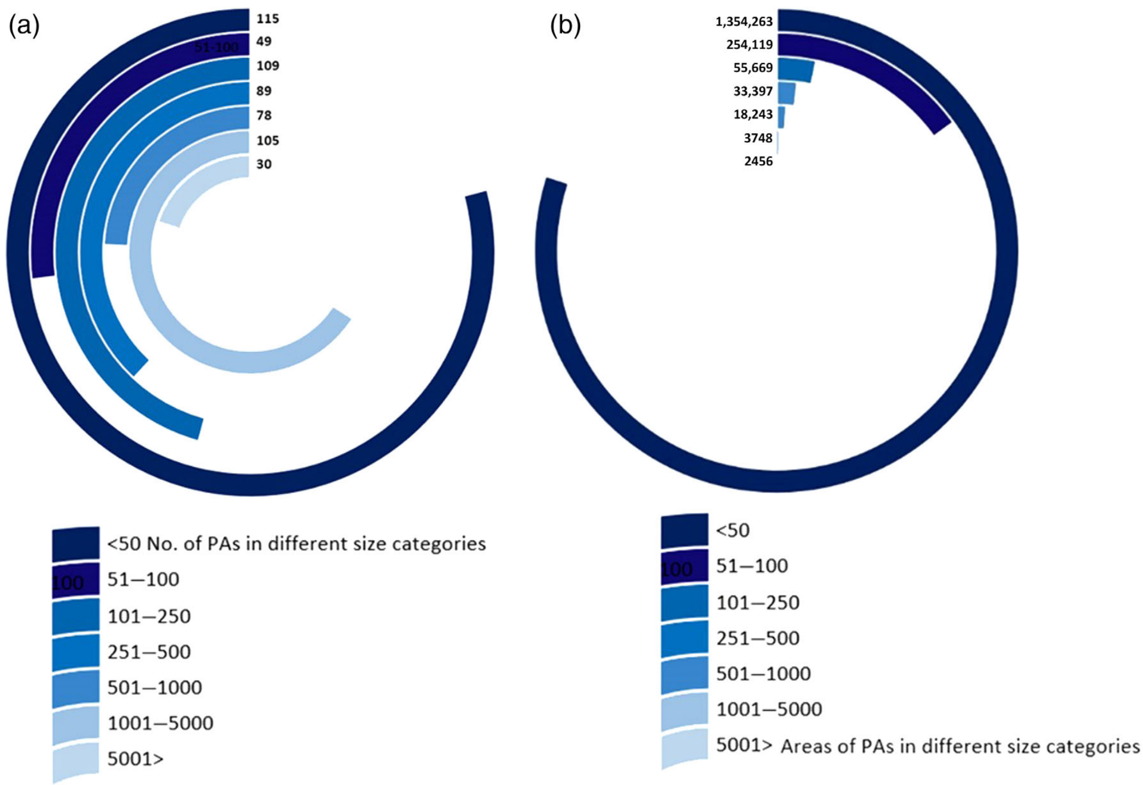

FIGURE 4 (a) Number of protected areas (PAs) in different size category (sq. km); (b) Areas of PAs in different size category (sq. km)

TABLE 3 Proximity of PAs within 100, 500, and 100 m distance from the centroid point

S. no.	Distance (m)	Number of PAs	Area (sq. km)
1	100	16	9735
2	500	6	6222
3	1000	553	1,705,937
Total		575	1,721,894

In terms of proximity (distance between the centroids of PAs), around 16 PAs are within 100 m of the centroid point (center point of each PA), six PAs are within 500 m, and the remaining 553 PAs are within or beyond 1000 m of the centroid point (see Table 3).

3.4 | Growth of PAs over a century

The number of PAs has increased significantly over the last century (1900–2020, see Figure 5). Until the 1970s, there were only 64 PAs; an additional 78 PAs were created by 1981. There was a significant growth in the number of PAs over the following decade (1981–1990) with an additional 176 PAs, reaching a total of 318 PAs by 1991. Similarly, an exponential growth in the number of PAs was noted over the following two decades (1991–2010), reaching a total of 467 by 2000, and 559 PAs by 2010. Over the last decade from 2011 to 2020, 16 more PAs have been designated in the HKH. These add up to a total of 575 PAs across the HKH.

3.5 | PAs across the elevational range

PAs are spatially distributed across elevational zones from south to north and east to west (see Figure 6). The Rudrasagar Lake, a Ramsar Site in Tripura, India is situated at an elevation of 19 masl, while Sagarmatha National Park of Nepal is located at an elevation of 8848.86 masl, showing extreme ends of the altitudinal range of the PA network in the HKH. Most PAs (around 40%) are at lower elevation (below 2000 masl) in the south, compared to the north, including the Tibet Autonomous Region of China above 4000 masl. Around 58% of PAs are below 3000 masl, covering 5, 82,524 sq. km, with only 5% are above 5000 masl, and 0.3% above 6000 masl. The Far-Western Himalaya also has limited PAs; for instance, Afghanistan has only 10 PAs.

3.6 | Ecological representation in the PA system

The HKH is extraordinarily rich in biodiversity and ecosystems, which are reflected in the number of IBAs,

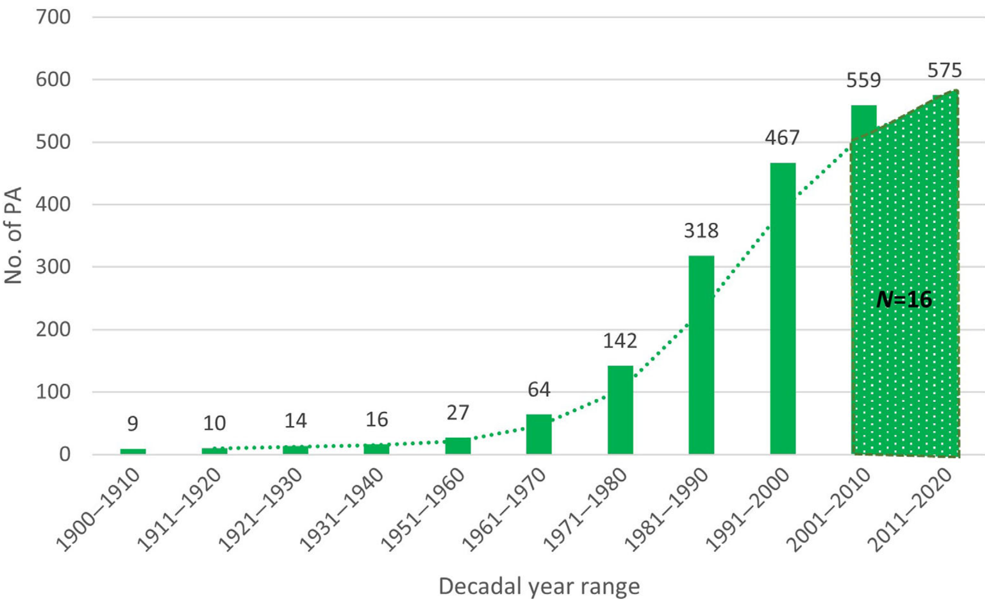

FIGURE 5 Growth in number of protected areas (PAs) from 1910 to 2020 (cumulative)

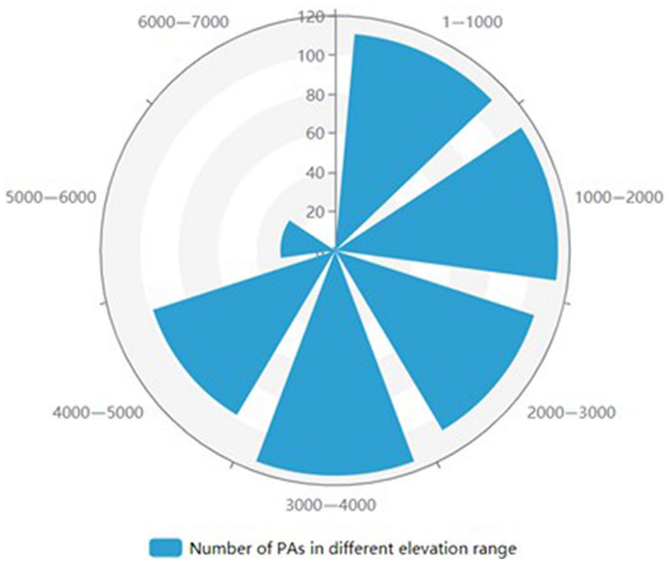

FIGURE 6 Number of protected areas (PAs) by elevation (1000 m elevation bands)

Global Biodiversity Hotspots, KBAs, Global 200 Ecoregions, and WHS. This section highlights the ecological representation in the PA system.

3.6.1 | Important bird and biodiversity areas

About 24% of IBAs are represented within the PA system, and 13.81% of PAs are located within IBAs. The HKH has a total of 335 IBAs covering an area of 861,714 sq. km. This represents about 20% of total area of the HKH (Annex 1). In terms of individual countries, China has 71 IBAs (687,497 sq. km) accounting for 16% of the HKH area and 2% of its IBAs are protected. India has 153 IBAs covering an area of 59,519 sq. km (1.38% of the HKH area), of which 6% are protected. Nepal has 27 IBAs covering an area of 33,092 sq. km (0.8% of the HKH) of which 2.4% are protected, followed by Myanmar which has 26 IBAs covering 29,046 sq. km (0.7% of the HKH area) of which 0.8% of IBAs are protected. Since the Aichi Target 11 commitment in 2010, an additional five IBAs have been designated in Myanmar and Pakistan.

3.6.2 | Global biodiversity hotspots

Around 32% of the HKH is covered by all or parts of four global biodiversity hotspots covering an area of 1,362,402 sq. km. The Himalaya hotspot covers 15%, followed by Indo-Burma (11%), Mountains of Southwest China (6%), and Mountains of Central Asia (<1%). Around 61% of the hotspot area is represented within the PA system, and about 48% of PAs are located within the four global biodiversity hotspots of the region. Of the 575 PAs, 305 fall within the four biodiversity hotspots, with 196 PAs in the Himalaya hotspot, 58 PAs in the Indo-Burma hotspot, 49 PAs in the Mountains of Southwest China, and only two PAs in the Mountains of Central Asia.

3.6.3 | Key biodiversity areas in the region

About 31% of the KBAs covering 318,904 sq. km is protected by the PA system in the HKH. The region has a total of 348 KBAs, covering 24% of the HKH area across the eight countries. Country-wise, China has 18% of its

HKH area under KBAs, of which 6% is protected. Similarly, India has 1.8% of its HKH area under KBAs of which 7.36% of KBA is protected, followed by Afghanistan with 1.71% of its HKH area under KBAs, of which 0.16% is protected. Myanmar has 1.7% of its HKH area under KBAs, of which 1.1% of KBA is protected, followed by Nepal with 0.8% of its HKH area under KBAs of which 2.4% of KBA is protected. Pakistan has 0.4% of its HKH area under KBAs of which 0.3% of KBA is protected.

3.6.4 | Global 200 Ecoregions

The HKH region hosts 12 Global 200 Ecoregions covering 64% of the HKH area (Figure 7). Of this, around 33% is covered by the PA network. A total of 421 PAs fall within these 12 Global Ecoregions, with the Tibetan Plateau Steppe covering 35% of the HKH area of which 19% is protected. Similarly, the Northern Indochina Subtropical Moist Forests cover 6% of the HKH area, of which 3.21% is protected, followed by Hengduan Shan Conifer Forests covering 6% of HKH area of which 3% is protected, and Naga-Manipuri-Chin Hills Moist Forests covering 5% of the HKH area with 1.65% of it under the PA system. Similarly, about 2.5% of the Western Himalaya Temperate Forests, 1.7% of Eastern Himalayan Alpine Meadow, and about 1.5% of Eastern Himalaya Broadleaf and Conifer Forests are protected. Less than 1% of the Terai-Duar Savannas and Grasslands (0.7%), and Middle Asian Montane Woodland and Steppe (0.1%) are protected, while the Indochina Dry Forests, Kayah-Karen/Tenasserim Moist Forests, and Southwest China Temperate Forests ecoregions are not protected.

3.6.5 | World heritage sites

Only 14% of WHS area is under the current PA system. The analysis showed a total of 10 WHSs covering 105,840 sq. km, which is 2.5% of the HKH area (see Annex 2). Among them, nine are natural heritage sites, and one is mixed heritage site. Of the ten, nine (except the Great Himalayan National Park Conservation Area of India) are within the PA system (Annex 2). While 86% which accounts for the Great Himalayan National Park Conservation Area is outside of the PA system.

4 | DISCUSSION

PAs are key for biodiversity conservation and sustainable development (Loos, 2021). We assessed the status of PAs in the HKH by analyzing the number, distribution, trend, and coverage of PAs. We also assessed the proximity of PA and ecological representativeness in relation to IBAs, KBAs, Global Biodiversity Hotspots, and the Global 200 Ecoregions.

4.1 | Growth of PAs

The HKH has 575 PAs covering around 40% of the region. The number of PAs has increased significantly over the last few decades, from 64 in the 1970s to 559 PAs by 2010.

In comparison to global scale, 12.7% of terrestrial area was under PAs system in 2010, which increased to 15% by 2020—showing an average of 2.3% increase over the decade (see Table 4). In the HKH region, an additional 16 PAs covering 73,195.75 sq. km were designated by 2020. Around 1.8% increase in PAs coverage over the last decade (Table 4).

This resonates the advocacy of CBD and global and regional trends (Bacon et al., 2019; Saura et al., 2019). This increase reflects progress against Aichi Target 11, as countries have committed to increase their PA coverage up to 17%. Overall, the PA coverage (i.e., 40% of the total area) and biological richness in the HKH is encouraging compared to the global PA coverage (15%).

However, the HKH only contributes 8.49% to the global coverage of PAs. This presents an opportunity to gear up efforts toward meeting Aichi Target 11 (Bacon et al., 2019) and Action Target 3 of post-2020 global biodiversity framework to conserve its unique biodiversity. At the country scale, many countries except Bhutan (51.44%) and Nepal (23.39%) have less area under PA coverage against their commitments. Afghanistan, Bangladesh, and Pakistan have only 4.54%, 6%, and 12% of their area under PAs, respectively. Increasing PA coverage could be challenging, considering the exponential population growth, high dependency on ecosystem services in the HKH (Sharma et al., 2019), limited livelihood options, and unsustainable development practices (Singh et al., 2019).

4.2 | Uneven distribution of PAs

PAs are unevenly distributed across the region. The majority are in the south at low to medium elevation, with only a limited number of PAs in the higher elevation (Elsen et al., 2018). This resonates the unprotected status of mountain areas at the global scale. Many mountain areas and ranges are either not adequately protected or completely unprotected (IUCN WCPA, 2021).

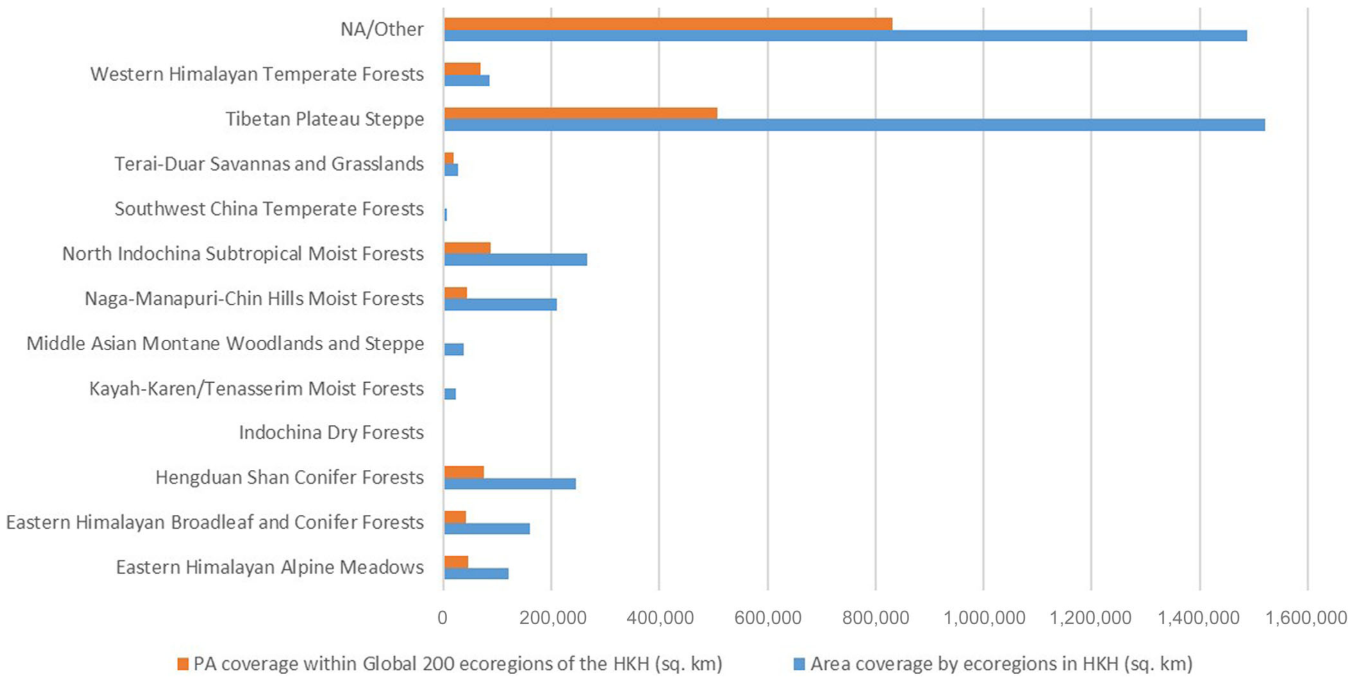

FIGURE 7 Protected area (PA) coverage within the Global 200 Ecoregions

TABLE 4 HKH and global protected area coverage over the last decade (2010–2020)

HKH				Global	
Year	Number	Area	%	Year	% of PA
2010	559	1,648,698.5	38.46	2010	12.7
2020	575	1,721,894.3	40.17	2020	15
Total	16	73,195.75	1.71	Difference	2.3

One of the major reasons could be the species richness in the lower elevation. Threatened species richness decreases along the elevational gradient with high richness at the lower elevation (Paudel et al., 2018).

This is an important gap to be considered for the HKH, as high mountain ecosystems are biodiversity hotspots sheltering diverse endemic species (Hughes & Eastwood, 2006; Payne et al., 2020) but vulnerable to global changes including climate change (Vincent et al., 2019). Warming in high mountains including the HKH is higher than other regions of the world showing an altitude-dependent temperature increase with impacts on ecosystem and people living in the mountains and beyond (Krishnan et al., 2019; Pepin et al., 2015). The limited PA network in higher elevation also means that the unique ecosystems and endemic species such as the snow leopard (*Panthera uncia*) and other flagship species are not protected under the PA network and are exposed to habitat fragmentation and degradation with significant impacts on their population (Li et al., 2016). As such, scholars strongly underline the need to establish a comprehensive PA network in alpine and sub-alpine ecosystems to conserve endemic species and build the resilience of high altitude species and ecosystems (Farrington & Li, 2016; Haight & Hammill, 2020). This will enhance ecological representation and support species when there are range shifts under climate change (Elsen et al., 2018).

4.3 | More small-sized PAs

Importantly, the analysis shows variations in PA size, with 115 PAs less than 50 sq. km, and 109 PAs ranging in size from 101 to 250 sq. km. Altogether, these 224 PAs cover only 20,699 sq. km and are scattered (Figure 5). Small PAs have limited capacity to support viable populations of species, especially megafauna like tiger (*Panthera tigris*), elephant (*Elephas maximus*), and rhinoceros (*Rhinoceros unicornis*) (Jacobson et al., 2016; Webb et al., 2020). As PAs cannot be managed as "islands," connectivity and corridors to ease the movement of species, enable climate induced habitat shifts and other ecological flows among PAs has been one of the priorities of biodiversity conservation (Lehikoinen et al., 2021; McGuire et al., 2016). It is estimated that only 7.7% of global PAs are connected through corridors (Saura et al., 2019) and the concept of corridors in the HKH is still evolving (Chettri et al., 2007; Gurung et al., 2019). In Kangchenjunga Landscape (KL), ICIMOD identified six corridors connecting 14 PAs through multi-stakeholder consultation and field appraisal (ICIMOD, 2015). Similarly, the Khata corridor, which links Nepal's Bardiya National Park with India's Katarniaghat Wildlife Sanctuary has been successful in supporting the movement of tiger and Asian elephant (Wegge et al., 2016). However, more corridors and connectivity are required considering the size of many PAs in the HKH. This is important for two reasons: (i) small-sized PAs without any connectivity to other PAs are vulnerable to declines in biodiversity even if they have high species richness, and focused conservation measures are in place (Fahrig, 2020; Pressey et al., 2015); and, (ii) climate change could further threaten biodiversity and make PAs inhospitable for many species, requiring species with limited habitat ranges to move to higher elevations. Without connectivity, these populations might end up in climate traps, resulting in species decline and even extinction (Thomas et al., 2014). Such situations could be further exacerbated by other drivers such as forest degradation, fragmentation, and unplanned development (Elias, 2020).

4.4 | Limited ecological representation

The study once again highlights the exceptional ecosystem diversity of the region with 4 Global Biodiversity Hotspots covering 32% and 12 Global 200 Ecoregions covering 64% of the total area of the HKH (Mittermeier et al., 2011). About 20% is covered by IBAs, 24% by KBAs and 2.5% by the WHSs. As such, the region has been regarded as a “key region of biodiversity” (Mittermeier et al., 2011; Olson & Dinerstein, 2002; Ricketts et al., 2005), with megadiverse countries like China and India (Bacon et al., 2019). However, there is limited representation of these biologically rich ecosystems in the current PA system. Our study reveals that only 24% of IBAs, 33% of Global 200 Ecoregions, and 31% of KBAs are within the PA system. This mirrors the global scenario where ecological representativeness of PAs has been reported to be extremely low (Visconti et al., 2019). As a result, vast areas of high biodiversity importance are under little or no protection and are subject to various drivers of change.

In the HKH, rapid demographic and economic growth have increased the demand for natural resources sometimes leading to overexploitation, significant land cover change, habitat fragmentation, and unsustainable socioeconomic activities (Wang et al., 2019). About 29.62% of the forest cover in South Asia was lost between 1930 and 2014 (Reddy et al., 2018). It is predicted that 80%–85% of the original habitat of the HKH will be lost by 2100 (Jantz et al., 2015). The region has been identified as an “area of imminent extinction” (Ricketts et al., 2005) and “crisis ecoregion” (Brooks et al., 2006). This loss will not only impact ecosystem integrity and biodiversity, but also the livelihoods of millions of people who are highly dependent on ecosystem services for their daily livelihoods (Chaudhary et al., 2018; Xu et al., 2019). Increased ecosystem degradation and loss of ecosystem services threatens to impact the livelihoods of millions and push them into a poverty trap.

4.5 | Implications for science, policy, and practice

This study advances our knowledge of the PA network in the HKH by providing updated information and insights into the status, distribution, and trends over a century, as well as their ecological representativeness. This is important for conservation planning and management in the regional member countries and relevant institutions could use this for conservation priority setting. Representation of ecosystems in conservation strategies is a core principle of global conservation priority setting (Sayre et al., 2020) and needs to be considered in PAs. The study highlights the need to consider ecological representation during PA establishment, as noted elsewhere (Kearney et al., 2018).

Our study also contributes to a better understanding of progress against multilateral agreements and commitments, particular Aichi Target 11 and the SDGs. SDGs in general and Goal 15 (Life on Land) in particular focus on conservation of terrestrial, freshwater, and marine ecosystems (UN, 2015) and seek to identify global protection goals (CBD, 2010). These policy mandates require reporting of the distribution of ecosystems, their conservation status, and representation in the PA network. Our study findings directly contribute to these policy mandates at regional scale by providing an overview of progress made against this target since the Strategic Plan was adopted in 2010. The 40% PA coverage and 64% Global Ecoregion coverage are promising contributions toward the movement on half of all terrestrial areas need to be conserved (Dinerstein et al., 2020; Schleicher et al., 2019). The post-2020 biodiversity agenda in the region could consider the current scenario of PAs status and recommend actions for more robust ecological representation in mountain PAs. The HKH is exceptionally important for biodiversity and the limited representation in the PA network holds huge potential for bringing additional areas under protection.

Based on the findings, we suggest the following ways forward for research and action:

1. A detailed assessment of corridors and connectivity between PAs beyond the political boundaries of countries in the HKH, especially for small PAs. This is important not only for species conservation, but also for ecosystem integrity (Chettri & Sharma, 2016). Regional member countries should put in more efforts to identify and demarcate biological corridors through regional cooperation (Tittley et al., 2021). This resonates the calls made for greater landscape and corridor connectivity in the region (Dong et al., 2017).
2. Ecological representation analysis should be done at national scale to identify conservation gaps and guide conservation planning.
3. Assessment of intact and contiguous ecosystems is required to understand fragmentation and degradation of ecosystems within and outside of PAs. This is important to conserve unique ecosystems and endemics. In addition, it is also important to analyze PA integration into wider conservation landscapes at the transboundary level.
4. Threatened and endemic species within and outside of PAs should be another important research priority. These demands detailed and regular assessments and monitoring of rare, endemic, and threatened species. This would help in priority setting and conservation of species especially outside PAs and maintain endemism and ecological integrity. Due consideration of ecological integrity and representativeness in the PA network would contribute to sustainable biodiversity conservation (Saura et al., 2019).
5. Other Effective area-based Conservation Measures (OECM), highly encouraged by the parties to the CBD, has huge potential in the HKH. Many areas under community and local ownership in the HKH that are often neglected can be reflected through OECM (Dudley et al., 2018). OECMs complement PAs and can be governed by diverse groups and arrangements, including national and sub-national governments, private entities, indigenous peoples, local communities, or through shared governance arrangements (IUCN-WCPA, 2019). Country-level efforts in identifying, mapping, and declaring OECMs in the HKH could provide natural corridors for species beyond PAs. This can also help the eight HKH countries progress toward their target on PAs. For instance, India has already identified, mapped, and submitted a list of potential OECMs to WDPA (GoI, 2021).
6. Improving management effectiveness of PAs is critically important to protect their values and achieve conservation goals in the eight HKH countries and to ensure that quality rather than extent is integrated and measured. This management effectiveness evaluation aims to assess the governance system of PAs to deliver equitable conservation and development outcomes (Geldmann et al., 2019).

AUTHOR CONTRIBUTIONS

Nakul Chettri and Eklabya Sharma conceived the idea and provided the overall guidance on the study. Sunita Chaudhary designed the study, analyzed the data, and led the writing of the manuscript. Kabir Uddin collected and analyzed the data. Rajesh Thapa helped in analyzing the datasets. All authors reviewed and commented on the manuscript.

ACKNOWLEDGMENTS

ICIMOD gratefully acknowledges the support of its core donors: the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Sweden, and Switzerland. Our special thanks go to three anonymous reviewers, associate editor, and editor-in-chief for constructive feedback and suggestions. Their comments and feedback helped us to improve the manuscript significantly. We thank Samuel Thomas from ICIMOD for thoughtful editing of the manuscript. We also thank Birdlife International for providing GIS data on Key Biodiversity Areas.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used in this study are publicly accessible and are readily available upon request.

ORCID

Sunita Chaudhary https://orcid.org/0000-0001-8273-5518
Kabir Uddin https://orcid.org/0000-0003-2711-5791
Nakul Chettri https://orcid.org/0000-0002-3338-8879
Rajesh Thapa https://orcid.org/0000-0002-5931-7147

REFERENCES

Bacon, E., Gannon, P., Stephen, S., Seyoum-Edjigu, E., Schmidt, M., Lang, B., Sandwith, T., Xin, J., Arora, S., & Adham, K. N. (2019). Aichi Biodiversity Target 11 in the like-minded megadiverse countries. *Journal for Nature Conservation*, *51*, 125723.

Bajracharya, S. R., Maharjan, S. B., Shrestha, F., Guo, W., Liu, S., Immerzeel, W., & Shrestha, B. (2015). The glaciers of the Hindu Kush Himalayas: Current status and observed changes from the 1980s to 2010. *International Journal of Water Resources Development*, *31*, 161–173.

Bawa, K. S., & Seidler, R. (2015). Deforestation and sustainable mixed-use landscapes: A view from the eastern Himalaya1. *Annals of the Missouri Botanical Garden*, *100*, 141–149.

Becker, J., Sandwell, D., Smith, W., Braud, J., Binder, B., Depner, J., Fabre, D., Factor, J., Ingalls, S., & Kim, S. (2009). Global bathymetry and elevation data at 30 arc seconds resolution: SRTM30_PLUS. *Marine Geodesy*, *32*, 355–371.

Bingham, H. C., Bignoli, D. J., Lewis, E., MacSharry, B., Burgess, N. D., Visconti, P., Deguignet, M., Misrachi, M., Walpole, M., & Stewart, J. L. (2019). Sixty years of tracking conservation progress using the world database on protected areas. *Nature Ecology and Evolution*, *3*, 737–743.

Birdlife. (2014). *Important bird and biodiversity areas: A global network for conserving nature and benefiting people*. BirdLife International www.birdlife.org

Birdlife. (2020). *Important bird and biodiversity areas (IBAs)*. Birdlife International https://www.birdlife.org/worldwide/programme-additional-info/important-bird-and-biodiversity-areas-ibas

Bolch, T., Shea, J. M., Liu, S., Azam, F. M., Gao, Y., Gruber, S., Immerzeel, W. W., Kulkarni, A., Li, H., Tahir, A. A., Zhang, G., & Zhang, Y. (2019). Status and change of the cryosphere in the extended Hindu Kush Himalaya region. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya Assessment: Mountains, climate change, sustainability and people* (pp. 209–255). Springer International Publishing.

Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A., Gerlach, J., Hoffmann, M., Lamoreux, J. F., Mittermeier, C. G., Pilgrim, J. D., & Rodrigues, A. S. (2006). Global biodiversity conservation priorities. *Science*, *313*, 58–61.

Buchanan, G. M., Butchart, S. H., Chandler, G., & Gregory, R. D. (2020). Assessment of national-level progress towards elements of the Aichi Biodiversity Targets. *Ecological Indicators*, *116*, 106497.

CBD. (1992). *Convention on Biological Diversity (CBD), United Nations Environment Programme*. https://www.cbd.int/doc/legal/cbd-en.pdf

CBD. (2006). *Programme of Work on Protected Area (PoWPA)*. Convention on Biological Diversity, Montreal, Canada. https://www.cbd.int/protected/.

CBD. (2010). *Process for the revision of the strategic plan*.

CBD. (2016). *Subsidiary Body on Scientific, Technical and Technological Advice*. Twentieth meeting, Information, 43: UNEP/CBD/SBSTTA/20?INF/43, p.11, Montreal, Canada.

CBD. (2019). *Protected areas—An overview*, https://www.cbd.int/protected/overview/.

CBD. (2020). *Strategic plan for biodiversity 2011–2020, including Aichi biodiversity targets*. Convention on Biological Diversity (CBD), Montreal, Canada. https://www.cbd.int/sp/.

CBD. (2022). *First draft of the post-2020 global biodiversity framework. Third meeting of Open Ended Working Group on the post-2020 global biodiversity framework*. Secretariat of the Convention on Biological Diversity (SCBD), Montreal, Canada. CBD/WG2020/3/3. https://www.cbd.int/doc/c/abb5/591f/2e46096d3f0330b08ce87a45/wg2020-03-03-en.pdf

Chaudhary, S., McGregor, A., Houston, D., & Chettri, N. (2018). Environmental justice and ecosystem services: A disaggregated analysis of community access to forest benefits in Nepal. *Ecosystem Services*, *29*, 99–115.

Chettri, N., Shakya, B., Thapa, R., & Sharma, E. (2008). Status of a protected area system in the Hindu Kush-Himalayas: An analysis of PA coverage. *International Journal of Biodiversity Science and Management*, *4*, 164–178.

Chettri, N., & Sharma, E. (2016). Reconciling the mountain biodiversity conservation and human wellbeing: Drivers of biodiversity loss and new approaches in the Hindu-Kush Himalayas. *Proceedings of the Indian National Science Academy*, *82*, 53–73.

Chettri, N., Sharma, E., Shakya, B., & Bajracharya, B. (2007). Developing forested conservation corridors in the Kangchenjunga landscape, eastern Himalaya. *Mountain Research and Development*, *27*, 211–214.

Chettri, N., Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., Oli, K., & Choudhury, D. (2010). *Biodiversity in the Eastern Himalayas: Status, trends and vulnerability to climate change*.

Dinerstein, E., Joshi, A. R., Vynne, C., Lee, A. T. L., Pharand-Deschênes, F., França, M., Fernando, S., Birch, T., Burkart, K., Asner, G. P., & Olson, D. (2020). A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate. *Science Advances*, *6*, eabb2824.

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., Hahn, N., Palminteri, S., Hedao, P., & Noss, R. (2017). An ecoregion-based approach to protecting half the terrestrial realm. *Bioscience*, *67*, 534–545.

Dong, S., Chettri, N., & Sharma, E. (2017). Himalayan biodiversity: Trans-boundary conservation institution and governance. In S. Dong, J. Bandyopadhyay, & S. Chaturvedi (Eds.), *Environmental sustainability from the Himalayas to the oceans: Struggles and innovations in China and India* (pp. 127–143). Springer International Publishing.

Dudley, N., Jonas, H., Nelson, F., Parrish, J., Pyhälä, A., Stolton, S., & Watson, J. E. M. (2018). The essential role of other effective area-based conservation measures in achieving big bold conservation targets. *Global Ecology and Conservation*, *15*, e00424.

Elias, S. A. (2020). Asian alpine mammals. In M. I. Goldstein & D. A. DellaSala (Eds.), *Encyclopedia of the world's biomes* (pp. 475–491). Elsevier.

Elsen, P. R., Monahan, W. B., & Merenlender, A. M. (2018). Global patterns of protection of elevational gradients in mountain ranges. *Proceedings of the National Academy of Sciences*, *115*, 6004–6009.

Fahrig, L. (2020). Why do several small patches hold more species than few large patches? *Global Ecology and Biogeography*, *29*, 615–628.

Farrington, J. D., & Li, J. (2016). Climate change impacts on snow leopard range. In *Snow leopards* (pp. 85–95). Elsevier.

Geldmann, J., Manica, A., Burgess, N. D., & Coad, L. (2019). A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. *Proceedings of the National Academy of Sciences of the United States of America*, *116*, 23209–23215.

GoI. (2021). *Other effective area-based conservation measures (OECMs)*, http://www.india-oecm.in/.

Guangwei, C. (2002). *Biodiversity in the eastern Himalayas: Conservation through dialogue. Summary reports of workshops on biodiversity conservation in the Hindu Kush-Himalayan ecoregion*. ICIMOD.

Gurung, J., Chettri, N., Sharma, E., Ning, W., Chaudhary, R. P., Badola, H. K., Wangchuk, S., Uprety, Y., Gaira, K. S., & Bidha, N. (2019). Evolution of a transboundary landscape approach in the Hindu Kush Himalaya: Key learnings from the Kangchenjunga Landscape. *Global Ecology and Conservation*, *17*, e00599.

Haight, J., & Hammill, E. (2020). Protected areas as potential refugia for biodiversity under climatic change. *Biological Conservation*, *241*, 108258.

Hoekstra, J. M., Boucher, T. M., Ricketts, T. H., & Roberts, C. (2005). Confronting a biome crisis: Global disparities of habitat loss and protection. *Ecology Letters*, *8*, 23–29.

Holdgate, M., & Phillips, A. (1999). Protected areas in context. In *Integrated protected area management* (pp. 1–24). Springer.

Hughes, C., & Eastwood, R. (2006). Island radiation on a continental scale: Exceptional rates of plant diversification after uplift of the Andes. *Proceedings of the National Academy of Sciences*, *103*, 10334–10339.

ICIMOD. (2015). *Proceedings on Regional Technical Meeting on 'Conservation and Development Strategy' and 'Regional Cooperation Framework' for Kangchenjunga Landscape Conservation and Development Initiative. Kathmandu*.

ICIMOD. (2020). *Regional policy dialogue on Aichi Target 11 in South Asia sub-region*.

IUCN. (2016). *Protected Planet Report*. UNEP-WCMC and IUCN: Cambridge, UK and Gland, Switzerland, pp. 78–95.

IUCN WCPA (2021). *Mountain Protected areas update*. No. 19. https://www.iucn.org/sites/dev/files/content/documents/mountain_update_march_2021_0.pdf

IUCN-WCPA. (2019). *Recognising and reporting other effective area-based conservation measures*. World Commission on Protected Areas Task Force on OECMs. Gland, Switzerland.

Jacobson, S. L., Bliss-Ketchum, L. L., de Rivera, C. E., & Smith, W. P. (2016). A behavior-based framework for assessing barrier effects to wildlife from vehicle traffic volume. *Ecosphere*, *7*, e01345.

Jantz, S. M., Barker, B., Brooks, T. M., Chini, L. P., Huang, Q., Moore, R. M., Noel, J., & Hurtt, G. C. (2015). Future habitat loss and extinctions driven by land-use change in biodiversity hotspots under four scenarios of climate-change mitigation. *Conservation Biology*, *29*, 1122–1131.

Kearney, S. G., Adams, V. M., Fuller, R. A., Possingham, H. P., & Watson, J. E. (2018). Estimating the benefit of well-managed protected areas for threatened species conservation. *Oryx*, *54*, 276–284.

Krishnan, R., Shrestha, A. B., Ren, G., Rajbhandari, R., Saeed, S., Sanjay, J., Syed, M. A., Vellore, R., Xu, Y., & You, Q. (2019). *Unravelling climate change in the Hindu Kush Himalaya: Rapid warming in the mountains and increasing extremes*. The Hindu Kush Himalaya Assessment (pp. 57–97). Springer.

Kullberg, P., Di Minin, E., & Moilanen, A. (2019). Using key biodiversity areas to guide effective expansion of the global protected area network. *Global Ecology and Conservation*, *20*, e00768.

Lehikoinen, P., Tiusanen, M., Santangeli, A., Rajasärkkä, A., Jaatinen, K., Valkama, J., Virkkala, R., & Lehikoinen, A. (2021). Increasing protected area coverage mitigates climate-driven community changes. *Biological Conservation*, *253*, 108892.

Li, J., McCarthy, T. M., Wang, H., Weckworth, B. V., Schaller, G. B., Mishra, C., Lu, Z., & Beissinger, S. R. (2016). Climate refugia of snow leopards in High Asia. *Biological Conservation*, *203*, 188–196.

Loos, J. (2021). Reconciling conservation and development in protected areas of the Global South. *Basic and Applied Ecology*, *54*, 108–118.

McGuire, L. A., Rengers, F. K., Kean, J. W., Coe, J. A., Mirus, B. B., Baum, R. L., & Godt, J. W. (2016). Elucidating the role of vegetation in the initiation of rainfall-induced shallow landslides: Insights from an extreme rainfall event in the Colorado Front Range. *Geophysical Research Letters*, *43*, 9084–9092.

Messerli, B., & Ives, J. D. (1997). *Mountains of the world: A global priority*. Parthenon Publishing Group.

Mittermeier, R. A., Turner, W. R., Larsen, F. W., Brooks, T. M., & Gascon, C. (2011). Global biodiversity conservation: The critical role of hotspots. In *Biodiversity hotspots* (pp. 3–22). Springer.

Molden, D. J., Vaidya, R. A., Shrestha, A. B., Rasul, G., & Shrestha, M. S. (2014). Water infrastructure for the Hindu Kush Himalayas. *International Journal of Water Resources Development*, *30*, 60–77.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*, 853–858.

Olson, D. M., & Dinerstein, E. (2002). The Global 200: Priority ecoregions for global conservation. *Annals of the Missouri Botanical Garden*, *89*, 199–224.

Payne, D., Spehn, E. M., Prescott, G. W., Geschke, J., Snethlage, M. A., & Fischer, M. (2020). Mountain biodiversity is central to sustainable development in mountains and beyond. *One Earth*, *3*, 530–533.

Pepin, N., Bradley, R. S., Diaz, H., Baraër, M., Caceres, E., Forsythe, N., Fowler, H., Greenwood, G., Hashmi, M., & Liu, X. (2015). Elevation-dependent warming in mountain regions of the world. *Nature Climate Change*, *5*, 424–430.

Pressey, R. L., Visconti, P., & Ferraro, P. J. (2015). Making parks make a difference: Poor alignment of policy, planning and management with protected-area impact, and ways forward. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*, 20140280.

Reddy, C. S., Saranya, K., Pasha, S. V., Satish, K., Jha, C., Diwakar, P., Dadhwal, V., Rao, P., & Murthy, Y. K. (2018). Assessment and monitoring of deforestation and forest fragmentation in South Asia since the 1930s. *Global and Planetary Change*, *161*, 132–148.

Rees, S. E., Foster, N. L., Langmead, O., Pittman, S., & Johnson, D. E. (2018). Defining the qualitative elements of Aichi Biodiversity Target 11 with regard to the marine and coastal environment in order to strengthen global efforts for marine biodiversity conservation outlined in the United Nations Sustainable Development Goal 14. *Marine Policy*, *93*, 241–250.

Ricketts, T. H., Dinerstein, E., Boucher, T., Brooks, T. M., Butchart, S. H., Hoffmann, M., Lamoreux, J. F., Morrison, J., Parr, M., & Pilgrim, J. D. (2005). Pinpointing and preventing imminent extinctions. *Proceedings of the National Academy of Sciences*, *102*, 18497–18501.

Rodríguez-Rodríguez, D., Bomhard, B., Butchart, S. H., & Foster, M. N. (2011). Progress towards international targets for protected area coverage in mountains: A multi-scale assessment. *Biological Conservation*, *144*, 2978–2983.

Saura, S., Bertzky, B., Bastin, L., Battistella, L., Mandrici, A., & Dubois, G. (2019). Global trends in protected area connectivity from 2010 to 2018. *Biological Conservation*, *238*, 108183.

Sayre, R., Karagulle, D., Frye, C., Boucher, T., Wolff, N. H., Breyer, S., Wright, D., Martin, M., Butler, K., & Van Graafeiland, K. (2020). An assessment of the representation of ecosystems in global protected areas using new maps of world climate regions and world ecosystems. *Global Ecology and Conservation*, *21*, e00860.

Schleicher, J., Peres, C. A., & Leader-Williams, N. (2019). Conservation performance of tropical protected areas: How important is management? *Conservation Letters*, *12*, e12650.

Sharma, B., Rasul, G., & Chettri, N. (2015). The economic value of wetland ecosystem services: Evidence from the Koshi Tappu Wildlife Reserve, Nepal. *Ecosystem Services*, *12*, 84–93.

Sharma, E., Chettri, N., & Oli, K. P. (2010). Mountain biodiversity conservation and management: A paradigm shift in policies and practices in the Hindu Kush-Himalayas. *Ecological Research*, *25*, 909–923.

Sharma, E., Molden, D., Rahman, A., Khatiwada, Y. R., Zhang, L., Singh, S. P., Yao, T., & Wester, P. (2019). *Introduction to the Hindu Kush Himalaya Assessment*. (The Hindu Kush Himalaya Assessment) (pp. 1–16). Springer.

Singh, S., Tanvir Hassan, S. M., Hassan, M., & Bharti, N. (2019). Urbanisation and water insecurity in the Hindu Kush Himalaya: Insights from Bangladesh, India, Nepal and Pakistan. *Water Policy*, *22*, 9–32.

Smallhorn-West, P., & Govan, H. (2018). Towards reducing misrepresentation of national achievements in marine protected area targets. *Marine Policy*, *97*, 127–129.

Tantipisanuh, N., Savini, T., Cutter, P., & Gale, G. A. (2016). Biodiversity gap analysis of the protected area system of the Indo-Burma hotspot and priorities for increasing biodiversity representation. *Biological Conservation*, *195*, 203–213.

Thomas, F., Sabel, C. E., Morton, K., Hiscock, R., & Depledge, M. H. (2014). Extended impacts of climate change on health and wellbeing. *Environmental Science & Policy*, *44*, 271–278.

Tittley, M. A., Butchart, S. H. M., Jones, V. R., Whittingham, M. J., & Willis, S. G. (2021). Global inequities and political borders challenge nature conservation under climate change. *Proceedings of National Academy of Sciences (PNAS)*, *118*(7), e2011204118.

UN. (2015). *Sustainable Development Goals (SDGs). The 17 Goals, UN Department of Economic and Social Affairs, Sustainable Development, United Nations*, www.sdgs.un.org.

UNEP-WCMC. (2021). *World Database on Protected Areas (WDPA)*. www.protectedplanet.net.

USGS & EROS. (2017). *Earth Resources Observation And Science (EROS) Center. Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global [Data set]*. U.S. Geological Survey. https://doi.org/10.5066/F7PR7TFT.

Vincent, C., Fernandes, R. F., Cardoso, A. R., Broennimann, O., di Cola, V., D'Amen, M., Ursenbacher, S., Schmidt, B. R., Pradervand, J. N., Pellissier, L., & Guisan, A. (2019). Climate and land-use changes reshuffle politically-weighted priority areas of mountain biodiversity. *Global Ecology and Conservation*, *17*, e00589.

Visconti, P., Butchart, S. H., Brooks, T. M., Langhammer, P. F., Marnewick, D., Vergara, S., Yanosky, A., & Watson, J. E. (2019). Protected area targets post-2020. *Science*, *364*, 239–241.

Wang, Y., Wu, N., Kunze, C., Long, R., & Perlik, M. (2019). *Drivers of change to mountain sustainability in the Hindu Kush Himalaya*. (The Hindu Kush Himalaya Assessment) (pp. 17–56). Springer.

Webb, E. L., Choo, Y. R., Kudavidanage, E. P., Amarasinghe, T. R., Bandara, U. G. S. I., Wanninayaka, W. A. C. L., Ravindrakumar, P., Nimalrathna, T. S., Liang, S. H., & Chua, M. A. H. (2020). Leopard activity patterns in a small montane protected area highlight the need for integrated, collaborative landscape conservation. *Global Ecology and Conservation*, *23*, e01182.

Wegge, P., Yadav, S. K., & Lamichhane, B. R. (2016). Are corridors good for tigers Panthera tigris but bad for people? An assessment of the Khata corridor in lowland Nepal. *Oryx*, *52*, 35–45.

Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (2019). *The Hindu Kush Himalaya Assessment*. Springer International Publishing.

WWF & ICIMOD. (2001). *Ecoregion-based conservation in the Eastern Himalaya: Identifying important areas for biodiversity conservation*. WWF Nepal, Kathmandu, Nepal.

Xu, J., Badola, R., Chettri, N., Chaudhary, R. P., Zomer, R., Pokhrel, B., Hussain, S. A., Pradhan, S., & Pradhan, R. (2019). *Sustaining biodiversity and ecosystem services in the Hindu Kush Himalaya*. (The Hindu Kush Himalaya Assessment) (pp. 127–165). Springer.

You, Z., Hu, J., Wei, Q., Li, C., Deng, X., & Jiang, Z. (2018). Pitfall of big databases. *Proceedings of the National Academy of Sciences*, *115*, E9026.

Zafra-Calvo, N., Garmendia, E., Pascual, U., Palomo, I., Gross-Camp, N., Brockington, D., Cortes-Vazquez, J.-A., Coolsaet, B., & Burgess, N. D. (2019). Progress toward equitably managed protected areas in Aichi Target 11: A global survey. *Bioscience*, *69*, 191–197.

How to cite this article: Chaudhary, S., Uddin, K., Chettri, N., Thapa, R., & Sharma, E. (2022). Protected areas in the Hindu Kush Himalaya: A regional assessment of the status, distribution, and gaps. *Conservation Science and Practice*, e12793. https://doi.org/10.1111/csp2.12793

APPENDIX A

ANNEX 1 Number and area of Important Bird and Biodiversity Areas (IBAs) in the Hindu Kush Himalaya

S. no.	Country	Total number of IBAs in HKH	Total area covered by IBAs in HKH	% of IBA area in the HKH	No of PAs within IBA	Area (sq. km)	Area (%)
1	Afghanistan	12	21,412	0.50	3	2751	0.16
2	Bangladesh	8	1312	0.03	5	627	0.04
3	Bhutan	23	13,028	0.30	10	15,145	0.88
4	China	71	687,497	16.03	57	42,108	2.45
5	India	153	59,519	1.4	66	118,626	6.89
6	Myanmar	26	29,046	0.67	4	12,751	0.74
7	Nepal	27	33,092	0.77	30	40,451	2.35
8	Pakistan	15	16,809	0.39	6	5113	0.3
	Total	335	861,714	20.1	181	237,572	13.81

ANNEX 2 Natural and mixed-world heritage sites in the Hindu Kush Himalaya

Name	Year of inscription	Category	Country	WHS area (sq. km)	Buffer zone area (sq. km)
Jiuzhaigou Valley Scenic and Historic Interest Area	1992	Natural	China	720	600
Huanglong Scenic and Historic Interest Area	1992	Natural	China	600	0
Three Parallel Rivers of Yunnan Protected Areas	2003	Natural	China	17,000	0
Sichuan Giant Panda Sanctuaries—Wolong, Mt Siguniang, and Jiajin Mountains	2006	Natural	China	9245	5271
Qinghai Hoh Xil	2017	Natural	China	37,356	22,909.04
Nanda Devi and Valley of Flowers National Parks	1988	Natural	India	718	5142.86
Great Himalayan National Park Conservation Area	2014	Natural	India	905	265.6
Khangchendzonga National Park	2016	Mixed	India	1784	1147.12
Sagarmatha National Park	1979	Natural	Nepal	1244	0
Chitwan National Park	1984	Natural	Nepal	932	0
Total				70,505	35,335.62