Ecosystem Services in a Snow Leopard Landscape: A Comparative Analysis of Two High-elevation National Parks in the Karakoram–Pamir

Authors: Din, Jaffar Ud, Nawaz, Muhammad Ali, Norma-Rashid, Yusoff, Ahmad, Farid, Hussain, Kamran, et al.

Source: Mountain Research and Development, 40(2)

Published By: International Mountain Society

URL: https://doi.org/10.1659/MRD-JOURNAL-D-19-00047.1

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

MountainResearch
Systems knowledge

Ecosystem Services in a Snow Leopard Landscape: A Comparative Analysis of Two High-elevation National Parks in the Karakoram–Pamir

Jaffar Ud Din[1,2], Muhammad Ali Nawaz[1,3], Yusoff Norma-Rashid[2], Farid Ahmad[4], Kamran Hussain[5], Hussain Ali[1,3], and Durriyyah Sharifah Hasan Adli[2]*

* *Corresponding author: durriyyah@um.edu.my*

[1] *Snow Leopard Foundation, 71-C, Street 54, E-11/3, 44000 Islamabad, Pakistan*
[2] *Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia*
[3] *Department of Animal Sciences, Quaid-i-Azam University, 15320 Islamabad, Pakistan*
[4] *International Centre for Integrated Mountain Development (ICIMOD), GPO Box 3226, Khumaltar, Lalitpur, Kathmandu, Nepal*
[5] *Forest, Wildlife and Environment Department, Forest Complex, Jutial Cantt, Gilgit-Baltistan, Gilgit, Pakistan*

The high-elevation mountain ecosystems in the Karakoram and Pamir mountain ranges encompass enchanting landscapes, harbor unique biodiversity, and are home to many indigenous pastoral societies that rely on ecosystem services for their survival. However, our understanding of the value of ecosystem services to a household economy is limited. This information is essential in devising sustainable development strategies and thus merits consideration. In this preliminary study, we attempted to assess and compare the value of selected ecosystem services of the Khunjerab and Qurumbar National Parks (KNP and QNP) in the Karakoram–Pamir in northern Pakistan using market-based and value transfer methods. Our results indicated that the economic benefits derived from the 2 high-elevation protected areas were US$ 4.6 million (QNP) and US$ 3.8 million (KNP) per year, translating into US$ 5955 and US$ 8912 per household per year, respectively. The monetary benefits from provisioning services constituted about 93% in QNP and 48% in KNP, which vividly highlights the prominence of the economic benefits generated from the protected areas for the welfare of disadvantaged communities. Together with the regulatory and cultural services valued in this study, the perceived economic impact per household per year was 10–15 times higher than the mean household income per year. Considering the limited livelihood means and escalating poverty experienced by buffer zone communities, these values are substantial. We anticipate that communities' dependency on resources will contribute to increased degradation of ecosystems. We propose reducing communities' dependency on natural resources by promoting sustainable alternative livelihood options and recognizing ecosystem services in cost–benefit analyses when formulating future policies.

Keywords: *ecosystem services; economic value; Karakoram–Pamir; Khunjerab; national park; Qurumbar.*

Peer-reviewed: *December 2019* ***Accepted:*** *April 2020*

Introduction

Spreading across a 1.8 million km^2 area, the Hindu Kush, Karakoram, Pamir, Himalaya, Tien Shan, Kunlun, Altai, and Sayan mountain ranges of South and Central Asia harbor unique biodiversity, support iconic species like the snow leopard (*Panthera uncia*), and are home to rich sociocultural diversity (Snow Leopard Working Secretariat 2013; SLN 2014). These gigantic mountain ecosystems have the largest glacier reserves outside the polar region and serve as repositories of biogeographical diversity. They deliver important services such as flora, fauna, fresh water, clean air, and minerals and offer food, fiber, shelter, medicine, firewood, grazing areas, fodder, hydropower, and tourism opportunities not only to marginalized agropastoral mountain communities but also to more than 1 billion people in downstream areas (Macchi 2010). The Millennium Ecosystem Assessment (MEA) framework (2005: 1–5) defines ecosystem services as "the paybacks that people acquire from the ecosystems" and recognizes these benefits as provisioning, regulatory, cultural, and supporting services. The MEA also states that the ecosystems have been extensively altered over the past 5 decades because of increasing anthropogenic pressures, particularly for fresh water, food, fiber, timber, and energy needs.

The ecosystems that support the snow leopard and associated biodiversity are less well understood in terms of their ecological importance (SLN 2014) and the invaluable advantages they offer to the mountain communities and downstream dwellers (Murali, Lkhagvajav, et al 2017) than other, more productive ecosystems worldwide (Van der Ploeg and de Groot 2010). These low-productivity ecosystems (Murali, Lkhagvajav, et al 2017) are inhabited by pastoral and agropastoral communities that depend on livestock rearing and floodplain agriculture for subsistence (Din et al 2017). However, large-scale development projects in these landscapes are causing environmental degradation, threatening the survival of snow leopards and human communities alike (Murali, Lkhagvajav, et al 2017). A review of the literature suggests that poor understanding and lack of appreciation of the importance and monetary benefits of these ecosystems' services in sustaining livelihoods, and the overall economy is one of the factors hampering better management of these landscapes and associated ecosystem services (Sharma et al 2015). Accordingly, valuation of the services generated by these mountain ecosystems is necessary to enhance our understanding of the importance of ecosystem services (Daily et al 2000; TEEB 2009), create support for ecosystem conservation (Kumar 2005), improve management mechanisms (Huang and Upadhyaya 2007), provide a framework for decision-making (Pearce 2001; Bateman et al 2010), and extend justice and equality to ascertain the distribution of these values in the society (Pagiola 2008).

The concept of ecosystem service appraisal is relatively new and not yet well understood in Pakistan (Dehlavi and Nawaz 2012). Pakistan spans an array of landscapes and ecosystems ranging from sea level in the south to the highest mountains in the north. However, these ecosystems are deteriorating and the associated services are diminishing because of unsustainable utilization, lack of knowledge, and improper policies and landscape planning (World Bank 2006). Acknowledging this gap, the Government of Pakistan revised its National Biodiversity Strategy and Action Plan in 2015 to prioritize understanding and valuation of ecosystem services.

The snow leopard range in Pakistan covers 81,000 km^2 and encompasses 4 high mountain systems, namely, the Hindu Kush, the Pamir, the Karakoram, and the western Himalayas (SLN 2014). Ecosystem service valuation studies in the snow leopard range are rare, except for a recent study of Gurez valley in the Himalayas (Murali, Lkhagvajav, et al 2017).

In the present study, we attempted to quantify and compare the provisioning, cultural, and regulatory services delivered by 2 high-elevation national parks (NPs)—Khunjerab National Park (KNP) and Qurumbar National Park (QNP)—to buffer zone communities. The 2 NPs fall in the Karakoram–Pamir landscape, which is 1 of 3 snow leopard landscapes in Pakistan selected for implementation of the Global Snow Leopard and Ecosystem Protection Program's goal to secure "20 landscapes by 2020" Davletbakov et al 2016: 419–425).

Megadevelopment projects, such as the China–Pakistan Economic Corridor, pass through the Karakoram–Pamir landscape, specifically through KNP. The findings of this study are expected to contribute to the economic analysis of such development projects in terms of their implications for the ecosystem services of associated landscapes. Moreover, the outcomes of the study will help in developing better strategies for the conservation of protected areas that consider the desires of the native people who depend on the resources of the protected areas. Lastly, this study will serve as an example and a basis for extending the research to other snow leopard landscapes in the area.

Material and methods

Study area

We compared selected ecosystem services of 2 high-elevation NPs, KNP and QNP, and their immediate buffer zones, also known as community-managed conservation areas (CMCAs), in Gilgit-Baltistan (Figure 1).

KNP (75°41′E, 36°26′N) falls in the Karakoram–Pamir mountain range and borders the Taxkorgan Nature Reserve of China in the north (Khan, Ablimit, et al 2016). The park was established in 1975 to protect the Marco Polo sheep (*Ovis ammon polii*) and other keystone species, such as the snow leopard (*Panthera uncia*), brown bear (*Ursus arctos*), wolf (*Canis lupus*), blue sheep (*Pseudois nayaur*), and ibex (*Capra ibex*). KNP spreads across 4455 km^2 (Khan et al 2014; Khan, Ablimit, et al 2016) and encompasses 3 major valleys, namely, Ghujerab, Khunjerab, and Shimshal. The Khunjerab River originates at the Pakistan–China border and joins the Hunza River after being joined itself by many small tributaries. All waterways are perennial (Khan 1996).

QNP (73°55′E, 36°45′N) lies in the Ghizer District of Gilgit-Baltistan and is surrounded by the Wakhan Corridor of Afghanistan in the north, Broghil NP of the Chitral District in the west, Hunza valley in the east, and Ghizer River in the south. The park has a mountain desert ecosystem in which the average annual rainfall rarely exceeds 150 mm. Its core area extends more than 740 km^2, and major land cover types include snow and glaciers (43%), soil and rocks (48%), and grasses, forbs, and shrubs (7%), with water, forest, and agricultural land together accounting for only 2% of the total land (WWF-P 2016). QNP was created in 2011 to conserve the natural flora, fauna, and wetlands and to improve the livelihoods of the local people.

The Qurumbar valley is subdivided into many villages, as are the buffer valleys of KNP. The buffer zone of QNP is more populated (~1200 households) than that of KNP (~560 households). Most buffer communities of KNP and QNP speak Wakhi. The Wakhi are a major ethnic group of the Pamir, along with the Kirghiz. The literacy rate in the communities of QNP is lower than in KNP, and the remote mountain communities lack basic civic facilities. Agropastoralism is the major source of livelihood. Sheep and goats constitute the bulk of the livestock, followed by cattle and yak (Din et al 2017). Because of the mountainous terrain, the average landholding is less than 1 ha per household, and cropping is mostly done on the irrigated alluvial fans. Both study sites fall in a single cropping zone because of the arid climatic conditions. An overview of the main characteristics of the 2 NPs is provided in Table 1.

Methods

Data collection: This study relied on semistructured questionnaire surveys of 190 households residing in the buffer zones of KNP ($n = 93$) and QNP ($n = 97$) conducted between May–August 2016 to quantify and evaluate selected essential ecosystem services. The data were complemented by the socioeconomic baseline data reported in the management plans of KNP (Khan 1996) and QNP (WWF-P 2016). In addition, consultations were carried out to gain technical inputs and validation from experts representing both government and private institutions, including agriculture, livestock, rural development, forest, wildlife, and tourism departments, as well as the World Wide Fund.

Analysis: This study considered provisioning services ($n = 10$), cultural services ($n = 2$), and regulatory services ($n = 1$), following the MEA report (2005). The main valuation tools used in this study were the market price method

FIGURE 1 Map of the study sites showing major land cover types. (Map by Spatial Lab, Snow Leopard Foundation Pakistan)

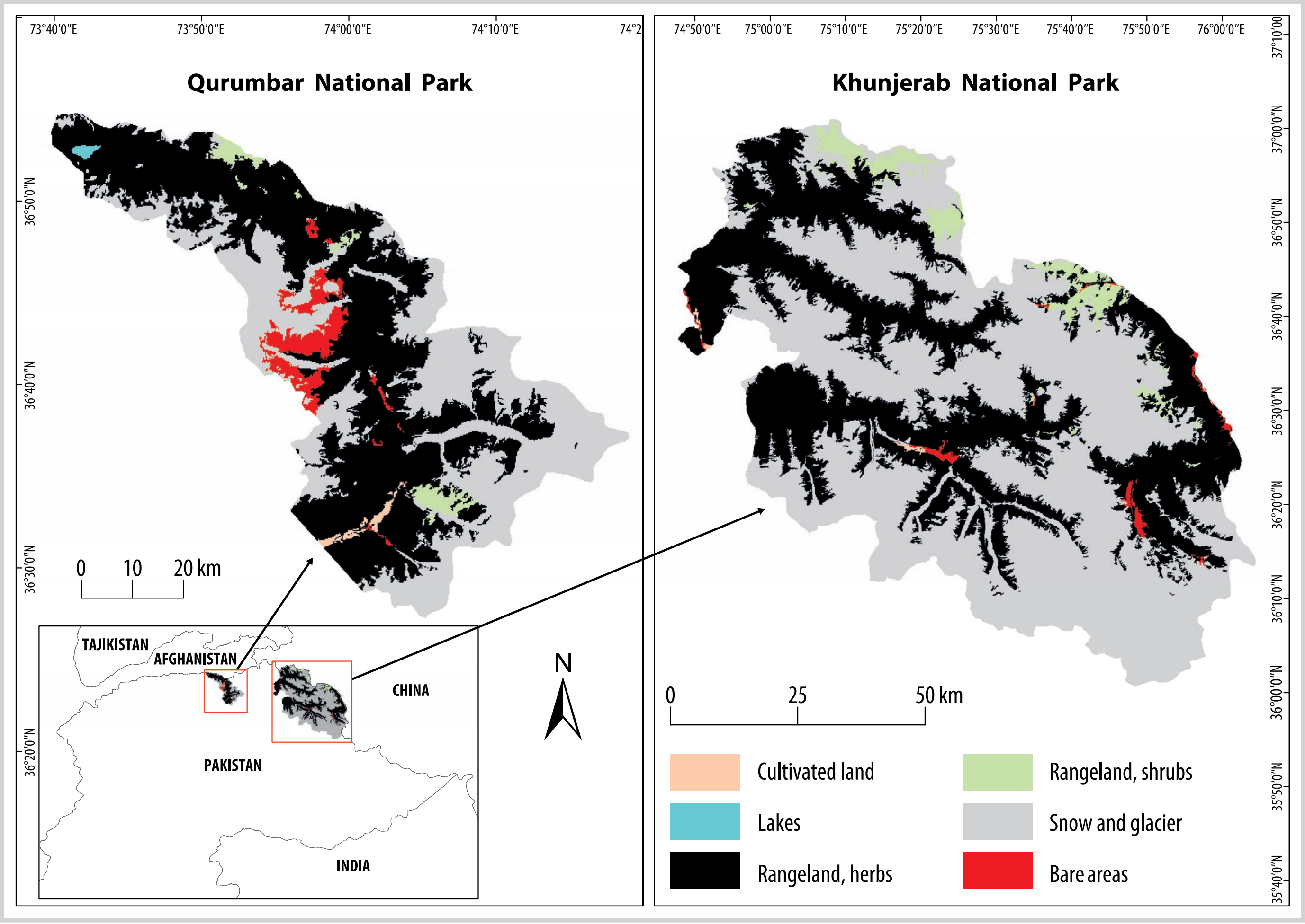


TABLE 1 Major socioecological attributes of the 2 NPs. (Source: Khan 1996; WWF-P 2016)

Socioecological characteristics	KNP	QNP
Major ecosystem types	Alpine and cold desert ecosystem	High-elevation wetland ecosystem
Total core area (km^2)	4455	740
Land cover types (%)		
Rangeland herbs and shrubs	54.10	40.65
Snow and glaciers	40.73	58.63
Barren area	4.30	0.61
Lakes	0.24	0.01
Cultivable land (buffer zone)	0.62	0.11
Average tourist flow/year	28,260	3512
Dependent buffer households	1200	560
Total livestock heads	13,250	33,696
No. of trophy hunts (2014–15) of ibex + blue sheep in the buffer zone	21 + 5	5 + 0

(provisioning services), the net revenue approach for cultural services (Sharma et al 2015), and the benefit transfer (unit value transfer) method for regulatory services. Descriptions of the services measured, data sources, and methodology adopted are provided in Table 2.

Following Sharma et al (2015), provisioning services were estimated using the following equation:

$$TVP_i = \sum_{i=1}^{n} (\%hh_i \times HH \times NV_i)$$

where i represents the different ecosystem provisioning services, $\%hh_i$ is the proportion of overall households reliant on the ith provisioning service (ie dependency weight), HH is the cumulative number of households living in the buffer zone, and NV_i is the annual average net benefit gained per household, calculated by deducting the annual price of the products from the respective gross value using the net benefit method (Viboonpun 2000; Sharma et al 2015).

Less than 2% of the area is under cultivation. The land cover classification of QNP and KNP showed cultivable land of about 0.62 and 0.11% of the total area, respectively. However, the mountains store water in the form of snow and glaciers and provide water for irrigation, which increases the productivity of crops. Local people grow wheat, maize, barley, cereals, potato, and various types of vegetables and fruits, mostly for household consumption. Both NPs fall in a single cropping zone, and this study used the market price method (Government of Gilgit-Baltistan 2014) to assess the value of crops (Table 2) following Sharma et al (2015); Murali, Mishra, et al (2017); and Murali, Lkhagvajav, et al (2017).

Winter is prolonged and harsh in the region, and fuelwood constitutes a key heating source for the locals. On average, 3240 kg of fuelwood was harvested by each household per year from the QNP and KNP buffer zones. The opportunity cost of time for labor in fuelwood collection was taken as 0 (Sharma et al 2015) because of the prevailing poverty and unemployment rate (Murali, Lkhagvajav, et al 2017).

The largest shares of the area of QNP (43,354 ha) and KNP (412,715 ha) consist of snow, glaciers, and lakes, which account for 41% (QNP) and 59% (KNP) of the total area and constitute the sole source of freshwater supply for locals residing in the buffer zones of the protected areas. This study used minimum per-capita water required (WHO 2013) and multiplied it by the local price of water (Murali, Lkhagvajav, et al 2017) to derive the total value per household per year by deducting the input cost.

The rich biodiversity and landscape of QNP and KNP attract domestic and foreign tourists each year. We collected tourist data from both park directorates and estimated the total values by multiplying by the unit prices calculated by USAID Pakistan (2014) for the Gilgit-Baltistan region. We subtracted the management costs (20%) set by the government to obtain the net total value.

We considered the rangelands, herbs and shrubs, and cultivated area (QNP = 57,899 ha; KNP = 286,888 ha), which make up about 55% of the total area of QNP and 41% of that of KNP, to estimate carbon sequestration. The carbon sequestration values estimated by Grace et al (2006) for temperate grasslands and the value of cultivated vegetation estimated by ICRAF (2006, see table 6) were applied to calculate the total monetary value of the carbon sequestration potential of the study area by putting US$ 5 on 1 ton of carbon dioxide equivalent (GCF 2017).

KNP and its buffer zone harbor good populations of Siberian ibex and blue sheep, whereas the only wild ungulate species of QNP is ibex. Trophy hunting has emerged as a conservation tool over the years in Gilgit-Baltistan and has been practiced in the buffer zones of QNP and KNP in designated CMCAs. We calculated annual net revenue generated by subtracting the management fee (20%) from the total amount secured from the trophy hunting in each CMCA (Table 2). The remainder (80%) of the net revenues generated goes to the communities to spend on collective civic needs (Shackleton 2001; Zafar et al 2014; Nawaz et al 2016).

Results

Economic value of provisioning services

Our results revealed that the mountain people collected a myriad of harvests from the 2 NPs. Table 3 shows the estimated annual economic worth of the provisioning services at the household level, in addition to the combined values all households in the buffer zones of the 2 protected areas. The overall value of provisioning services was estimated to be approximately US$ 4.3 million per year for QNP, which translates into US$ 5673 per household per year, and US$ 1.8 million per year for KNP, equating to US$ 5384 per household per year. There was no significant difference in the mean value of provisioning services per household per year in QNP (mean = 630 ± 264) and KNP (mean = 598 ± 216), $t(15) = 0.09$, $P = 0.92$. The provisioning services constituted about 92.87% (QNP) and 47.64% (KNP) of the aggregated value of the ecosystem services assessed in this study. Altogether, fodder, water, and fuelwood made up about 93% of the total provisioning services measured in this study for both NPs (Figure 2).

Agriculture (crops and fruits): An average annual net return value of US$ 109 and US$ 154 per household per year for crops and fruits in QNP and US$ 108 and US$ 247 per household per year for KNP was estimated, respectively, after deducting average input costs, which were assumed to be 60 and 30% of the gross value of crops and fruits, respectively (Tables 2, 3). Constituting about 63–89% (QNP) and 58–78% (KNP) of subsistence farming, the net annual value raised from harvests and fruits in QNP and KNP was estimated at US$ 160,951 and US$ 125,977, respectively. This accounted for 3.7 and 7% of the total value of provisioning services, respectively.

Fodder: Livestock rearing constitutes a major source of livelihood for mountain communities (Din et al 2017), and up to 90% of households were engaged in pastoral practices for subsistence. The average herd size was calculated to be 32 animals in QNP and 26 animals in KNP (Khan et al 2014). Goat and sheep made up the bulk (QNP = 70%; KNP = 75%) of the total livestock owned (QNP = 33,696; KNP = 13,250), followed by cattle, yak, and equines. The livestock depend heavily on the rangelands and alpine pastures of the NPs and the buffer zones for their fodder requirements. The net total value of forage was estimated to be US$ 2.57 million and US$ 0.98 million per year for QNP and KNP, which translates

TABLE 2 Descriptions of the ecosystem services measured, data sources, and methodology adopted. (Table continued on next page.)

Ecosystem service	Valuation method	Assessment description	Source
Provisioning services			
Crops	Market price	Net annual crop income per household = (crop yield per hectare × local crop price per kilogram) − input cost of 60% of gross income	Government of Gilgit-Baltistan (2014); Sharma et al (2015); Murali, Mishra, et al (2017)
Fruits	Market price	Net annual income per household = (fruit yield per bearing tree × local price per kilogram) − (losses 15–30% + input cost of 30% of gross income)	Government of Gilgit-Baltistan (2014)
Fodder	Market price	Net fodder value = (average fodder consumption per cattle and sheep or goat per year × market price per kilogram of fodder × total number of livestock in the study sites) − input cost of 60% of gross value	Government of Gilgit-Baltistan (2014); Murali, Mishra, et al (2017); livestock vaccination data of SLF (personal communication, 24 December 2015)
Medicinal plants	Market price	Net income per household = (average quantity of medicinal plants collected in kilogram × market price per kilogram) − collection per time cost	Government of Gilgit-Baltistan (2014)
Fuelwood	Market price	Average annual value = (average annual quantity in kilograms harvested per household per year × per-kilogram price in local market × total households in the study sites) − input, ie labor or transportation cost	Government of Pakistan (2015); Sharma et al (2015); Government Forest Department (personal communication, 15 June 2016)
Timber	Market price	Net annual value = timber (85 square feet) required to construct a traditional rural house with 11,000 square feet of covered area × average number of new houses constructed in the study sites, taking into account the annual population growth rate of 2.5% × market price of 1 square foot of timber (500 PKR = US$ 4.76)	Unit values from Gilgit-Baltistan Planning and Development Department (2013)
Physical material (stone, sand, or soil)	Market price	Net annual value = stone and soil or sand (1650 square feet) required to construct a traditional rural house with 16,500 square feet of covered area × average number of new houses constructed in the study sites, taking into account the annual population growth rate of 2.5% × market price of 1 square foot of stone (50 PKR = US$ 0.47) and soil or sand (30 PKR = US$ 0.28)	Unit values from Gilgit-Baltistan Planning and Development Department (2013)
Domestic water consumption	Market price/ benefit transfer	Net value per year = (per-capita water consumption per day of 15 L × average household size of 8 × 365 days × total households [QNP = 1170, KNP = 560] × market price of locally produced 1 L of water [6.5 PKR]) − input cost (project cost + tariff per household per year)	WHO (2013); Water and Sanitation Extension Program (WASEP) of AKDN, Gilgit (personal communication, 20 November 2015)
Electricity	Market price	Net annual value = average units consumed per household per month × 12 months × total households × per-unit rate	Government Water and Power Department (personal communication, 14 July 2015)
Cultural services			
Tourism	Net revenue	Annual net revenue from tourism = (number of tourists × net tourist spending per trip) + revenue from tourist entry fee − tourism management cost •National visitor = US$ 50/day •International visitor = US$ 75/day	USAID Pakistan (2014) for daily tourist spending; Sharma et al (2015) for method; NP directorates for tourist data (KNP, personal communication, 8 February 2016; QNP, personal communication, 9 February 2016

 https://doi.org/10.1659/MRD-JOURNAL-D-19-00047.1

TABLE 2 Continued. (First part of Table 2 on previous page.)

Ecosystem service	Valuation method	Assessment description	Source
Sports (trophy) hunting	Net revenue	Annual net revenue from trophy hunting = (total number of hunts [ibex, blue sheep] made in each CMCA × fee per bag) − management fee collected	Parks and Wildlife Department, Gilgit-Baltistan (2015)
Regulatory services			
Carbon sequestration	Benefit transfer	Annual benefit = area under cultivation and grassland × corresponding carbon sequestration index (CSI) × price per unit of CSI	Grace et al (2006), area under rangeland; ICRAF (2006), area under cultivated land; Sharma et al (2015); GCF (2017), CSI and unit value

into US$ 2436 and US$ 1944 per household per year, respectively. This represented about 59.6% (QNP) and 54.5% (KNP) of the total provisioning services considered in this study.

Medicinal plants: Although both NPs are rich in medicinal plant diversity, most locals were unaware of these. Hence, few households (20 in QNP and 25 in KNP) reported collecting medicinal plants, mostly for local use. Thus, the value of the medicinal plants was not significant (US$ 6–10 per household per year) in the provisioning services measured in this study (Table 3).

Fuelwood, timber, and other physical material: The net annual value of fuelwood was estimated to be US$ 0.51 million and US$ 0.18 million per year and US$ 432 and US$ 540 per household per year for QNP and KNP, respectively. This constituted 11.7% (QNP) and 9.9% (KNP) of the total provisioning services considered in this study.

Similarly, most local construction needs were met by growing poplar trees in plantations and collection of *Salix,* birch, and juniper trees from local forest patches. The total worth of timber was calculated to be US$ 11,839 per year for QNP and US$ 5667 per year for KNP, which translates into US$ 405 per household per year for both NPs investigated. In addition, locals collected stone, sand, and gravel from the buffer area of the NPs for construction purposes. These had a net annual value of US$ 36,771 per year for QNP and US$ 17,600 per for KNP.

Domestic water benefits: All households in the buffer zones of QNP and KNP relied on snow or glacier meltwater for domestic use. This amounted to US$ 0.97 million per year for QNP and US$ 0.46 million for KNP, or about 22.45% (QNP) and 25.73% (KNP) of the net value of provisioning services.

Electricity: The buffer communities have access to cheap hydroelectricity produced locally through small hydropower plants. The monetary impact per household per year was calculated to be US$ 48 for both NPs, with a net worth of US$ 56,160 per year in QNP to US$ 26,880 in KNP.

Economic value of cultural services

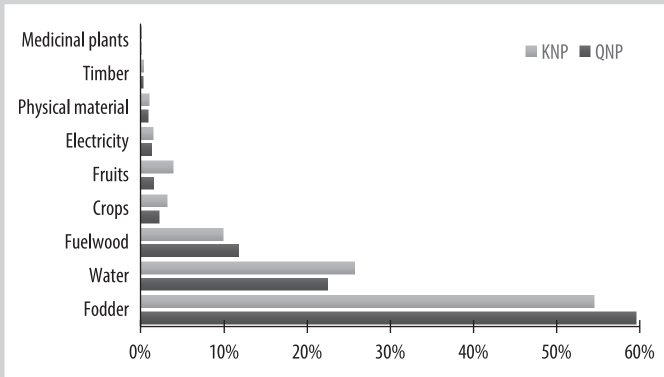
Ecotourism: The aggregate gain from the tourism sector was estimated to be US$ 150,720 per year in QNP and US$ 1,162,384 in KNP (US$ 41–43 per tourist per year), which

TABLE 3 Estimated annual economic value of provisioning services provided by QNP and KNP.

Type of provisioning service	Total annual value (US$)		Average value (US$/hh/y)		Share in provisioning services (%)		Dependent households (%)	
	QNP	KNP	QNP	KNP	QNP	KNP	QNP ($n = 1170$)	KNP ($n = 560$)
Crops	95,201	56,509	109	108	2.2	3.1	89	78
Fruits	65,751	69,468	154	247	1.5	3.9	63	58
Fodder	2,565,276	979,689	2436	1944	59.6	54.5	90	88
Medicinal plants	1309	1381	6	10	0.03	0.1	20	25
Fuelwood	505,440	177,660	432	540	11.7	9.9	94	59
Timber	11,839	5667	405	405	0.3	0.3	75	60
Physical material (stone, sand, soil)	36,771	17,600	1257	1257	0.9	1.0	100	100
Domestic water consumption	966,643	462,667	826	826	22.5	25.7	100	100
Electricity	56,160	26,880	48	48	1.3	1.5	100	100
Aggregated value	4,304,389	1,797,520	5673	5384	100.0	100.0	11	11

hh, household.

FIGURE 2 Relative contributions of each provisioning service type in QNP and KNP.



constituted about 3.25% (QNP) and 30.81% (KNP) of the total ecosystem services valued.

Trophy hunting: A total of 21 ibex and 5 blue sheep were offered for trophy hunting in KNP during 2014–15, which accounted for a net revenue of US$ 46,789, translating into US$ 84 per household per year. Similarly, 5 ibex hunted in QNP generated a net income of US$ 2925, which equated to US$ 2.50 per household per year.

Economic value of regulatory services

Carbon sequestration: The total value of carbon sequestered by rangelands, herbs and shrubs, and cultivated areas in QNP and KNP was estimated to be US$ 176,813 and US$ 766,108 per year, which translates into US$ 151 and US$ 1368 per household per year, respectively (Table 4). In aggregate, this accounted for 3.81% (QNP) and 20.31% (KNP) of all ecosystem services measured.

Aggregated economic values

The overall economic benefits from the provisioning services considered in this study were approximately US$ 4.6 million per year for QNP and US$ 3.8 million per year for KNP (Table 4). This translates into US$ 5955 per household per year in QNP (1200 households) and US$ 8912 per household per year in KNP (560 households). Furthermore, the spatial distribution of the value was higher in QNP (US$ 44/ha) than in KNP (US$ 5/ha). The economic benefits generated from provisioning services were highest in both QNP (93%) and KNP (48%), followed by cultural services (QNP = 3%; KNP = 32%) and regulatory services (QNP = 4%; KNP = 20%).

Discussion

Our analyses revealed that QNP and KNP provide ecosystem services worth an estimated US$ 4.6 million and US$ 3.8 million annually, which translates into US$ 5955 and US$ 8912 per household per year, respectively. Our results show that both NPs are of immense importance for the sustenance and survival of the remote mountain communities living in their buffer zones. Although this paper considers only 3 types of ecosystem service, the perceived economic impact per household per year in the protected areas is ~10 times (QNP) to ~15 times (KNP) higher than the average annual household income of US$ 600 (World Bank 2011). We anticipate that dependency on resources will contribute to increased degradation of ecosystems. Recognition of these NP ecosystem services in the formulation of management frameworks and policies is essential for the sustenance of both people and resources.

The economic benefits (per household per year) generated from provisioning services alone were comparatively higher (QNP = US$ 5673 and KNP = US$ 5384) than those reported from other snow leopard landscapes. For instance, provisioning services are worth an estimated US$ 4125 in the Himalayan landscape in Pakistan, US$ 3964 in the Hemis–Spiti landscape of India (Murali, Lkhagvajav, et al 2017; Murali, Mishra, et al 2017), and US$ 818 in the Koshi Tappu Wildlife Reserve, Nepal (Sharma et al 2015). This variation may result from the type of the services measured, resource use patterns, and scarcity of alternate livelihood sources. A review of the provisioning ecosystem services measured across the snow leopard landscapes is crucial to develop a holistic understanding of direct benefits from nature.

In this study, fodder, fuelwood, and domestic water usage together constituted 90–94% of all provisioning services measured. The rangelands of the NPs and their buffer zones support ~47,000 livestock (QNP = 33,696 and KNP = 13,250), in addition to wild ungulates, such as ibex in QNP and ibex, blue sheep, and Marco Polo sheep (Khan, Ablimit, et al 2016) in KNP. Because there is no information available on the resilience, carrying capacity, and climate change impact on

TABLE 4 Aggregate economic value of ecosystem services provided by QNP and KNP.

Ecosystem services	Total value (US$)		Average value (US$/hh/y)		Share of total ES assessed (%)	
	QNP	KNP	QNP	KNP	QNP	KNP
Provisioning services	4,304,389	1,797,520	5673	5384	92.87	47.64
Cultural services						
Ecotourism	150,720	1,162,384	129	2076	3.25	30.81
Trophy hunting	2925	46,789	3	84	0.06	1.24
Regulatory services						
Carbon sequestration	176,813	766,108	151	1368	3.81	20.31
Total economic value	4,634,848	3,772,801	5955	8912	100.00	100.00

hh = household.

the rangelands (Khan, Khan, et al 2016) of the NPs, these figures are alarming and call for informed management measures. The rapid increase in population (both human and livestock) in the vicinity of the NPs has intensified the dependency of the communities on ecosystem services. Consequently, the resources are depleting at a greater pace (Khan et al 2013).

The total area of KNP (703,881 ha) is bigger than that of QNP (105,808 ha), but the number of resource-dependent households in KNP ($n = 560$) is significantly lower than the number in QNP ($n = 1200$). Hence, QNP is more susceptible to human-induced degradation than KNP.

Water was used by all households in both KNP and QNP. Both NPs have snow, glaciers, and high-elevation lakes, which account for 41–59% of total area and constitute major sources of freshwater supply for the locals residing in the buffer zones of the protected areas and beyond. Water is also used to generate hydropower, which is vital to reduce communities' dependency on high-elevation forest resources to meet household energy needs; thus, water constitutes an important ecosystem service (Fu et al 2014). Despite the high potential for hydropower generation, this primary resource is underutilized.

The role of regulatory (carbon sequestration) and cultural services was also assessed in this study. In KNP, regulatory services accounted for about 20% of all services measured. The impact of cultural services was significant in KNP. A total of 28,260 tourists visited KNP in 2015, generating a total revenue of US$ 1.16 million, which translates into US$ 1661 per household per year. However, despite its great potential, QNP is less developed than KNP and revenues generated from tourism remain marginal. Combined with trophy hunting of wild ungulates, cultural services provided 32% of the total services evaluated in this study. Proper planning, regulation, and management of ecotourism by involving local communities could boost the tourism industry. Despite criticism of its moral and ethical implications, trophy hunting of wild ungulates as a conservation measure was initiated in northern Pakistan in 1990s and has since proved to be an effective tool for conservation and livelihood improvement (Shackleton 2001; Zafar et al 2014; Nawaz et al 2016). Of the revenue generated from trophy hunting, 80% goes directly to the communities, which has raised up to US$ 4.05 million (US$ 1.4 million in Gilgit-Baltistan and US$ 2.65 million in Khyber Pakhtunkhwa) during the period of 1998 to 2015 (Nawaz et al 2016). Furthermore, a multiplier effect has to be ascertained. For instance, in the Karakoram–Pamir, humans and wildlife, such as snow leopards, other carnivores, and wild ungulates, share the high-elevation ecosystem. Large carnivores, like snow leopards and wolves, often kill livestock, causing economic losses of more than US$ 200 per household per year (Khan et al 2014; Din et al 2017, 2019). In such a scenario, the trophy hunting program as a conservation tool has helped enhance public tolerance of large carnivores and has provided a substantial cash injection into local livelihoods with quantifiable wildlife and habitat conservation benefits in the long run (Nawaz et al 2016). The revenues generated through this scheme are used by the communities to implement other predation mitigation and compensation measures, such as livestock insurance schemes and construction of predator-proof corrals (Din et al 2017, 2019).

Conclusion

In this preliminary study, we assessed the value of some important ecosystem services delivered by the 2 high-elevation NPs in the Karakoram–Pamir, a model snow leopard conservation landscape in Pakistan. Our results revealed that mountain societies largely rely on services provided by ecosystems for their livelihood and sustenance; hence, careful and calculated sustainable management of ecosystem services is essential for the local economy and resource conservation. This involves understanding variations in the ecosystem services under different land-use settings and how these changes may influence human wellbeing. The 2 high-elevation NPs considered in this study have significant socioeconomic, cultural, and environmental values, and these must be recognized and considered in future planning and investments. Healthy ecosystems are a prerequisite for ensuring the supply of resources such as water and food that are critical to meet civic needs like health, livelihood, and production (Murali, Lkhagvajav, et al 2017). Having considered the trade-off between provisioning and regulating services and the interest of local stakeholders, it is important that state authorities, conservation societies, and other stakeholders take robust measures and extend the financial incentives required for conservation and sustainable development in these areas (Sharma et al 2015). Market-oriented mechanisms such as payment for ecosystem services (Wunder and Wertz-Kanounnikoff 2009), certification schemes (Giovanucci and Ponte 2005), biodiversity offsets (McKenney and Kiesecker 2010), and climate change adaptation measures (Clouse 2016) can be used to ensure better management practices.

ACKNOWLEDGMENTS

We extend our gratitude to the Parks and Wildlife, Forest, and Agriculture, Livestock, and Fisheries Departments of Gilgit-Baltistan; the communities of Qurumbar, Shimshal, and the Khunjerab Village Organization for the cooperation they extended during the data collection; and the University of Malaya (PPP grant PG002–2015B) for funding. The Wildlife Conservation Network (WCN) provided a scholarship for the PhD study of Jaffar Ud Din.

REFERENCES

Bateman IJ, Mace GM, Fezzi C, Atkinson G, Turner K. 2010. Economic analysis for ecosystem service assessments. *Environmental and Resource Economics* 48:177–218.
Clouse C. 2016. Design for autonomy: Water resources in Ladakh. *In:* Goswami A, Mishra A, editors. *Economic Modeling, Analysis, and Policy for Sustainability*. Hershey, PA: IGI Global, pp 250–265.
Daily GC, Söderqvist T, Aniyar S, Arrow K, Dasgupta P, Ehrlich PR, Folke C, Jansson A, Jansson B, Kautsky N, et al. 2000. The value of nature and the nature of value. *Science* 289:395–396.
Davletbakov A, Rosen T, Anarbaev M, Kubanychbekov Z, Samanchina J, Sharma K. 2016. Central Asia: Kyrgyzstan. *In:* McCarthy TM, Mallon DP, editors. *Snow Leopards*. New York, NY: Elsevier, pp 419–425.
Dehlavi A, Nawaz R. 2012. Economic valuation of wetlands: Acknowledging values and services. *Records Zoological Survey of Pakistan* 21:56–59.
Din JU, Ali H, Ali A, Younus M, Mehmood T, Norma-Rashid Y, Nawaz MA. 2017. Pastoralist–predator interaction at the roof of the world: Conflict dynamics and implications for conservation. *Ecology and Society* 22(2):32. https://doi.org/10.5751/ES-09348-220232.
Din JU, Nawaz MA, Mehmood T, Ali H, Ali A, Adli DS, Norma-Rashid Y. 2019. A transboundary study of spatiotemporal patterns of livestock predation and prey preferences by snow leopard and wolf in the Pamir. *Global Ecology and Conservation* 20:00719. https://doi.org/10.1016/j.gecco.2020.e00911.
Fu B, Wang YK, Xu P, Yan K, Li M. 2014. Value of ecosystem hydropower service and its impact on the payment for ES. *Science of the Total Environment* 472:338–346.
Gilgit-Baltistan Planning and Development Department. 2013. *Gilgit-Baltistan at a Glance*. Gilgit, Pakistan: Statistical Cell of Planning and Development Department, Government of Gilgit-Baltistan.

Giovannucci D, Ponte S. 2005. Standards as a new form of social contract? Sustainability initiatives in the coffee industry. *Food Policy* 30(3):284–301.
Government of Gilgit-Baltistan. 2014. *Agriculture Statistics Surveys of Gilgit-Baltistan*. Gilgit, Pakistan: Agriculture Department.
Government of Pakistan. 2015. *National Biodiversity Strategy and Action Plan*. Islamabad, Pakistan: Ministry of Climate Change.
Grace J, San Jose J, Meir P, Miranda H, Montes R. 2006. Productivity and carbon fluxes of tropical savannas. *Journal of Biogeography* 33:387–400.
GCF [Green Climate Fund]. 2017. *Pilot Programme for REDD+ Results-based Payments*. GCF/B.17/13. Incheon, Republic of Korea: Green Climate Fund.
Huang M, Upadhyaya SK. 2007. *Watershed-Based Payment for Environmental Services in Asia*. Working paper No. 06–07. Blacksburg, VA: Virginia Tech, Office of International Research, Education, and Development, Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program. http://www.oired.vt.edu/sanremcrsp/documents/research-themes/pes/Sept.2007.PESAsia.pdf; accessed on 10 December 2017.
ICRAF [International Centre for Research in Agroforestry]. 2006. *World Agroforestry Centre. Working Paper: An Assessment of the Potential for Carbon Finance in Rangelands*. Nairobi, Kenya: ICRAF.
Khan AA. 1996. *Management plan for Khunjerab National Park*. Lahore, Pakistan: World Wide Fund for Nature.
Khan B, Ablimit A, Khan G, Jasra AW, Ali H, Ali R, Ahmad E, Ismail M. 2016. Abundance, distribution and conservation status of Siberian ibex, Marco Polo and Blue sheep in Karakoram–Pamir mountain area. *Journal of King Saud University* 28(3):216–225.
Khan B, Ablimit A, Nawaz MA, Ali R, Khan MZ, Din JU, Rakhshanda K. 2014. Pastoralist experience and tolerance of snow leopard, wolf and lynx predation in Karakoram Pamir Mountains. *Journal of Biodiversity and Environmental Sciences* 5(4):214–229.
Khan MA, Khan JA, Ali Z, Ahmad I, Ahmad MN. 2016. The challenge of climate change and policy response in Pakistan. *Environmental Earth Sciences* 75(5):412. https://doi.org/10.1007/s12665-015-5127-7.
Khan MZ, Khan B, Awan S, Khan G, Ali R. 2013. High-altitude rangelands and their interfaces in Gilgit-Baltistan, Pakistan: Current status and management strategies. *In:* Ning Wu, Rawat GS, Joshi S, Ismail M, Sharma E, editors. *High-Altitude Rangelands and their Interfaces in the Hindu Kush Himalayas*. Kathmandu, Nepal: International Centre for Integrated Mountain Development, pp 66–202.
Kumar P. 2005. *Market for ES*. Manitoba, Canada: International Institute for Sustainable Development.
Macchi M. 2010. *Mountains of the World—Ecosystem Services in a Time of Global and Climate Change*. Kathmandu Nepal: International Centre for Integrated Mountain Development.
McKenney B, Kiesecker J. 2010. Policy development for biodiversity offsets: A review of offset frameworks. *Environmental Management* 45(1):165–176.
MEA [Millennium Ecosystem Assessment]. 2005. *Ecosystems and Human Well-Being*. Vol 5. Washington, DC: Island Press.
Murali R, Lkhagvajav P, Saeed U, Kizi VA, Zhumbai-Uulu K, Nawaz MA, Bhatnagar YV, Sharma K, Mishra C. 2017. *Valuation of ES in Snow Leopard Landscapes of Asia*. Report submitted to the Global Environment Facility (GEF) funded United Nations Development Program (UNDP) project on Transboundary Cooperation for Snow Leopard and Ecosystem Conservation. Bishkek, Kyrgyz Republic: Snow Leopard Trust, Nature Conservation Foundation, Snow Leopard Conservation Foundation, Snow Leopard Foundation Kyrgyzstan, and Snow Leopard Foundation Pakistan.
Murali R, Mishra C, Redpath S. 2017. The value of ES in the high altitude Spiti Valley, Indian Trans-Himalaya. *Ecosystem Services* 28:115–123.
Nawaz MA, Din JU, Shah SA, Khan AA. 2016. The trophy hunting program: Enhancing snow leopard prey populations through community participation. *In:* McCarthy TM, Mallon DP, editors. *Snow Leopards*. New York, NY: Elsevier, pp 220–227.
Pagiola S. 2008. Payments for environmental services in Costa Rica. *Ecological Economics* 65:712–724.
Parks and Wildlife Department, Gilgit-Baltistan. 2015. *An Update on the Trophy Hunting Program in Gilgit-Baltistan*. Gilgit, Pakistan: Parks and Wildlife Department, Gilgit-Baltistan.
Pearce D. 2001. Valuing biological diversity: Issues and overview. *In:* Biller D, editor. *Valuation of Biodiversity Benefits: Selected Studies*. Paris, France: Organization for Economic Co-operation and Development, pp 27–45.
Shackleton DM. 2001. *A Review of Community-Based Trophy Hunting Programs in Pakistan*. Islamabad, Pakistan: International Union for Conservation of Nature Pakistan.
Sharma B, Rasul G, Chettri N. 2015. The economic value of wetland ES: Evidence from the Koshi Tappur Wildlife Game Reserve, Nepal. *Ecosystem Services* 12:84–93.
SLN [Snow Leopard Network]. 2014. *Snow Leopard Survival Strategy*. Seattle, WA: SLN.
Snow Leopard Working Secretariat. 2013. *Global Snow Leopard and Ecosystem Protection Program*. Bishkek, Kyrgyz Republic: Snow Leopard Working Secretariat.
TEEB [The Economics of Ecosystems and Biodiversity]. 2009. *TEEB for Policy Makers—Summary: Responding to the Value of Nature*. Bonn, Germany: TEEB. http://www.teebweb.org/Portals/25/Documents/TEEB%20for%20National%20Policy%20Makers/TEEB%20for%20Policy%20exec%20English.pdf; accessed on 20 November 2017.
USAID Pakistan [United States Agency for International Development Pakistan]. 2014. *Position Paper for Draft Tourism Policy, Gilgit-Baltistan*. Gilgit, Pakistan: Office of the Economic Growth and Agriculture, USAID Pakistan.
Van der Ploeg S, de Groot RS. 2010. *The TEEB Valuation Database—A Searchable Database of 1310 Estimates of Monetary Values of ES*. Wageningen, the Netherlands: Foundation for Sustainable Development.
Viboonpun B. 2000. *Economic Incentives for Teak Plantation: A Case Study in Amphoe U Thong, Changwat Suphan Buri* [MSc dissertation]. Bangkok, Thailand: Kasetsart University.
WHO [World Health Organization]. 2013. *How Much Water Is Needed in Emergencies? Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies*. Geneva, Switzerland: Water, Sanitation, Hygiene and Health Unit.
World Bank. 2006. *Pakistan Strategic Country Environmental Assessment. South Asia Environment and Social Development Unit*. Washington, DC: World Bank.
World Bank. 2011. *Pakistan–Gilgit-Baltistan Economic Report: Broadening the Transformation*. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/939151468062972670/Pakistan-Gilgit-Baltistan-economic-report-broadening-the-transformation; accessed on 18 February 2019.
Wunder S, Wertz-Kanounnikoff S. 2009. Payments for ES: A new way of conserving biodiversity in forests. *Journal of Sustainable Forestry* 28(3–5):576–596.
WWF-P [World Wide Fund for Nature, Pakistan]. 2016. *Draft Management Plan of Qurumbar National Park*. Gilgit, Pakistan: WWF-P.
Zafar M, Khan B, Khan E, Garee A, Khan A, Rehmat, A, Abbas AS, Ali M, Hussain E. 2014. Abundance distribution and conservation of key ungulate species in Hindu Kush Karakoram and Western Himalayan (HKH) mountain ranges of Pakistan. *International Journal of Agriculture and Biology* 16:1050–1058.