VALUATION OF ECOSYSTEM SERVICES IN SNOW LEOPARD LANDSCAPES OF ASIA

INTERNATIONAL SNOW LEOPARD AND ECOSYSTEM FORUM
BISHKEK
KYRGYZ REPUBLIC
2017
AUGUST 24-25

SNOW LEOPARD FOUNDATION
SNOWLEOPARD CONSERVATION FOUNDATION
nature conservation foundation
Snow Leopard Trust
gef
UNDP
Empowered lives. Resilient nations.

Acknowledgments

We are grateful to the UNDP, GEF, the Snow Leopard Trust, and the Whitley Fund for Nature for funding various parts of this study. We would like to thank our partner organizations the Snow Leopard Conservation Foundation, Mongolia, the Snow Leopard Foundation, Pakistan, the Snow Leopard Foundation, Krygyzstan, and the Nature Conservation Foundation, India for institutional support. This work would not have been possible without the assistance of several people in the field – Mijji and Oyona in Mongolia, Mirza, Cholpon, and Arsin in Kyrgyzstan, Dorje and Karma Sonam in Ladakh, Tanzin Thinley, Kalzang Gyurmet, Stanzin Sheraf, Sartaj, Sanju, and Dorje in Spiti, Muhammad Arshad, Tahir Mehmood, and Muhammad Shakil in Pakistan. CM is especially thankful for Keshav Varma's foresight and unending questions about snow leopard landscapes and regional economies, since 2012, which motivated the development of our research program on ecosystem services.

Pictures by

Saloni Bhatia, Kulbhushansingh Suryawanshi, Munib Khanyari, Ranjini Murali

Suggested Citation

Murali, R., Lkhagvajav, P., Saeed, U., Kizi, V.A., Zhumbai-Uulu, K., Nawaz, M.A., Bhatnagar, Y.V., Sharma, K., Mishra, C. 2017. Valuation of ecosystem services in snow leopard landscapes of Asia. Snow Leopard Trust, Nature Conservation Foundation, Snow Leopard Conservation Foundation, Snow Leopard Foundation Kyrgyzstan, and Snow Leopard Foundation Pakistan. Report Submitted to the Global Environment Facility (GEF) funded United Nations Development Program (UNDP) project on Transboundary Cooperation for Snow Leopard and Ecosystem Conservation.

VALUATION OF ECOSYSTEM SERVICES IN SNOW LEOPARD LANDSCAPES OF ASIA

AUGUST 2017

Ranjini Murali

Purevjav Lkhagvajav

Uzma Saeed

Venera Amankul Kizi

Kubanychbek Jumabay-Uulu

Muhammad Ali Nawaz

Yash Veer Bhatnagar

Koustubh Sharma

Charudutt Mishra

SUMMARY

Snow leopards occur in Asia's high mountain ranges of the Himalayas, Hindu Kush, Karakoram, Pamir, Tien Shan, Kunlun, Altai and Sayan. In all the 12 countries where they occur, snow leopards face intensifying threats to their survival, including habitat fragmentation and degradation due to increasing human populations, mining and developmental projects, poaching and illegal wildlife trade, weak law enforcement, inadequate involvement of local people in conservation efforts, and depletion of natural prey populations due to hunting by people and overgrazing by livestock.

To address the urgent needs of conservation of the snow leopard and the sustainable development of mountain peoples, the Governments of snow leopard range countries came together and agreed to invest efforts to conserve snow leopards in 23 large landscapes across its range under the Global Snow Leopard Ecosystem Protection Program (GSLEP).

These landscapes where the snow leopards occur are inhabited by agro-pastoral and pastoral peoples who depend on well functioning ecosystems for ecosystem services, i.e., the benefits that humans derive from nature. Many threats that impact snow leopards also impact the well-being of people living in these landscapes. However, till date, there have been no studies that have attempted to quantify peoples' dependence on ecosystem services in snow leopard landscapes, or understand the impacts that alternate land-use decisions such as mining or infrastructure can have on the ecosystem services and on the local people who are dependent on them.

In this report, we provide the first assessment of the economic value of provisioning ecosystem services – the material goods from ecosystems – used by local people in five study sites from four GSLEP landscapes: Spiti Valley and Changtang region of Ladakh in India's Hemis-Spiti Landscape, Gurez Valley in the Himalayan Landscape of Pakistan, Tost Nature Reserve in the South Gobi Landscape of Mongolia, and the Sarychat region in the Central Tien Shan Landscape of Kyrgyzstan. In study sites that had both pastoral and agro-pastoral communities, we estimated ecosystem services separately for the two production systems.

The average value (± SE) of ecosystem services per household amongst the agro-pastoral

communities of Gurez Valley (4125 ± 190 USD/HH/yr) was 2.5 times the average local household income. In the agro-pastoral communities of Spiti Valley (3964 ± 334.8 USD/HH/yr) it was 3.6 times the average local household income, while it was 3.7 times amongst the agro-pastoral communities of Changtang (15083 ± 1656 USD/HH/yr). Amongst the pastoral communities, the value of ecosystem services used by households was several times higher than the average household income: it was 26.1 times amongst the pastoral communities of Changtang (79303 ± 9204 USD HH/yr), 38.7 times among communities in Tost Nature Reserve (150100 ± 13290 USD/HH/yr), and 7.4 times among the pastoral communities of Sarychat (25473 ± 5236 USD/HH/yr). It was lower, although still substantial at 0.6 times, for the downstream agro-pastoral communities living outside the landscape boundary in Sarychat (2094 ± 189 USD/HH/yr).

Our work reveals substantially high levels of dependence of local communities on ecosystem services provided by snow leopard landscapes of Asia. The estimated economic value of provisioning ecosystem services used by human households in these landscapes ranged from 0.6 to up to 40 times the local annual household incomes. This economic support that nature provides people is critical for humanity but remains hidden and unaccounted for. Land use change decisions, especially those that are damaging for nature and biodiversity, must start accounting for the value of ecosystem services in their cost-benefit analyses.

CONTENTS

I
INTRODUCTION

The concept of ecosystem services was motivated by the idea that ecosystems make crucial contributions to human well-being, which are often unaccounted for or undervalued (Costanza ***et al.*** 1997). In part due to the undervaluing of natural systems, human activities tend to often lead to the fragmentation and degradation of ecosystems, which in turn, can negatively impact human well-being (Cardinale ***et al.*** 2012). Globally, human pressures on ecosystems, arising from rapid economic development, increasing per capita consumption, and growth in human population, have been intensifying.

Until recently, snow leopard landscapes in the mountains of Asia remained relatively free of these pressures because of their mountainous terrain and low accessibility (Murali ***et al.*** 2017). However, in the last two decades, large-scale development projects, increasing urbanization, linear intrusions and mining have placed pressure on these landscapes (Snow Leopard Working Secretariat 2013). Recognizing the need for securing these landscapes for the conservation of the snow leopard and associated biodiversity, and for ensuring the well-being and sustainable development of mountain people, the Global Snow Leopard and Ecosystem Protection Program (GSLEP) was launched in Bishkek in 2013.

Across the range of the snow leopard, local communities and wildlife shared space for millennia (Mishra ***et al.*** 2016). Today's developmental pressures threaten the survival of snow leopards, and environmental degradation impacts human communities living here. While economic development is essential, the associated environmental cost of large-scale development projects and extractive industries are rarely taken into account. Many threats that impact snow leopards also impact the well-being of people living in these landscapes. However, till date, there have been no studies in snow leopard landscapes that have attempted to quantify peoples' dependence on ecosystem services, or understand the impacts that alternate land-use decisions such as mining or infrastructure can have on ecosystem services and on the local people who are dependent on them.

In an attempt to understand the importance of these ecosystems to local people, we conducted economic evaluations of provisioning services – the nutritional, material, and energetic outputs from ecosystems – used by local communities in five representative sites of four GSLEP landscapes across Asia. These included parts of Spiti Valley and Changtang of Ladakh in the Hemis-Spiti Landscape of Trans-Himalayan India, the Sarychat region in the Central Tien Shan Landscape of Kyrgyzstan, Tost Nature Reserve in the South Gobi Landscape of Mongolia, and Gurez Valley in the Himalayan Landscape of Pakistan.

Snow leopard landscapes

Snow leopards are distributed in large parts of Asian Mountains from Southern Siberia in the North to the Himalayas in the South (McCarthy ***et al.*** 2016). They are thought to occur over an area of approximately 1.2 million km^2 that includes the mountain ranges of the Sayan, Tien Shan, Altai, Kunlun, Pamir, Hindu Kush, Karakoram, and the Himalayas (Snow Leopard Network 2014). Cold, arid and semiarid shrub land, grassland, or barren areas, harsh climate with extreme seasonal shifts, poor rocky soils and steep slopes are distinctive features of the snow leopard habitat (Nowell and Jackson 1996).

Snow leopards are known to occur in twelve counties: Afghanistan, Bhutan, China, India, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan, Tajikistan, Russia, and Uzbekistan. While they frequently occur at higher altitudes above 2700 m, in Russia they can occur at 500 to 800 m, and, in Mongolia, around 1200 m (Sunquist and Sunquist 2017). Snow leopards are mostly found in high rocky areas, alpine meadows and alpine steppe shrub, but have also been reported from high altitude forests (Snow Leopard Working Secretariat 2013).

Snow leopards face intensifying threats to their survival, including habitat fragmentation and degradation due to increasing human populations and developmental projects (Snow Leopard Network 2014), poaching and illegal wildlife trade (Li and Lu 2014), poor law enforcement (Snow Leopard Network 2014), inadequate involvement of local people in conservation efforts (Mishra ***et al.*** 2017) and depletion of their wild ungulate prey due to hunting and overgrazing by livestock (Berger ***et al.*** 2013, Lovari and Mishra 2016). Snow leopards and their habitats are also expected to be impacted by climate change (Forrest ***et al.*** 2012, Li ***et al***. 2016).

To address the urgent need for conservation of the snow leopard and its habitat, governments of the 12 snow leopard range countries agreed in 2013 to intensify conservation efforts and secure 20 landscapes across its range by 2020 under GSLEP. Secure landscapes are defined as landscapes that contain at least 100 breeding age snow leopards with adequate wild prey populations and have connectivity with other snow leopard landscapes. Conservation in these landscapes is to be achieved through close involvement and sustainable development of local communities. In June 2014, the representatives of snow leopard range country governments identified and increased the number of landscapes for concerted action to 23.

Snow leopard in Changtang, Ladakh.

As mentioned earlier, Pastoral and agro-pastoral human communities have shared space with snow leopards in these landscapes for millennia (Mishra ***et al.*** 2016). Pollen records indicate signs of pastoral habitation as far back as 8,200 years before present (Brantingham ***et al***. 2007). Agriculture on the Tibetan plateau dates back to 5500 years before present (Guedes 2014). Currently, 7 of the 12 range countries have more than a quarter of their total land area under permanent pasture (Mishra ***et al.*** 2003a). Human communities living in snow leopard landscapes are dependent on the ecosystem for their lifestyles and livelihoods (Murali ***et al.*** 2017).

Threats to the snow leopard that have large scale impacts on the landscape –such as mining for sub-soil resources, new road and rail transportation networks, and construction of dams for hydropower generation – also have impacts on the local communities living here (Snow Leopard Working Secretariat 2013). While many of these activities are beneficial for human well-being, there are adverse consequences of ecosystem changes (MA 2005). In the Indian Himalayas, a conservative estimate of the impact of the proposed dams suggests the submergence of more that 540 km^2 of forest and damage to an additional 1144 km^2 by dam related activities (Pandit and Grumbine 2012). In drier parts of Central Asia, such as Mongolia, the limited water has been threatened by expanding mining and industrial activities, urbanization, and intensified land-use for agriculture (Farrington 2005). Mining has impacted

Mongolia’s environment by polluting grazing lands, ground and surface water, and air (Suzuki 2013).

Recognition of the adverse impacts that human activities can have on ecosystems and the resultant negative impact on human well-being led to the conceptualization of the ecosystem services concept. Ecosystem services are the outputs of natural, semi-natural or modified ecosystems that affect human well-being (Haines-Young and Potschin 2012). In this report, we catalogue the ecosystem services used by local people and provide the first evaluation in monetary terms of the value of ecosystem services to the local communities in five representative sites belonging to four GSLEP landscapes in India, Kyrgyzstan, Mongolia, and Pakistan.

Ecosystem services

Ecosystem services are defined as the outputs of ecosystems that affect human well-being (Haines-Young and Potschin 2012). A fundamental characteristic of ecosystem services is that they retain a connection to the underlying biodiversity-dependent ecosystem functions, processes and structures that generate them.

The ecosystem services cascade model (Figure 1) can be used to describe the pathway for the delivery of ecosystem services from ecological structures and processes to human well-being (Haines-Young and Potschin 2010). Ecosystem services are at the center of the model, connecting the biophysical production units to the socio-economic aspects of the system. Ecological structures give rise to processes and functions, i.e the ecosystem’s capacity to deliver an ecosystem service, that then give rise to an ecosystem service in the presence of a human beneficiary.

Ecosystem services provide benefits that enhance human well-being. Depending on the benefits that people obtain from ecosystem services, different kinds of values are assigned to the services. The cascade model can be unpacked into four components: ecological structures and processes, ecosystem services, benefits, and values.

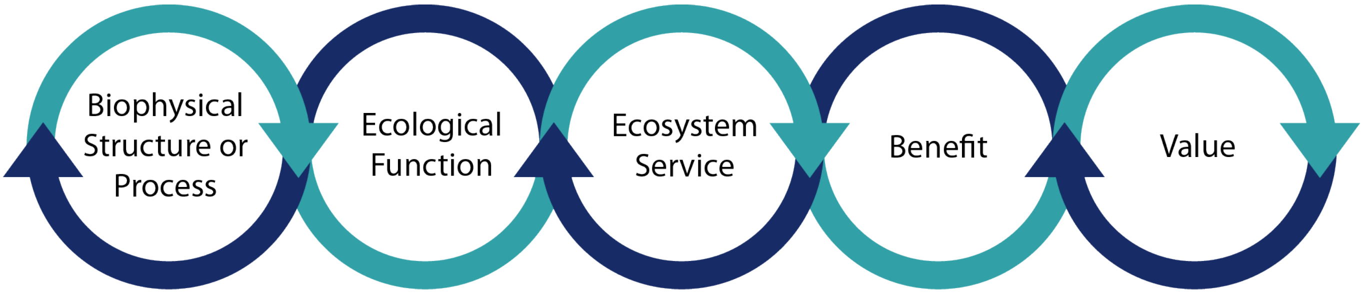


Figure 1: The ecosystem services cascade model as described by Haines-Young and Potschin (2010). Ecosystem structures give rise to functions, which give rise to ecosystem services, which lead to benefits that contribute to human well-being. Based on the benefits received, humans ascribe value to ecosystem services. Figure adapted from Haines-Young and Potschin (2010).

1) Ecological structures and processes: On the ecological side, ecosystem structures, processes and functions are crucial to ecosystem service provision. There is some confusion in the literature defining the terms structure, processes, and functions (La Notte ***et al***. 2017). Here we treat ecosystem structures as separate and ecosystem processes and functions as synonyms as suggested by Wallace (2007). Ecosystem structures are defined as "the architecture of an ecosystem as a result of the interaction between the abiotic, physical environment and the biotic communities, in particular vegetation" (La Notte ***et al***. 2017, p. 394). Examples of ecosystem structures are forest tree cover, grasslands, inland water bodies, and rivers. Ecological processes or functions are "…ecological interactions among components in an ecosystem over time. Processes may generate several ecosystem services" (La Notte ***et al.*** 2017, p. 400). Examples of ecological processes include net primary production, carbon cycling and nutrient cycling. There are layers of different ecological structures and processes that underpin the provisioning of all ecosystem services (Daily 2003). Several ecosystem functions can give rise to a single ecosystem service or vice versa (Gamfeldt 2013). For example, primary productivity can lead to pollination, water regulation, and nutrient storage. The linkages between biodiversity, ecosystem structures and functions, and ecosystem services are still being extensively researched (Mace ***et al.*** 2012).

2) Ecosystem services: Ecosystem services arise only in the presence of a human beneficiary. There are several classification systems for ecosystem services (MA 2005, Kumar and Martinez Alier 2011). We used The International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin 2012), as it is a consolidated effort to review and merge previous typologies. CICES classifies ecosystem services into provisioning, regulating, and cultural services. Provisioning services are all nutritional, material, and energetic outputs from living systems, for example, ecosystem services used for crop production, production of wild goods or clean water. Regulating services are all the ways in which living organisms can mediate or moderate the ambient environment that affects human performance, such as maintaining soil fertility, maintaining the chemical condition of water, and climate regulation. Cultural services are all the non-material, and normally non-consumptive outputs of ecosystems that affect physical and mental states of people, like a sense of place and experience of nature.

Ecosystem services might be generated with different degrees of human input (Bateman ***et al.*** 2011). Some services like scenic beauty need no human intervention but use of other services such as crop production need intensive human input. Ecosystem services are scale, time, and location dependent (MA 2005). At a local scale, a particular fruit may only be produced and consumed in a certain area, and only in certain seasons. Climate regulation, on the other hand, may occur over large regions and long periods of time. Local communities, especially the poor, are particularly reliant on local ecosystem services (Suich 2015). Local people tend to be reliant on a larger range of ecosystem services from the surrounding landscape as compared to regional or global users.

Within snow leopard landscapes, local communities are dependent on livestock rearing, and to some extent, agriculture, for their sustenance (Mishra ***et al.*** 2003a; Jackson 2012). In some areas, trans-humant pastoralists from lower elevations also use the pastures in snow leopard habitats to graze their livestock in the spring and summer seasons (Mishra ***et al.*** 2003). They depend on firewood and animal dung for their energy needs and wild plants for roofing material, as fertilizers, and for consumption. At a regional scale, snow leopard landscapes provide water for more than 2 billion users downstream (Foggin 2008). Globally, they are of conservation importance as they support a unique biodiversity assemblage with adaptations to cold temperatures and high altitudes. The assemblage includes large mammals such as the Tibetan wolf (***Canis lupus***), Lynx (***Lynx lynx***), Pallas Cat (***Felis manul***), Argali (***Ovis ammon***), Markhor (***Capra falconeri)***, Asiatic Ibex (***Capra sibirica***), and Kiang (***Equus kiang***). Birds include the Snow Cock (***Tetraogallus spp***.), Lammergier (***Gypaetus barbatus***), and Griffon (***Gyps spp***.). Organic carbon is stored in soil and in glaciers, providing global carbon sequestration services (Lal ***et al.*** 2004).

3) Benefits: Ecosystem services are essential for providing material and non-material benefits that enhance human well-being (Haines-Young and Potschin 2012). The Millennium Ecosystem Assessment (MA 2005) has consolidated research to identify a set of factors that contribute to human well-being. These components of well-being refer to personal and social functioning, and they express what a person values doing or being (Sen 1999). It includes basic material needs for a good life, the experience of freedom, health, personal security, and good social relations. Together, these provide the conditions for physical, social, psychological, and spiritual fulfillment. Some aspects of human well-being, such as the feeling of security, are psychological, but are shaped by the access to ecosystem services. In many

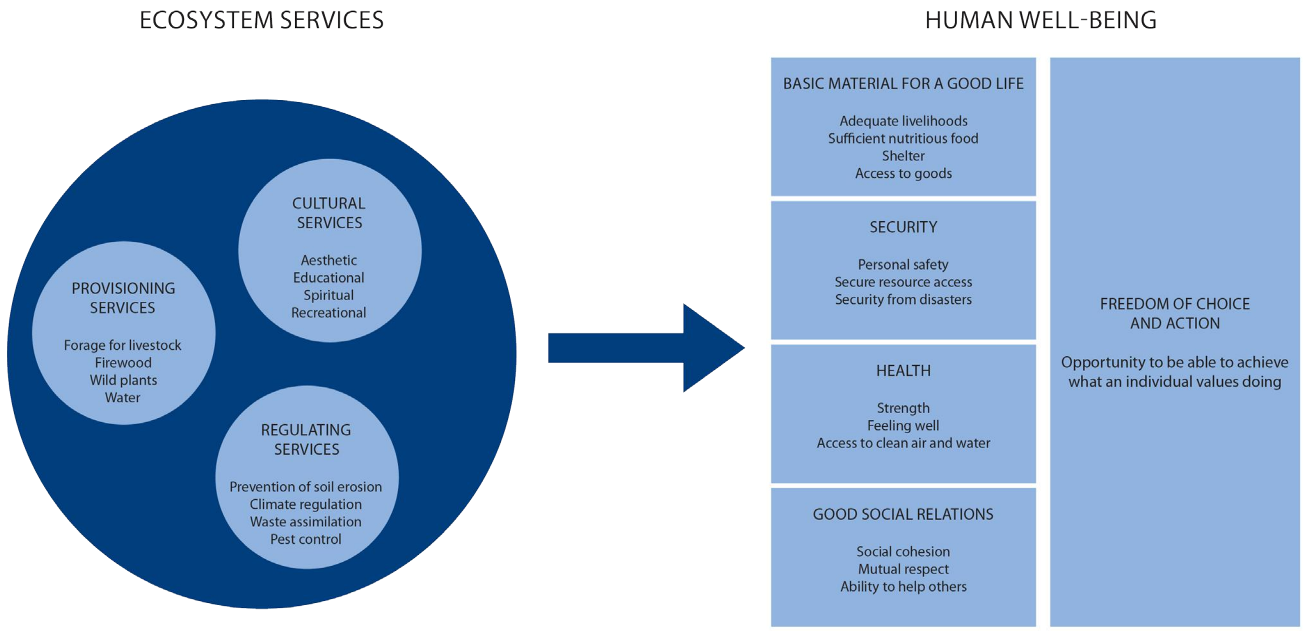


Figure 2 The Millennium Ecosystem Assessment highlighted the links between ecosystem services and human well-being. Provisioning, regulating, and cultural services contribute to security, basic materials for a good life, good social relations, health, and freedom of choice and action. (Adapted from the Millennium Ecosystem Assessment, 2005)

cases, limited access to ecosystem services contributes to a sense of insecurity, and often, to poor social relations. The Millennium Ecosystem Assessment drew the links between ecosystem services and the different aspects of human well-being (Figure 2).

4) Values: Value can refer to underlying ideals and held values such as a sense of fairness or to the relative importance of things such as the monetary value of goods (Brown 1984). The values that humans place on ecosystem services are contextual, relative to different groups of people, at a certain place and time, based on the impact that ecosystem services might have on human well-being (Maris and Bé chet 2010). The ecosystem services framework recognizes the multiplurality of values (Norton and Noonan 2007). Ecosystem service values can be monetary/economic or non-monetary/socio-cultural.

Monetary values for ecosystem services are important as they express values for ecosystems in metrics that have relevance to policy and decision makers (Daily ***et al.*** 2009, Bateman 2013). Conservation scientists have used monetary valuation to make ecosystem services values explicit and to be considered while making land-use decisions (Gomez-Baggethun ***et al.*** 2010). This has also led to novel conservation strategies to halt biodiversity loss, such as payments for ecosystem services (Wunder and Wertz-Kanounnikoff 2009).

As mentioned earlier, however, monetary value is only one facet of overall value. Socio-cultural values examine the importance, preferences, needs or demands that people have toward nature and they are expressed in non-monetary terms (Chan ***et al.*** 2012). They can be moral, social, and aesthetic. This incorporates a person's perception of ecosystem services, their held values and the context of valuation (Brown 1984). Socio-cultural valuation is important as it recognizes value pluralism attached to ecosystem services such as ethical, symbolic, cultural, philosophical, religious, and spiritual (Marté n-Lé pez ***et al.*** 2012). For many people, the ecosystem they live in and are dependent on can form a large part of their sociocultural identity and influence how they live and who they are.

Critiques of ecosystem services

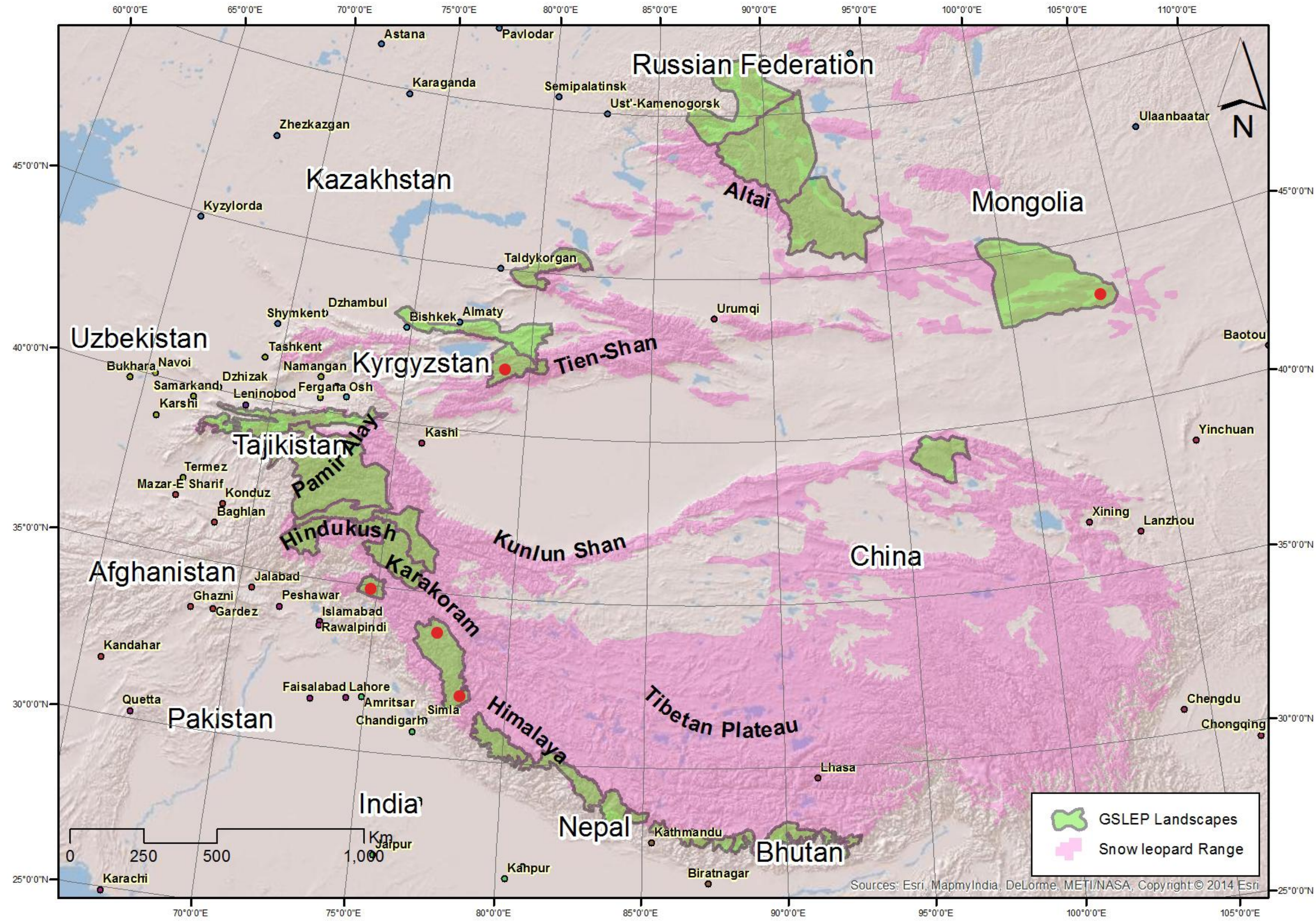
The concept of ecosystem services has gained popularity in the last two decades, with the idea being adopted by researchers and governments (Dé az ***et al.*** 2015). However, there have been several critiques of ecosystem services, which broadly fall under five themes. Firstly, the concept has been criticized for its anthropogenic focus and the exclusion of intrinsic values of nature (McCauley 2006, Redford and Adams 2009). Secondly, there are concerns that the strong economic focus of the concept might promote an exploitative view of nature (Raymond ***et al.*** 2013). Thirdly, there is confusion in the way biodiversity is viewed in the ecosystem services literature and the fear that ecosystem service-based conservation might replace biodiversity-based conservation (Vira and Adams 2009). The conservation of ecosystem services need not necessarily imply the conservation of biodiversity. Fourthly, ecosystem service valuation is often purely monetary and this tends to commodify nature (Turnhout ***et al.*** 2013). All human-nature relationships cannot be monetized and monetizing them underplays the myriad interactions humans have with nature. Lastly, the ecosystem service concept is considered too optimistic as nature might not always be beneficial to humans (Zhang ***et al***. 2007). There are often many costs that people incur because of nature.

While many of these criticisms are valid, the idea of the ecosystem service concept is not meant to replace other arguments for biodiversity conservation, but rather augment existing ones. It aims to strengthen and highlight human links with biodiversity. It underlines human dependence on healthy ecosystems, viewing humans as a part of nature. Cultural ecosystem services try to incorporate intrinsic values of nature by capturing them under the class of existence value. The strongly monetary outlook of the ecosystem services paradigm and the issue of commodification needs to be addressed through non-monetary valuation in ecosystem service assessments. It is important to recognize that people hold a plurality of values for nature and economic valuation should not be the only metric used for ecosystem service valuation.

The strength of the ecosystem services approach lies in the emphasis that it places on the wider ecological, social and economic contexts while making decisions that impact ecosystems (Haines-Young ***et al.*** 2014.) One of the primary reasons for the development of the ecosystem services framework was for the conservation of biodiversity and natural habitats by making explicit the linkages between the status of ecosystems and human well-being (Haines-Young and Potschin 2010). This is particularly relevant in snow leopard landscapes, where large-scale developmental pressures have rapidly increased over the last twenty years. Ecosystem services impacted and human dependence on ecosystem services have rarely been examined and taken into account while making such land use decisions.

In an attempt to fill this gap, we assessed the economic value of provisioning services for the local communities in five study sites from four of Asia's GSLEP landscapes. Provisioning services are important as they are directly used by local households and indicate how connected people are to their environments. Local communities are particularly reliant on provisioning services, due to their direct dependence on ecosystems to meet their basic needs (Adekola ***et al.*** 2015). It is important to describe and value ecosystem services not only for local communities, but especially for the government and policy makers to understand the typically unaudited value of nature.

II
LANDSCAPE PROFILES



Map depicting the high mountain ranges of Asia inhabited by snow leopards and the 23 GSLEP landscapes. Our five study sites are marked by red dots. They include Spiti Valley and the Changtang region of Ladakh, in the Hemis-Spiti Landscape of India; Gurez Valley in the Himalayan Landscape of Pakistan; Tost Nature Reserve in the South Gobi Landscape of Mongolia, and Sarychat region in the Central Tien Shan Landscape of Kyrgyzstan.

Spiti Valley, Hemis-Spiti Landscape, India

Spiti Valley (31°35' to 33°0' N and 77°37' to 78°35' E) is a cold desert with altitude ranging from 3350 m to 6700 m (Anonymous 2011) in the Indian Trans-Himalayas. Temperatures range from -40° C in peak winter to over 30° C in peak summer. Precipitation is received mainly in the form of snow in winter, which starts to melt in late March. The landscape is rocky, with steep slopes largely dominated by grasses and shrubs.

There are around 12,000 inhabitants in Spiti. Most people are resident agro-pastoralists.

Spiti Valley, Hemis-Spiti Landscape, India.

In summer, a few transhumant pastoralists – who migrate seasonally in montane systems – visit the region with their livestock from Ladakh in the north and from relatively lower altitudes of the main Himalaya in the south (Mishra ***et al.*** 2003b).Some of the communities rent out their pasturelands to herders and the grazing charge can vary from about 83 US$ to 1250 US$ for three months based on the size of the pasture and forage quality (Murali ***et al***. 2017). A few people are employed by local government offices (Mishra ***et al.*** 2003b). Some community men also work as tourist guides during the summer, as contractors of civil work and as taxi drivers.

Households own agricultural land and most of the grazing land is common to the community (Mishra ***et al.*** 2003b). The main cash crop is green pea (***Pisum sativum***), which is grown throughout the valley. Apple (***Malus pumila***) is also a cash crop grown in the relatively lower altitudes (c. 3300 m) of the valley. Barley (***Hordeum vulgare***) and wheat (***Tricitum sp.***) are grown, as well.

The livestock reared are sheep (***Ovis aries***), goat (***Capra hircus***), donkey (***Equus asinus***), yak (***Bos grunniens***), cattle (***Bos indicus***), dzomo (yak-cattle hybrid), and horses (***Equus caballus***). Livestock are occasionally used for meat and other products such as milk, butter, manure and wool, with the exception of horses and donkeys that are not consumed. Every community has access to grazing pastures around the community. Local people have traditional grazing and collection rights in the pastures but cultivation is not permitted.

Changtang region, Hemis-Spiti Landscape, India

Changtang region, Hemis-Spiti Landscape, India

The geographical and climatic features of this region are similar to Spiti Valley. Changtang is contiguous with Spiti to the south-east. Two kinds of communities live in the Changtang region of Ladakh, agro-pastoral and nomadic pastoralists, who have a combined population of about 31,000 (Leh district profile, Government of India, 2015). Agro-pastoral communities have permanent settlements with agricultural land and livestock. They depend on agriculture and livestock rearing. Nomadic communities depend on livestock for their sustenance. Their main income is from the sale of cashmere. They move their settlements four to twelve times a year, based on the availability of forage for livestock. There were two nomadic communities in our study area. Agricultural land is owned by communities while pasture lands are owned by the forest department but managed by the local communities based on historical and traditional land tenure rights. The livestock reared are similar to those in Spiti Valley. The agricultural crops grown include green pea, black pea, barley, wheat, mustard (***Brassica sp.***), and vegetables like turnip (***Brassica rapa subsp.***).

Gurez Valley, Himalayan Landscape, Pakistan

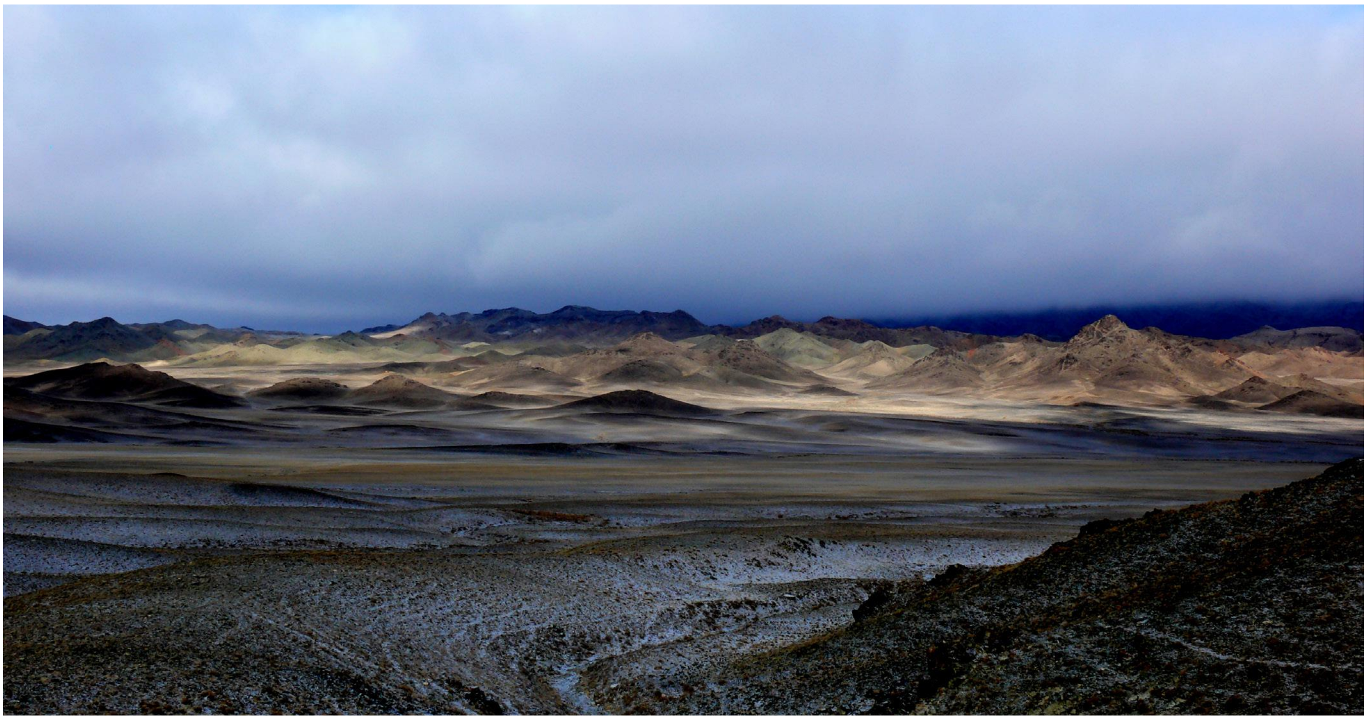
The Himalayan Landscape (43° to 36°45' North and 74° to 75° East) identified under GSLEP in Pakistan is a 7055 km^2 area situated in the Himalayan orogenic belt. Gurez Valley within the Himalayan Landscape was chosen for this study. Altitudinal variation within this landscape is

large, with elevations ranging between 2000 m to above 6000 m.
The vegetation zones represented within this altitudinal gradient are coniferous forests, alpine meadows and scrub, and alpine desert. The climate varies widely from moist temperate, at lower elevations, to arid and semi-arid cold desert at higher altitudes. Below 3000 m, the annual precipitation is approximately 200 mm and at 6000 m the region receives approximately 2000 mm of annual snow fall. Temperatures range from 45°C in summer to -4°C in the winter at lower elevations and -20°C at higher elevations. As the area is out of the monsoon range, it receives very little rainfall during summer.

There are 18 communities in the valley with a total population of 26,000. The local communities depend on subsistence farming and livestock for their livelihood. Crops include maize (***Zea mays***), wheat, barley, millet (***Pennisetum glaucum***), potatoes (***Solanum tuberosum***), peas, beans (***Phaseolus***), and fruit and nuts.. The livestock are sheep, goat, donkey, cattle, and horses. Irrigation channels, sometimes 20 km long, bring water to the agricultural fields. Collection of medicinal herbs, mushrooms, timber logging and sometimes hunting of wild animals, from the forests at lower elevations, are other sources of income.

Human land use has a characteristic attitudinal pattern. Human settlements, roads, and irrigated cultivation are concentrated along the valley bottoms. Summer settlements lie between 2000 to 3000 m, with summer pastures and crops. Alpine pastures start at about

Gurez Valley, Himalayan Landscape, Pakistan



Tost Nature Reserve, South Gobi Landscape, Mongolia

3,000 m and go up to the snow line, usually at 5,000 m (Ehlers and Kreutzmann 2000).

Tost Nature Reserve, South Gobi Landscape, Mongolia

The Tost Nature Reserve is located in the South Gobi Province and covers 7430 km^2. Tost is an extension of the Altai Mountains and a westward extension of the desert valleys. Temperature in winter can go as low as -20°C and in summer it can go up to 23°C. Altitude varies from 1000 m to 2500 m. Precipitation is between 100 and 250 mm and is highest in the months of July and August. Snow cover is uneven with some parts receiving approximately 130 mm of snow in winter and other parts not having any snow at all. The vegetation types include desert steppe and semi-desert grasslands. Various sources place the number of herding households living in the study area between 68 to 90, although according to our estimates, 68 households is more likely. They move seasonally and live in gers, which are portable tents made of sheep wool. Nomadic herders lease land from the government. Their main income is from the sale of cashmere. The livestock reared are goats, sheep, camels (***Camelus bactrianus***) and horses. Crop production is largely absent. This landscape is impacted by mining, ninja mining, and road development.

Sarychat region, Central Tien Shan Landscape, Kyrgyzstan

The landscape is located in the Tien Shan mountains, within the Issyk Kul region of Kyrgyzstan.

Altitude ranges from 2000 m to over 7000 m. Vegetation consists of arid grasslands, wet meadows, and tundra cushion plants interspersed with barren rock at higher altitudes (Jumabay-Uulu ***et al***. 2014). Average annual precipitation is approximately 295 mm, with almost half of it falling between June to August. Mean temperatures range from 4.2° C to -21.5° C. There were two small communities within our study area, Ak-shiyrak and Enylchek, which had 40 and 25 households, respectively. People from here herd livestock including sheep, goat, horses, cows and yaks. Outside the landscape along it's northern boundary, there are more than 90 agro-pastoral communities with the number of households ranging from 250 to 1500. Water for agriculture is derived from within the Central Tien Shan Landscape. People from these communities use the study area as summer pastures for their livestock, while the communities inside use the landscape year round. Under a decentralized pasture management system instituted by the Government in 2009, livestock owners pay a fee per head of livestock to the local government (ayil okmotu) to use the pastures. Herders graze community livestock in the region for six months, during which time they live in tents called yurt. The livestock are grazed close to the community during the winter, spring and autumn seasons.

Sarychat region, Central Tien Shan Landscape, Kyrgyzstan.

III
ECONOMIC VALUATION OF PROVISIONING SERVICES

Methodology

We used structured interviews and group discussions to identify ecosystem services used by local people across the five study sites. The questionnaire to evaluate the household value of provisioning services was based on the International Forestry Resources and Institutions (IFRI) field manual (Wertime ***et al.*** 2007). We first had discussions with different stakeholders to understand the use of ecosystem services. Following this we developed a questionnaire that was administered to households in each study area. Ecosystem services were defined as the benefits people received from nature. We asked questions about the amount of agricultural produce sold, crops harvested for subsistence, livestock owned (age-sex classification), water used, and collection of forage, firewood, wild plants and dung from the pastures. Interviews have been shown to provide reliable information on harvesting patterns (Jones ***et al.*** 2008). The human populations in our study sites were divided based on their livelihood strategies or their location with respect to the landscape and use of ecosystem services from the landscape.

The team conducting interviews in Gurez Valley

In Spiti Valley, the population was all agro-pastoral. We interviewed members from 20 % to 30 % of the households (HH) in 19 communities based on their availability and willingness to be interviewed. In total, 156 semi-structured interviews were conducted with members of the local communities. This included 30 focal group and 126 individual interviews. The communities sampled were distributed throughout the valley, and were chosen to maximize the coverage of community blocks differing in the crops grown, livestock reared, and the type and quantity of natural resource collection from the pastures. This included medicinal plants, forage, and wild plants (largely used as food or dye). The data from Spiti Valley are published in Murali ***et al.*** (2017). In this report, for consistency of methods amongst all landscapes, we recalculated the ecosystem services related to forage by multiplying the annual forage consumption per species of livestock with the value of forage in the particular landscape.

In Changtang, we divided the population into two categories based on their production systems: agro-pastoral and pastoral. There were two nomadic pastoral communities in the study area with 20 and 40 households. Respondents from 80% of the HH were interviewed. There were 50 agro-pastoral communities, and respondents from 30% of the HH in 12 agro-pastoral communities were interviewed. A total of 179 interviews were conducted in this study area.

Herders in Tost Nature Reserve.

The communities of Gurez Valley were agro-pastoral. We conducted interviews in 6 of the 18 communities. Respondents from 10 % of the households were randomly chosen and interviewed in each of the communities. A total of 176 interviews were conducted in this study area. We also recorded peoples' perception on climate change and its impacts on ecosystem services by asking respondents about their perceived impact of climate change on crop production, livestock rearing, and water.

In the Tost Nature Reserve, the herder households depended exclusively on livestock for their livelihood. These households move between 4 and 12 times a year based on the availability of forage for their livestock. We interviewed people from 50 of the estimated 68 herder households. We also collected information on their perceptions of the impact of mining by asking them if mining had an impact on their lives, and the kind of impact it had.

In the Sarychat region, the communities were divided into two categories: the two permanent communities within the study area (in-situ users) who were largely pastoral, and approximately 90 agro-pastoral communities along the border of the landscape (downstream users). We interviewed people from 50 % of the households from the two pastoral communities, who were randomly selected, and amounted to 40 interviews. In the agro-pastoral communities just outside the northern boundaries of the landscape, we chose the focal communities based on initial discussions with community members explaining our purpose. They helped us select representative communities. As the communities were large, we partitioned them into five sections, and interviewed a person from every fifth household within each section. We interviewed a total of 180 people from 10 agro-pastoral communities. There was one city in the landscape in which interviews were not conducted, as most of the residents did not own livestock and therefore did not use the pastures. A total of 220 interviews were conducted in this region. Across all the five study areas, we conducted a total of 781 interviews.

Analyses

Economic value of ecosystem services

The economic value of provisioning services was calculated using the Total Economic Valuation Framework, proposed by The Economics of Ecosystems and Biodiversity (Kumar and Martinez Alier 2011). Table 1 provides the list of services measured, the methodology adopted, and the unit of measurement.

Crop production: Ecosystem services that contributed to crop production were evaluated

Ecosystem services	Economic valuation method	Unit price
Cultivated crops	Market price based approach	Kg HH^{-1} yr^{-1}
Reared animals and their outputs	Market price based approach	Number of livestock/ HH
Wild plants, algae and their outputs	Replacement cost method	Kg HH^{-1} yr^{-1}
Water for household purposes	Replacement cost method	Litres HH^{-1} yr^{-1}
Fibres and other materials from plants, algae and animals for direct use or processing	Market price based approach and replacement cost method	Kg HH^{-1} yr^{-1}
Materials from plants, algae and animals for agricultural use	Replacement cost method	Kg HH^{-1} yr^{-1}
Plant and animal based resources	Replacement cost method	Kg HH^{-1} yr^{-1}

Table 1: Methods used and units of measurement for estimating the economic value of provisioning ecosystem services used by the local communities in the five study areas in GSLEP landscapes of four countries. We used the Total Economic Valuation Framework (Kumar and Martinez Alier 2011).

by estimating the quantity of all the crops harvested per year and multiplying them with the market value. The value of external inputs such as chemical fertilizers and pesticides, labor hired, and the price of seeds was subtracted from the value of the crops produced to get the ecosystem service value of crop production.

Reared animals and their outputs: The value of livestock outputs per year such as milk, meat, and wool was estimated. External inputs such as vaccinations and the cost of herding were subtracted from this value. The value of the animals themselves was not used as the forage used by the animals was evaluated and considering the economic value of animals would have led to double counting.

Forage consumed by livestock: We estimated the annual forage consumed by livestock using standard equations of forage consumption and body size for foregut and hindgut fermenters (Cordova ***et al.*** 1978). The total estimated forage consumption was multiplied by the price of forage in each landscape. If local prices for forage were unavailable, we used the regional price.

Water for livestock: In Tost, herders were able to provide us the amount of water collected for their livestock, which was then multiplied by the local price of water. In the other study sites, the economic value of water consumed by livestock was calculated by multiplying the species-wise annual water consumption (Ward 2015), with the local price of water. If local prices were unavailable, we used the prices from the closest town.

Water for household purposes: We asked interviewees to report their daily household water consumption. Most households were able to accurately report this as water was stored in fixed containers of known volume. This was then multiplied with the local or regional price of water. In some of the study sites, households paid for water. In these cases we used those prices. In the cases where people did not know how much water they used, we used the per capita consumption of water for arid regions (WHO 2014) multiplied by the number of people in the household and the local price of water.

Wild plants collected: We estimated the annual household consumption of the different wild plants in each study site and multiplied it with the local market price, if they had one, or with the price of the closest substitute.

Animal based resources: We estimated the annual household usage of animal dung and multiplied it by the local price of dung. If there was no local price, we estimated it based on calorific value by comparing it with the calorific value of wood.

Fuel wood: Annual household consumption of fuel wood was estimated through interviews. The economic value of fuel wood was then calculated by multiplying it with the local price of fuel wood.

Total economic value: The total economic value was estimated by adding the economic value of all the individual provisioning services.

We derived values for household income by asking the respondents for all their different income sources (employment, agriculture, livestock products sold) and adding them to estimate the average income in each study site.

Across the five study areas, local peoples' main livelihoods were dependent on local provisioning of ecosystem services like those required for agriculture and livestock rearing (Table 2). Spiti Valley was the only site where a significant proportion (12.9 %) of the respondents were dependent solely on employment for their income. Across the five sites, some proportion of the respondents was employed in addition to using agriculture and livestock rearing related ecosystem services. This was highest in Sarychat region where 54.0 % of the respondents had other sources of income in addition to livestock rearing and agriculture, followed by Spiti Valley (40.7 %), Gurez Valley (43.0 %), Changtang region (24.5 %), and Tost Nature Reserve (24.0 %).

Income sources	Spiti (%)	Changtang (%)	Gurez (%)	Tost (%)	Sarychat (%)
Only agriculture and/or livestock	46.4	75.5	57.0	76.0	46.0
Agriculture, livestock, and other sources	40.7	24.5	43.0	24.0	54.0
Only employment	12.9	0	0	0	0

Table 2: Income sources of the respondents in the five study sites in the GSLEP landscapes of four countries. "Only agriculture and/or livestock" refers to respondents whose households depended solely on agriculture and/or livestock for their livelihood. "Agriculture, livestock, and other sources" include respondents from those households that also had one or more individuals employed in addition to agriculture and livestock rearing. "Only employment" included respondents from those households that were reliant only on employment for their livelihood.

Water was the only ecosystem service that was used by all respondents across the five landscapes (Table 3). There was no crop production in our study communities living inside the landscapes in Tost and Sarychat region. Livestock rearing and forage for livestock were among the most used services across the landscapes, with users in Tost Nature Reserve and Sarychat region (100 %) using them the most, followed by those in Gurez Valley (97.7 %), Changtang region (95.8 %), and Spiti Valley (86.0 %). Table 3 provides a list of all the provisioning services used in the landscapes with the percentage of respondents using these services.

The estimated economic contribution of provisioning services alone was 2.5 times the annual household income in Gurez Valley, 3.6 times the annual household income in Spiti Valley, 3.7 times the annual household income for agro-pastoral communities in Changtang region,

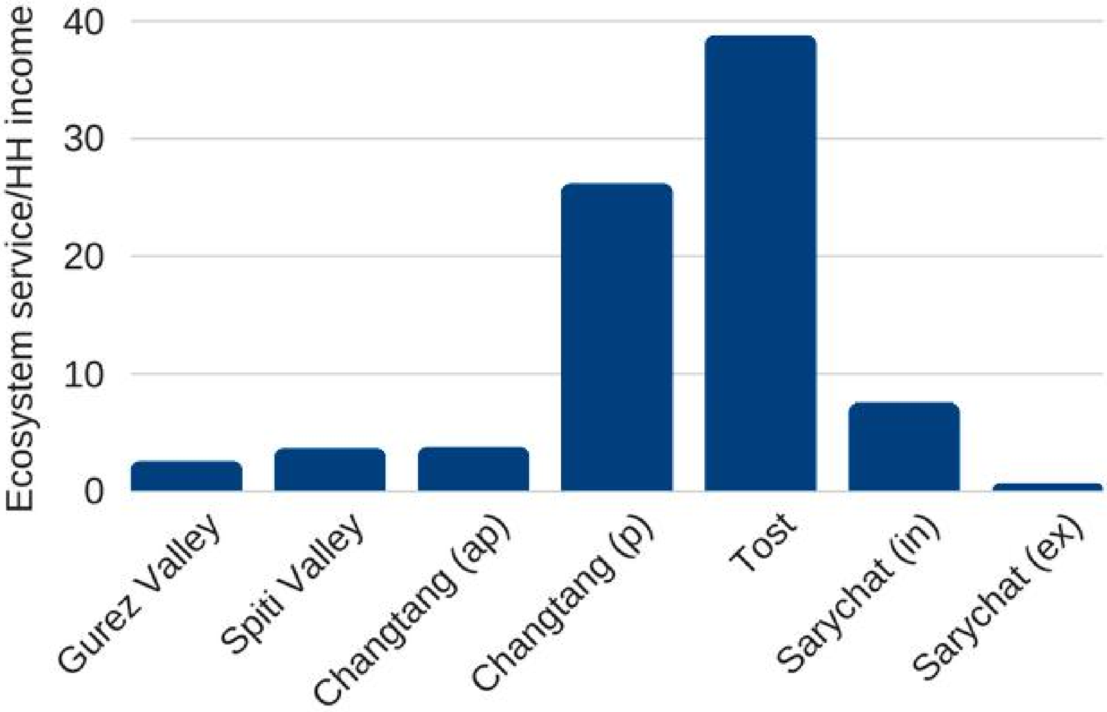
Study area	Spiti Valley, India		Changtang, India		Gurez Valley, Pakistan		Tost, Mongolia		Sarychat, Kyrgyzstan	
Ecosystem service	Services identified	Service used (%)	Services identified	Service used (%)	Services identified	Service used (%)	Services identified	Services used (%)	Services identified	Services used (%)
Cultivated crops	Crops include green pea, barley, apple, black pea, wheat.	82.0	Crops include barley, green pea, black pea, mustard, turnips, wheat, potatoes, cauliflower, alpha-alpha (for livestock).	85.0	Crops cultivated only by downstream users.	0	No crops cultivated	0	Crops cultivated only by downstream users.	0
Reared animals and their outputs	Livestock include sheep and goat for wool, meat from all livestock except donkeys and horses, yak hair used to make ropes, cow and dzomo for milk, butter and cheese.	86.0	Goats reared for commercially valuable cashmere, sheep for wool, cow and dzomo for milk, yaks for wool and animal-based energy. All livestock except donkeys and horses for meat.	95.8	Livestock reared are horse, cow, goat, sheep, and donkey. Cow used for milk and meat, goat and sheep used for meat, horses and donkeys used for transport.	97.7	Livestock reared are goat, sheep, camel, cow, and horse. Goats are reared for commercially valuable cashmere, sheep for wool. The milk and meat of all animals are consumed.	100	Livestock reared are sheep, goat, cow, horse,yak. Reared for wool, milk, and meat.	100
Wild plants, algae and their outputs	Wild onion, mushroom, rhubarb, and green leafy plants to eat.	26.0	Wild onion, mushroom, rhubarb, stinging nettle, local green leafy vegetables.	41.3	Not used from the landscape.	0	Wild onion.	76.0	Blackberry, mushroom, wild onion, and rhubarb.	70.5
Wild animals and their outputs	Not used.	0	Not used.	0	Not used from the landscape.	0	Wolves for skin and organs used in traditional medicine, ibex and argali horn to rid corrals of parasites and protect the corral,	30.0	Wolves for organs in traditional medicine and selling their skin. Trophy Hunting. Use of Golden eagles in	9.0

Surface water	Water for household and agricultural purposes. Snow melt. Water for downstream users.	100	Water for household and agricultural purposes. Water for downstream users.	100	Water for downstream users for household, livestock, and agricultural purposes.	100	Surface water ocassionally used for livestock and household purposes.	100	Water for household purposes, for livestock, and for downstream users as well.	100
Ground water	Not used.	0	Not used.	0	Not used.	0	Mostly dependant on ground water which is accessed by wells.	100	Ground water recharge for downstream users.	0
Fibres and other materials from plants, algae and animals for direct use or processing	Medicinal plants, plants for dyes, plants for roofing.	100	Medicinal plants, plants for dyes, plants for roofing	43.7	Medicinal plants not used from the landscape.	0	Medicinal plants.	60.0	Medicinal plants.	45.5
Materials from plants, algae and animals for agricultural use	Animal dung as fertilizer, wild plants as fertilizer, forage for livestock.	80.0	Animal dung as fertilizer, wild plants as fertilizer, forage for livestock.	100	Forage for livestock.	100	Forage for livestock.	100	Forage for livestock.	100
Plant-based resources	Wood for heating.	70.0	Wood for heating.	70.4	Not used from the landscape.	0	Wood for heating.	100	Wood for heating.	25.0
Animal-based resources	Animal dung for heating.	70.0	Animal dung for heating.	67.7	Not used from the lanscape.	0	Animal dung for heating.	100	Animal dung for heating.	86.4
Animal-based energy	Yak to plough the land, donkey to transport materials.	39.0	Horses used for herding, ploughing, and transport, yak for ploughing the land, donkey to transport material	42.5	Donkey and horse for transport, and ox for ploughing the land.	36.7	Horses used for herding and transport.	42.0	Horses used for herding and transport.	63.6

Table 3: List of provisioning services used by local people in each of the study areas in GSLEP landscapes of four Asian countries. The first row header identifies the study area. Under each study area, the first column lists the provisioning services used, classified according to the Common International Classification of Ecosystem Services (Haines-young and Potschin 2012). The second column gives the percentage of respondents that used the respective ecosystem service.

26.1 times the annual household income for nomadic pastoralists in Changtang, 38.7 times the annual household income for pastoral communities in Tost Nature Reserve, 7.4 times the annual household income for in-situ users in the Sarychat region and 0.6 times the annual household income for downstream users in Sarychat (Figure 3).

Figure 3: Total ecosystem service value in comparison to household income. The ratio of ecosystem services to household income (ecosystem services/household income) is on the y-axis. The study sites and their communities surveyed are shown on the x-axis. Changtang (ap) refers to the agro-pastoral communities and Changtang(p) to the nomadic communities in the Changtang, respectively. Sarychat (in) refers to the in-situ users and Sarychat (ex) refers to the downstream users in the Sarychat region.



The average value (± SE) of ecosystem services used by households in Spiti Valley was estimated at 3964 ± 335 USD/HH/yr (Table 4), in Tost Nature Reserve, it was 150100 ± 13290 USD/HH/yr (Table 5), and in Gurez Valley, it was 4125 ± 190 USD/HH/yr (Table 6). In Changtang, for nomadic communities largely dependent on livestock rearing, the value was 79303 ± 9204 and for the agro-pastoral communities it was 15083 ± 1656 USD/HH/yr (Table 7). In Sarychat region, for local communities within living in the landscape, it was USD 25473 ± 5236, and for downstream users it was USD 2094 ± 189 (Table 8).

Comparisons of values across landscapes is not appropriate, as in each case, local prices were used and these prices are driven by local or regional markets, and are likely to vary between the landscapes. We are, however, able to infer the extent of use of different ecosystem services within each landscape.

Forage for livestock was the highest valued service in all five study areas. In Spiti Valley, it contributed relatively the lowest to the total value of ecosystem services (57 %) (Table 4) while in the other four study areas, it contributed to more than 90 % of the total ecosystem service value (Tables 5 to 8). Ecosystem services related to crop production were the highest for Spiti Valley, contributing to 28 % of the total ecosystem service value (Table 4). In Sarychat region and Gurez Valley, downstream users used water for agriculture and household purposes from the landscape, but the agricultural fields were not located in the landscape. The downstream users, however, grazed their livestock in these landscapes for five months, during the summer season. In Changtang, there was variation in ecosystem service use between the two types of communities, with nomadic pastoralists using the most forage for livestock.

Tables 4 to 8 show the total value of ecosystem services and the value of individual services used by local people within each of our study areas. They also indicate the percent contribution of individual services to the total value in each study area.

Landscape	Spiti	
	Ecosystem service value (USD/HH/yr)	Contribution to total ES (%)
Total ecosystem services	3964 ± 334.8	
Cultivated crops	1092 ± 42	27.5
Outputs of reared animals	523 ± 46.2	13.2
Wild plants and their outputs	8 ± 1	0.2
Medicinal plants	3.4 ± 0.3	0.1
Wild animals and their outputs	0	0
Water for household use	9 ± 0.7	0.2
Water for agriculture/ livestock use	26 ± 3.6	0.7
Plants for roofing/ livestock fibre for housing	142 ± 16	3.4
Forage for livestock	1960 ± 208	49.4
Plant and animal based resources	201 ± 17	5.1

Table 4: Economic value of ecosystem services in Spiti Valley. The first column lists the ecosystem services, while the second column shows their respective value in USD/HH/yr. The third column indicates the percentage contribution of individual ecosystem service value to the total ecosystem service value. Total ecosystem service value is mentioned first, followed by the value of individual services.

Landscape	Tost	
	Ecosystem service value (USD/HH/yr)	Contribution to total ES (%)
Total ecosystem services	150100 ± 13290	
Cultivated crops	0	0
Outputs of reared animals	3881 ± 360	2.6
Wild plants and their outputs	20 ± 9.1	0.01
Medicinal plants	6 ± 2	0
Wild animals and their outputs	0	0
Water for household use	9 ± 0.7	0
Water for agriculture/livestock use	524 ± 59	0.3
Plants for roofing/ livestock fibre for housing	13 ± 7.2	0
Forage for livestock	145381 ± 13027	96.9
Plant and animal based resources	206 ± 16	0.1

Table 5: Economic value of ecosystem services in Tost Nature Reserve. The first column lists the ecosystem services, while the second column shows their respective value in USD/HH/yr. The third column indicates the percentage contribution of individual ecosystem service value to the total ecosystem service value. Total ecosystem service value is mentioned first, followed by the value of individual services.

Landscape	Gurez	
	Ecosystem service value (USD/HH/yr)	Contribution to total ES (%)
Total ecosystem services	4125 ± 190	
Cultivated crops	0	0
Outputs of reared animals	0	0
Wild plants and their outputs	0	0
Medicinal plants	0	0
Wild animals and their outputs	0	0
Water for household use	11.4	0.3
Water for agriculture/livestock use	18.5 ± 0.5	0.4
Plants for roofing/ livestock fiber for housing	0	0
Forage for livestock	4105 ± 306	99.5
Plant and animal based resources	0	0

Table 6: Economic value of ecosystem services in Gurez Valley. The first column lists the ecosystem services, while the second column shows their respective value in USD/HH/yr. The third column indicates the percentage contribution of individual ecosystem service value to the total ecosystem service value. Total ecosystem service value is mentioned first, followed by the value of individual services.

Landscape	Changtang			
	Nomadic		Agro-pastoral	
	Ecosystem service value (USD/HH/yr)	Contribution to total ES (%)	Ecosystem service value (USD/HH/yr)	Contribution to total ES (%)
Total ecosystem services	79303 ± 9204		15083 ± 1656	
Cultivated crops	0	0	282 ± 43	1.9
Outputs of reared animals	3042 ± 437	3.8	929 ± 67	6.2
Wild plants and their outputs	233 ± 35.9	0.3	80.9 ± 12.8	0.5
Medicinal plants	0	0	0	0
Wild animals and their outputs	0	0	0	0
Water for household use	3.4 ± 0.2	0	3.5 ± 0.1	0.02
Water for agriculture/ livestock use	99.2 ± 12.1	0.1	38 ± 3	0.3
Plants for roofing/ livestock fibre for housing	0	0	2.5 ± 0.6	0.02
Forage for livestock	75025 ± 8848	94.6	13550 ± 1606	89.8
Plant and animal based resources	900 ± 151	1.1	197 ± 23	1.3

Table 7: Economic value of ecosystem services in Changtang, for nomadic and agro-pastoral communities. The first column, under each community, lists the ecosystem services, while the second column shows their respective value in USD/HH/yr. The third column indicates the percentage contribution of individual ecosystem service value to the total ecosystem service value. Total ecosystem service value is mentioned first, followed by the value of individual services. The ecosystem service values for the agro-pastoral and pastoral communities of Changtang were estimated separately.

Landscape	Sarychat			
	In-situ users		Downstream users	
	Ecosystem service value (USD/HH/yr)	Contribution to total ES (%)	Ecosystem service value (USD/HH/yr)	Contribution to total ES (%)
Total ecosystem services	25473 ± 5236		2094 ± 189	
Cultivated crops	0	0	0	0
Outputs of reared animals	1182 ± 177	4.6	0	0
Wild plants and their outputs	35 ± 6	0.1	0	0
Medicinal plants	2.1 ± 0.6	0	0	0
Wild animals and their outputs	0	0	0	0
Water for household use	12.3 ± 0.9	0.05	12.2 ± 0.9	0.6
Water for agriculture/ livestock use	0	0	14.1 ± 1.5	0.7
Plants for roofing/ livestock fibre for housing	0	0	0	0
Forage for livestock	24073 ± 5115	94.5	2061 ± 187.7	98.4
Plant and animal based resources	169 ± 25	0.7	0	0

Table 8: Economic value of ecosystem services in Sarychat. The first column lists the ecosystem services, while the second column shows their respective value in USD/HH/yr. The third column indicates the percentage contribution of individual ecosystem service value to the total ecosystem service value. Total ecosystem service value is mentioned first, followed by the value of individual services. 'In-situ users' refers to the two pastoral communities located within the landscape and 'downstream users' refers to the agro-pastoral users along the boundary of the landscape who graze their livestock in the landscape.

Ecosystem services and human well-being

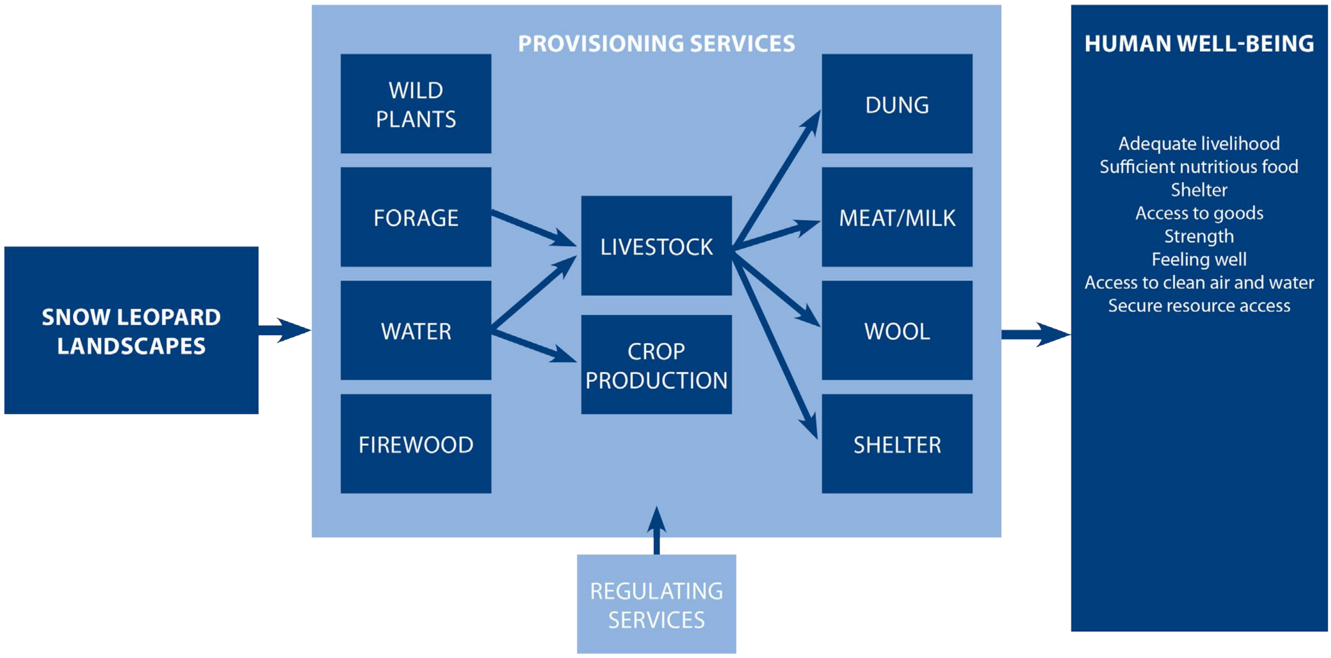


Figure 4: Depiction of the ecosystem services that local communities use in our study sites in four GSLEP landscapes of Asia. People use direct services such as water, forage, and firewood and indirect services through crop production and livestock rearing, such as dung, meat, and wool. These services contribute to different aspects of human well-being such as adequate livelihood, nutritious food, and access to clean air and water.

In our five study sites, provisioning services contributed directly to livelihood generation activities and sustenance of the local people (Figure 4). The landscapes provided direct ecosystem services such as water for agriculture, human and livestock consumption, forage for livestock, firewood, useful wild plants. Indirectly, through crop production people derived nutritional benefits and through livestock rearing, people derived benefits such as wool, dung, milk, and meat. These provisioning services contributed to different aspects of human well-being such as adequate livelihood, sufficient nutritious food, clothing, shelter, access to clean air and water, strength, and health. Their lifestyles and nature of dependence on ecosystem services have contributed to a unique way of life, forming a strong cultural identity in each of these landscapes.

Livestock rearing and agriculture were the main livelihood generating activities across the five study sites. Communities in snow leopard landscapes have traditionally been pastoralists. Low productivity landscapes have historically supported livestock rearing as the main livelihood option as crop production is difficult (Dong ***et al.*** 2011). In regions where livestock are not the main income source, they provide a source of security as they are sold in times of need and can be used for meat and milk. Across all our five study sites, forage was the highest valued ecosystem service, contributing to more than 90 % of the total ecosystem service value in every study site except Spiti Valley. The ecosystem service values for the nomadic pastoral communities in Tost Nature Reserve and Changtang were especially high, primarily because of the high number of livestock holdings per household. The mean livestock holding (± SE) per HH in Tost Nature Reserve was 369 ± 33 and it was 303 ± 36 among the pastoralists in Changtang, as compared to 4.5 ± 0.5 livestock per HH in Spiti Valley, 45 ± 6 livestock per HH for agro-pastoralists in Changtang, and 94 ± 14 livestock per HH for in-situ pastoralist users in Sarychat region.

Traditionally, nomadic pastoralism is believed to have been the prevalent land-use across much of snow leopard habitat. This is still prevalent in Mongolia, but rapidly reducing in Ladakh, with only about 60 households (3600 people) in our study site who still continue with this way of life. They rear goats that produce the commercially high-valued cashmere for which the price per kg as per the data we collected was 39 USD/kg as compared to other wool which sells at 8 USD/kg. The cold weather conditions in Tost and Changtang favor the growth of thin underwool that is highly priced in the international market (Tumurjav 2015). Mongolian and Ladakhi cashmere are considered to be among the finest in the world (Butola 2012 ***et al.,*** Tumurjav 2015). The external demand for cashmere, has a direct impact on the local use of ecosystem services (Berger ***et al.*** 2013).

The ecosystem service input for producing cashmere is substantial. We estimated that in Tost it costs 704 USD worth of ecosystem services (forage and water consumption value of livestock) to produce 1 kg of cashmere, and in Changtang we estimated it to cost 495 USD. The costs of rearing these large herds, while heavily offset by the natural ecosystem, also place immense pressure on it. Traditionally, mobility among pastoralists was a livelihood strategy to distribute the pressure across a larger resource area, and prevent over-grazing. However, over the last few years, the increased demand for cashmere has led to increasing herd sizes, and caused the degradation of pastures. This is particularly evident on the Tibetan plateau, where overgrazing has led to the formation of degraded soil that supports little forage growth (Dong ***et al.*** 2012)

The contribution of forage to total ecosystem services in Spiti Valley was substantial but relatively lower as the main livelihood came from crop production, and there were relatively more employment opportunities in this region (12.0 % of the respondents derived income from only employment), as compared to the other four landscapes. In Spiti, the commercial crop, green pea, has a high market value, which has caused a shift from livestock rearing to crop production over the last 25 years. External markets influence the local use and value of ecosystem services even in these seemingly remote communities.

In Sarychat region, the value of provisioning services per household in the communities living inside the landscape was 11.5 times higher than the value of services used per household in the communities living downstream. However, even though the per household value of ecosystem service use was lower for communities living downstream, the total number of these users was high. The total number of communities or people using the landscape is currently unknown; it was estimated that roughly 90 communities with 250 to 2000 households send their livestock to graze in these pastures during the five summer months. About 2 % of the households in each community were herders who bring livestock to the pastures during this period. The downstream communities used water from this landscape for household and agricultural purposes for crops worth 1039 ± 99 USD/HH/yr.

This is a similar case in Gurez Valley, where the pastures were used by communities living at lower altitudes of about 2200 m above sea level. The local communities grazed their livestock within the snow leopard landscape during the five summer months. They depended on water from this landscape for their household and subsistence agricultural needs.

Economic value alone is an insufficient reflector of overall value of ecosystem services. Economic values of ecosystem services are based on local pricing and prices are based on a range of external factors which do not necessarily reflect value. For example, the price of water is most often set by the optimal volumetric pricing rule that requires that the water price be set equal to the marginal cost of water supply. Different countries and regions use different versions of this method to charge for water. Irrigation water involves a volumetric water charge to cover operation and maintenance costs, and a per hectare water charge to recover the public investment in off-farm irrigation infrastructure (Dinar and Subramanian 1997). In India, a volumetric rate per estimated volume of water consumed is used in areas with pumped irrigation and tubewells (Dinar and Subramanian 1997). However, the price of water is different from the value of water, which is infinite, as water is essential for survival. Non-monetary valuation techniques explore other aspects of why people value ecosystem services.

An important value from these landscapes is bequest value, that is the value of the landscape to future generations. The land and lifestyle of people are inherited by their descendants, and the ecosystems provide them with livelihood security. If well managed, ecosystem services will ensure the well being of future generations.

IV

IMPACT OF INFLUENTIAL FACTORS ON THE USE OF ECOSYSTEM SERVICES IN SNOW LEOPARD LANDSCAPES

There are several external influential factors that change the use of ecosystem services and the capacity of ecosystems to produce ecosystem services. We explored the change in the use of ecosystem services with urbanisation, and the percieved impact of mining and climate change on the provisioning of ecosystem services. We explored the change in ecosystem service use with urbanization in Spiti Valley, which captures the initial gradient of the urbanization process. We looked at the perceived impacts of mining on ecosystem services in Tost Nature Reserve and the Sarychat region, two landscapes which are currently threatened by mining. The impact of climate change on ecosystem services was explored in Gurez Valley and the Sarychat Region.

Urbanization, Spiti Valley, Hemis-Spiti Landscape, India

The potential role of urbanization was explored by comparing the use of ecosystem services by inhabitants living in different kinds of habitations within Spiti Valley. We classified the settlements in Spiti into towns, villages, and hamlets based on the size of the settlement, population density, and the presence of infrastructure, with hamlets being the least urbanized. We conducted a total of 284 interviews. Of these 100 interviews, each, were of people from 3 towns and 9 villages and 84 interviews were from 14 hamlets. We did interviews at a household level with households randomly selected.

An ANOVA was used to test for differences between the three settlement types.
There was a significant difference in the use of ecosystem services between the three settlement types ($F(282)= 39.94$, $p <0.005$). The Tukey HSD test showed a difference between town and hamlet and town and village, but not between hamlet and village (Figure 5).

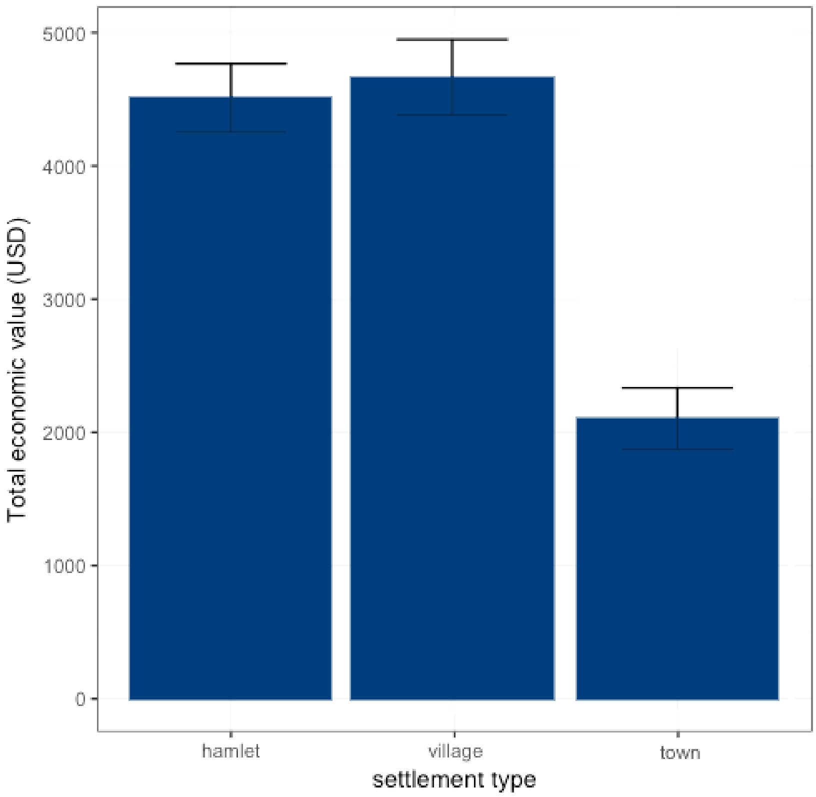


Figure 5: The bar graph shows a significant difference in the total economic value of household use per year of ecosystem services ($F(282)= 39.94$, $p <0.005$) between town and hamlet and town and village but not between village and hamlet. On the y-axis it is the total economic value expressed in USD/HH/yr. The x-axis shows the settlement type.

While the per household use of local ecosystem services decreased from villages to towns, the overall use of ecosystem services in towns was likely higher due to a larger number of households. Globally, rural systems are characterized by high dependance on local ecosystem services and in urban systems, almost all individuals secure their basic needs for food, water and other materials through markets supplied by distant ecosystems (Cummings ***et al.*** 2014). Understanding the change in ecosystem service use is essential for tailoring policies to manage the particular resource use and human well-being challenges in different areas.

Perceived impact of mining on ecosystem services

In Tost Nature Reserve, 95.8 % of the respondents felt that mining had negative impacts on ecosystem services, while 4.2 % felt that it had no impact on ecosystem services. In Sarychat, 75.6 % of the respondents felt that mining had negative impacts on their lives, 19.8 % felt that it had no impact, and 4.7 % felt it had a positive impact. Mining was perceived to negatively impact pasturelands, water, air, livestock, and human health and positively impact income (Table 9). Perceived negative impacts on pasturelands include pollution of grazing lands, reduction of grazing pastures, fragmentation of grasslands due to road networks, and the soil collapsing in exploratory mining areas.

Table 9: The ecosystem services that were perceived to be impacted by mining, the kind of impact, and the

Ecosystem services	Percieved impact	Nature of impact
Pasture	Negative	Pollution of grazing land
	Negative	Reduction of grazing pastures
	Negative	Fragmentation of grasslands due to road networks
	Negative	Soil collapse in exploratory mining areas
Water	Negative	Reduction in ground water level,drying up of surface water, pollution of ground and surface water, reduction in precipitation
	Negative	Drying up of surface water
	Negative	Pollution of ground and surface water
	Negative	Reduction in precipitation
	Negative	Pollution of precipitation
Air	Negative	Pollution of air with dust
Livestock	Negative	Respiratory ailments
	Negative	Pollution of meat (lining of the stomach turns black, this makes it difficult to sell the meat)
Health	Negative	Respiratory ailments
Income	Positive	Increase in household income

nature in which the respondents expected themselves to be impacted, in Tost Nature Reserve, Mongolia and Sarychat region, Kyrgyzstan.

Mining impacts were perceived to be negative by local people and were reported to impact crucial ecosystem services like pasture availability, water, and air. Income was the only recognized benefit from mining, and in our sample, 3.4 % of the households reported a member being employed by mining companies. However, the negative fallouts of mining were perceived to impact the whole population. In Mongolia, households are reported to be compensated with 2000 USD if mining impacts their pastures. This amount is 75 times lower than the estimated value of ecosystem services each household derived from the landscape in a single year. In addition, if the generational and bequest value of the ecosystem services are taken into account, the compensation currently offered appears to be based on a severely gross underestimation. Monetary compensations for land acquisition themselves have several issues. Most of these communities have knowledge in managing ecosystem services but have limited experience and knowledge managing money, and this can often lead to poverty (Downing 2002). In addition to the monetary value of the land, people also have traditional and cultural attachment to the land, which is rarely accounted for in compensation packages.

Mobility is an important strategy employed by pastoralists to prevent over-grazing of pastures. When mining companies acquire land, the households on that land maybe re-located. Grazing pressure on existing pastures can then increase, as there are the same number of livestock in lesser area of land. This might require the herders to move more frequently, move longer distances, or not move at all, because of limited land. To prevent overgrazing, they would have to reduce herd sizes. This can lead to an overall decrease in well-being.

Perceived impact of climate change on ecosystem services

Amongst our respondents in Sarychat, 90.1 % felt that the climate was changing in Sarychat while 10.9 % felt that there was no change in the climate. Table 10 outlines the perceived impacts that people reported of changing climate on ecosystem services in Sarychat.

Table 10: The ecosystem services perceived by local people to be impacted by climate change, and the kind and the nature of impact on ecosystem services in Sarychat region, Kyrgyzstan.

Ecosystem services	Perceived impact	Nature of impact
Crop production	Negative	Increased pests and disease, lower yield
	Positive	Increased rains, which can be good for productivity
	Negative	Erratic weather, so difficult to plan the season, when to plant, etc
	Neutral	Late harvest
	Negative	Loss of soil moisture as the summers are very hot
	Negative	Erratic weather causes crop losses
	Negative	Changes in crop quality and quantity
Livestock	Negative	Longer winters, so livestock are sent to the pastures later which means there is more stall feeding and therefore more expensive to look after them
	Negative	Fall sick more frequently and more kinds of disease. They need to use more vaccines
	Negative	Less milk productivity
	Negative	Livestock death due to unpredictable weather. Livestock are sheared and sent to the pastures, but when the weather changes suddenly, they can die.
Pasture	Negative	The grass gets scorched as the summers can be very hot
	Positive	Increased rains which can be good for the grass
Water	Negative	Flooding
	Negative	The glaciers are melting
	Negative	Murky water as there are more sediments
Health	Negative	Headaches as it is becoming very hot
	Negative	More disease, as it is raining more
Biodiversity	Negative	Decrease in bird species diversity. Increase in crows
	Negative	Frogs disappearing from the garden

In Gurez Valley, 90.7 % of the respondents felt that the climate was changing. Table 11 outlines the percieved impacts that people reported of changing climate in Gurez Valley.

Table 11: The ecosystem services perceived by local people to be impacted by climate change, and the kind and the nature of impact on ecosystem services in Gurez Valley, Pakistan.

Ecosystem services	Perceived impact	Nature of impact
Crop production	Negative	Reduction in crop yield due to flash flooding, thunderstorms, irregular rain, and hot weather
	Negative	Increase in crop disease and pests
	Positive	Increase in crop production due to more precipitation
Livestock	Negative	Decrease in milk production due to decreased forage
	Negative	Disease in livestock
Pasture	Negative	Decrease in productivity
Water	Negative	Reduction in quantity and quality of spring water
	Negative	Decrease in the water table

The local people in Sarcychat region and Gurez Valley that we interviewed reported already experiencing the impacts of climate change. Unpredictable weather conditions are making it difficult for people to plan their cropping and grazing strategies. It is believed to be leading to economic loss due increased pest and disease outbreaks in crops and livestock. The livestock sometimes die in the mountains as it gets unexpectedly cold. Longer duration of cold spells in the mountains implies that pasture-grazing is delayed, which means that people have to invest in more feed for stall feeding.

For people in our study areas, climate change effects are likely to have considerable negative repercussions. It is important to develop strategies that minimize the negative impacts of climate change on ecosystem services and peoples' lives.

V
CULTURAL ECOSYSTEM SERVICES

Cultural ecosystem services are all the non-material, and normally nonconsumptive, outputs of ecosystems that affect the physical and mental well being of people (Haines-young 2012). In traditional tribal societies, cultural services are particularly relevant as they contribute directly to the identity, culture, traditions, and rituals of people, creating a deep attachment to the natural environment (Chan ***et al*** 2012). Across snow leopard landscapes, the connection of the local communities with the natural environment was strong, with their way of life defining their identity as nomadic pastoralists or agro-pastoralists.

In Mongolia and Kyrgyzstan, the mobile home ('ger' in Mongolian and 'yurt' in Kyrgyz), which is made of felted sheep wool and wood, is an integral part of their culture. While it is still extensively used in Mongolia, it is less used in Kyrgyzstan, but a representation of the yurt is on the national flag, as a reference to their nomadic roots. The traditional music instrument of Mongolia is a Morin Khuur (horse-head fiddle), and their traditional dance involves a mounted Mongolian horseman and a horsewoman who circle each other. In Kyrgyzstan, the national sport is called Kok boru, in which horse mounted players attempt to place a dead goat in a goal. These represent strong cultural linkages to their nomadic, livestock rearing lifestyles, which are ultimately dependent on ecosystem services.

Wildlife and the natural environment are depicted in their songs, stories, and traditions.In Spiti, people sing songs while ploughing, asking for forgiveness in case their actions lead to inadvertent killing of creatures living in the soil. In Ladakh, there are songs about the sun, moon, mountain ranges, weather, rivers, valleys, and wildlife which are called Jung-lhuh. There are several stories in the local culture that reference the ecosystem. For example, the Ama Danmo is a famous story about an ibex that is shot by a hunter, and says goodbye to her foal as she lays dying. Just before she dies, she passes advice about grazing in the pastures during the day but sleeping close to the rocks at night. There is also a song about the birds coming to eat in the barley fields.

In Spiti, local people believe that the ibex is the vehicle of one of the deities. In Tost, the argali is sacred as it is believed to be the food of the gods. The horns of the argali are burnt near the corrals to protect the livestock from predators. A red fox charm is hung over the head of a sleeping baby to prevent bad dreams. The snake is considered sacred and never killed.

Humans, deities, and wild animals depicted on a wall painting in a monastery in Ladakh, Hemis-Spiti Landscape

People can't kill the raven, as they believe that it will curse them before it dies. In Kyrgyzstan, the golden eagle is trained to hunt.

Across snow leopard landscapes, the local peoples' relationship with the wolf is a complex one. Viewed as a source of inspiration in some, while consistently regarded as a threat to livestock, it is extensively hunted across the range. Once hunted, in Mongolia and Kyrgyzstan, the wolf is used in traditional medicine and parts of the wolf, such as the bones, the ankles and teeth, are used as protective charms.

Barley is used in all the important religious functions in Ladakh and Spiti. Most trees that are found in Spiti and Ladakh are considered sacred and believed to be the home of 'naga' or the snake. In Kyrgyzstan, juniper is considered sacred, and the twigs of the plant are burnt when people are sick. Juniper leaves are also used as incense while making daily offerings to the deities in Spiti and Ladakh.

There were numerous sacred places in our study landscapes where collection of plants, or hunting was forbidden. In some of the sacred spaces, people are not even allowed to enter. In most of the landscapes, water sources are considered sacred and cannot be polluted. These stories depict the strong cultural links that communities still have with the landscape, and the contribution that the ecosystem makes to their culture and identity.

Tourism and hunting are other ecosystem services in these landscapes. Hunting concessions are given out to companies in the Sarychat region. However, local communities reportedly benefit little from this. From our interviews, the proportion of respondents involved in tourism was also low across the landscapes: 10.4 % in Spiti Valley, 2.4 % in Changtang, 6.6 % in the Sarychat region, and none in Tost Nature Reserve. Among the respondents in Tost Nature Reserve, 80 % believed that they would benefit from nature tourism if it was developed. However, unless it is developed in an inclusive way, very little of the overall benefits of tourism will go to the local communities. In the Sarychat region, 4.5% of the respondents benefited from hunting by being employed by hunting concessions. Here, majority of the benefits from hunting were reported to be obtained by external people. We did not include hunting in our ecosystem service assessments.

VI
CONCLUDING THOUGHTS ON ECOSYSTEM SERVICES

Across snow leopard habitats of Asia, people rely directly on ecosystem services for their livelihood and sustanence and are highly vulnerable to changes in the ecosystem. Managing ecosystem services in a manner that ensures present and future well-being is essential. This involves understanding how ecosystem services change under different land-use scenarios and how these changes impact on human well-being.

Often, attempting to maximize the outputs of provisioning services like crop and livestock production can cause a decrease in regulatory services such as soil fertility and prevention of soil erosion. For example, rangeland degradation in Mongolia, Kazakhstan, Kyrgyzstan, and Tajikistan, due to unsustainable human use is considered to be a serious issue (Harris 2010). Rangeland degradation on the Qinghai-Tibet Plateau in China is thought to have caused an increase in dust storms, increased soil erosion, reduced C and N storage capacity of the soil, desertification, and decline in soil fertility (Harris 2010). Soil organic carbon decreased by 25% over 15 years of heavy grazing in a desert steppe ecosystem in northern China (Fu ***et al.*** 2004). Other land-use practices such as mining and tourism have impacted ecosystem service provision. Mining in Mongolia and Kyrgyzstan has caused soil pollution, surface and ground water pollution, decreased water availability, and increased soil erosion and run-off (Upton 2012). These threats and unsustainable use of the ecosystem to maximize short-term gains impact the long-term ability of the ecosystem to provide ecosystem services essential for human well-being.

Well-functioning ecosystems are essential to sustain the supplies of resources critical to health, livelihoods and production, such as water and food. It is important to understand the trade-offs that land-use practices can have on ecosystem services and the users of ecosystem services that it is going to impact. Further, biodiversity, ecosystem processes and functions, are essential for the provision of ecosystem services.

Adopting practices that safeguard biodiversity are essential for sustainable management of ecosystem services. For example, agricultural systems that promote diversity and maintain important ecological flows are more resistant to perturbations and threats to the system (Frison ***et al.*** 2011). Involving local communities and harnessing traditional knowledge systems can be key to sustainable management (Foggin 2012).

Market-based mechanisms can also be used to incentivize better management practices. They rely on economic and market-based principles for effective conservation outcomes. Some examples are given below:

1) Payment for Ecosystem Services (PES): This is a voluntary transaction where a well-defined ecosystem service is bought by an ecosystem service buyer from an ecosystem service provider if the ecosystem service provider secures ecosystem service provision (Wunder and Wertz-Kanounnikoff 2009). PES schemes are effective when specific management practices can increase or protect the supply of a particular service, when there is a clear demand for the service, and when the buyers and sellers can be clearly identified. The Wessex water quality scheme is an example of a PES scheme. Here, Wessex water, a regional water and sewage treatment buisness, invests in catchment management for the benefit of improved raw water quality (Howard and Sherrington 2011). Payments are made to farmers to implement improvements to farming operations which can contribute to improved water quality by reducing nitrates, phosphates, agrochemicals and sediment in surface run-off.

2) Certification schemes: certification schemes assure that products are generated through sustainabaly managed systems. These products are then sold at a higher premium to the consumer. The producers also make higher margins. For example, biodiversity-friendly schemes for agricultural produce certify that agricultural products are grown in systems that don’t employ practices that are harmful for wildlife. In some cases, there are proactive steps taken to conserve biodiversity on these farms. The Rainforest Alliance, for example, is a certification scheme for coffee farms that grow coffee under a diverse shade canopy and promote biodiversity-friendly practices (Giovanucci and Ponte 2005).

3) Biodiversity offsets: These tools seek to balance conservation and development. They are based on the premise that development projects have to compensate for their potential environmental impact after taking all the steps to reduce and minimize impact on-site (McKenney 2010). Biodiversity offsets should have measurable conservation outcomes that have no net loss and preferably have a net positive effect on biodiversity. In the United States, under the Wetlends Mitigation Action Plan (2002), impacts that damage wetlands must be mitigated either by relacing or enhancing habitats elsewhere (Zedler 1996). In Europe, under EU Natura 2000, biodiversity offsets aim to create new habitats by establishing a network of Natura 2000 conservation sites across Europe (McKenney and Kiesecher 2010).

While market based mechanisms for biodiversity conservation have been gaining popularity over the last few years, they have also been criticized for commodifying nature (McCauley 2006).

Climate change is an overarching issue that impacts the provisioning of ecosystem services. Mountain systems and communities are particularly vulnerable to the impacts of climate change. The Tibetan plateau, along with the polar regions, has warmed more than the rest of the globe (Li ***et al.*** 2012). The Intergovernmental Panel on Climate Change (IPCC 2007) describes vulnerability to climate change as the 1) exposure to hazards such as flooding; 2) sensitivity to those hazards, such as when communities rely on agriculture and pastoralism for their primary livelihood; and 3) the capacity to adapt to the hazards such as when farmers have the money, skill, or access to growing drought-resistant crops. Adaption measures seek to reduce vulnerability by recognizing the hazards people can be potentially exposed to, lowering their sensitivity, and building adaptive capacity. This could also involve people capatilizing on the benefits such as growing crops in previously unsuitable areas.

In snow leopard landscapes, the main ecosystem services used for livelihood are agricultural services, pasture-related services, and water services. Climate change adaptation will need to address the threats to each of these services. For example, water scarcity is one of the main anticipated problems that climate change will bring to these systems (Vé ré smarty ***et al.*** 2000). For instance, artificial glaciers and ice stupas developed in Ladakh help local people adapt to shrinking glaciers and water shortages caused by global warming (Norphel 2012, Clouse 2016). Similar efforts are required for other services as well.

In our work, we have recorded unexpectedly high economic values of ecosystem services that local communities use in snow leopard landscapes. This dependence on ecosystem services makes Asia's mountain people highly vulnerable to the degradation of these ecosystems. Proper management of Asia's snow leopard landscapes, addressing the present and future threats to ecosystem services, is essential for the continued provisioning of ecosystem services and human well-being.

VII
REFERENCES

Anonymous (2011) Management plan for the Upper Spiti landscape including the Kibber Wildlife Sanctuary. Wildlife Wing, Himachal Pradesh Forest Department & Nature Conservation Foundation, Mysore.

Adekola, O., Mitchell, G., and Grainger, A. (2015) Inequality and ecosystem services: the value and social distribution of Niger Delta wetland services. Ecosystem Services, 12, p.42-54.

Bateman, I., Mace, G., Fezzi, C., Atkinson, G., and Turner, K. (2011) Economic analysis for ecosystem service assessments. Environmental and Resource Economics, 48(2), p.177-218.

Bateman, I., Harwood, A., Mace, G., Watson, R., Abson, D., Andrews, B., Binner, A., Crowe, A., Day, B., Dugdale, S., and Fezzi, C. (2013) Bringing ecosystem services into economic decision-making: land use in the United Kingdom. Science, 341(6141), p.45-50

Berger, J., Buuveibaatar, B., and Mishra, C. (2013) Globalization of the cashmere market and the decline of large mammals in Central Asia. Conservation Biology, 27(4), p.679-689.

Brantingham, P., X. Gao, J. Olsen, H. Ma, D. Rhode, H. Zhang, and Madsen, D. (2007) A short chronology for the peopling of the Tibetan Plateau. In Madsen, D., Fahu, C. and Xing, G., Late Quaternary Climate Change and Human Adaptation in Arid China, Elsevier, Amsterdam, Netherlands.

Brown, T. (1984)The concept of value in resource allocation. Land economics, 60(3), p.231-246.

Butler, C. and Oluoch-Kosura, W. (2006) Linking future ecosystem services and future human well-being. Ecology and Society, 11(1).

Butola, J., Malik, A., and Baba, J. (2012) Livelihood diversification in cold arid desert of Indian Himalaya: urgent need of transforming traditional agroforestry system with emphasis on adoption of herbal farming. International Journal of Medicinal and Aromatic Plants, 2(3), p.544-548.

Cardinale, B., Duffy, J., Gonzalez, A., Hooper, D., Perrings, C., Venail, P., Narwani, A., Mace, G., Tilman, D., Wardle, D., and Kinzig, A. (2012) Biodiversity loss and its impact on humanity. Nature, 486(7401), p.59.

Chan, K., Satterfield, T., and Goldstein, J. (2012) Rethinking ecosystem services to better address and navigate cultural values. Ecological economics, 74, p.8-18.

Clouse, C. (2016) Design for Autonomy: Water Resources in Ladakh. In Clouse, C., Economic Modeling, Analysis, and Policy for Sustainability. IGI Global, p. 250-265

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J., and Raskin, R.G. (1997) The value of the world's ecosystem services and natural capital. Nature, 387(6630), p.253-260.

Cordova, F.J., Wallace, J.D. and Pieper, R.D., (1978). Forage intake by grazing livestock: a review. Journal of range management, pp.430-438.

Cumming, G., Buerkert, A., Hoffmann, E., Schlecht, E., von Cramon-Taubadel, S., and Tscharntke, T. (2014) Implications of agricultural transitions and urbanization for ecosystem services. Nature, 515(7525), p.50.

Daily, G. (2003) What are ecosystem services? Global environmental challenges for the twenty-first century: Resources, consumption and sustainable solutions, p.227-231.

Daily, G., Polasky, S., Goldstein, J., Kareiva, P., Mooney, H., Pejchar, L., Ricketts, T., Salzman, J., and Shallenberger, R. (2009) Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment, 7(1), p.21-28.

Dé az, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Bé ldi, A., and Bartuska, A. (2015) The IPBES Conceptual Framework—connecting nature and people. Current Opinion in Environmental Sustainability, 14, p.1-16.

Dinar, A. and Subramanian, A. (1997) Water pricing experiences: An international perspective. The World Bank, USA

Dong, S., Wen, L., Liu, S., Zhang, X., Lassoie, J., Yi, S., Li, X., Li, J., and Li, Y. (2011) Vulnerability of worldwide pastoralism to global changes and interdisciplinary strategies for sustainable pastoralism. Ecology and Society, 16(2).

Dong, S., Wen, L., Li, Y., Wang, X., Zhu, L., and Li, X. (2012) Soil-quality effects of grassland degradation and restoration on the Qinghai-Tibetan Plateau. Soil Science Society of America Journal, 76(6), p.2256-2264.

Downing, T.E. (2002) Avoiding new poverty: mining-induced displacement and resettlement (Vol. 52). International Institute for Environment and Development, London, UK.

Ehlers, E. and Kreutzmann, H. (2000) High mountain pastoralism in Northern Pakistan (No. 132). Franz Steiner Verlag, Germany.

Farrington, J. (2005) The impact of mining activities on Mongolia's protected areas: a status report with policy recommendations. Integrated Environmental Assessment and Management, 1(3), p.283-289.

Foggin, J. (2008) Depopulating the Tibetan grasslands: national policies and perspectives for the future of Tibetan herders in Qinghai Province, China. Mountain Research and Development, 28, 26–31

Forrest, J., Wikramanayake, E., Shrestha, R., Areendran, G., Gyeltshen, K., Maheshwari, A., Mazumdar, S., Naidoo, R., Thapa, G., and Thapa, K. (2012) Conservation and climate change: Assessing the vulnerability of snow leopard habitat to treeline shift in the Himalaya. Biological Conservation, 150(1), p.129-135.

Frison, E., Cherfas, J., and Hodgkin, T. (2011) Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. Sustainability, 3(1), p.238-253.

Foggin, M. (2012) Pastoralists and wildlife conservation in western China: collaborative management within protected areas on the Tibetan Plateau. Pastoralism: Research, Policy and Practice, 2(1), p.17.

Fu, H., Chen, Y., Wang, Y., and Wan, C. (2004) Organic carbon content in major grassland types in Alex, Inner Mongolia. Acta Ecologica Sinica, 24, 469–476.

Gamfeldt, L., Sné ll, T., Bagchi, R., Jonsson, M., Gustafsson, L., Kjellander, P., Ruiz-Jaen, M., Fré berg, M., Stendahl, J., Philipson, C., and Mikusié ski, G. (2013) Higher levels of multiple ecosystem services are found in forests with more tree species. Nature Communications, 4, p.1340.

Giovannucci, D. and Ponte, S. (2005) Standards as a new form of social contract? Sustainability initiatives in the coffee industry. Food policy, 30(3), p.284-301.

Gé mez-Baggethun, E., De Groot, R., Lomas, P., and Montes, C. (2010) The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. Ecological economics, 69(6), pp.1209-1218.

Government of Leh (2015) Leh District profile. Accessed at : http://leh.gov.in/pages/leh.pdf

Guedes, J., Lu, H., Li, Y., Spengler, R., Wu, X., and Aldenderfer, M (2014) Moving agriculture onto the Tibetan plateau: the archaeobotanical evidence. Archaeological and Anthropological Sciences, 6(3), p.255-269.

Haines-Young, R. and Potschin, M. (2010) The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis, pp.110-139.

Haines-Young, R. and Potschin, M. (2012) Common international classification of ecosystem services (CICES, Version 4.1). European Environment Agency, p. 33.

Harris, R. (2010) Rangeland degradation on the Qinghai-Tibetan plateau: a review of the evidence of its magnitude and causes. Journal of Arid Environments, 74(1), pp.1-12.

Howard, B. and Sherrington, C. (2011) Introduction to Payments for Ecosystem Services. The Katoomba Group, Uganda

Intergovernmental Panel on Climate Change (IPCC) (2007) Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Jones, J., Andriamarovololona, M., Hockley, N., Gibbons, J., and Milneré Gulland, E. (2008) Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. Journal of Applied Ecology, 45(4), p.1205-1212.

Jumabay-Uulu, K., Wegge, P., Mishra, C., and Sharma, K. (2014) Large carnivores and low diversity of optimal prey: a comparison of the diets of snow leopards Panthera uncia and wolves Canis lupus in Sarychat-Ertash Reserve in Kyrgyzstan. Oryx, 48(4), p.529-535.

Kumar, P. and Martinez-Alier, J. (2011) The economics of ecosystem services and biodiversity: An international assessment. Economic and Political Weekly, p.76-80.

Lal,R., (2004) Carbon sequesteration in soils of Central Asia. Land degradation and development, 15 (6), pp. 563-572.

La Notte, A., D'Amato, D., Mé kinen, H., Paracchini, M.L., Liquete, C., Egoh, B., Geneletti, D., and Crossman, N.D. (2017) Ecosystem services classification: A systems ecology perspective of the cascade framework. Ecological Indicators, 74, p.392-402.

Li, X., Jin, R., Pan, X., Zhang, T., and Guo, J. (2012) Changes in the near-surface soil freeze–thaw cycle on the Qinghai-Tibetan Plateau. International Journal of Applied Earth Observation and Geoinformation, 17, p.33-42.

Li, J., and Lu, Z. (2014) Snow leopard poaching and trade in China 2000–2013. Biological Conservation, 176, p.207-211.

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

Lovari, S., and Mishra, C. (2016) Living on the Edge: Depletion of wild prey and survival of the snow leopard In McCarthy, T., Mallon, D., and Nyhus, P., Snow Leopards: Biodiversity of the world: Conservation from genes to landscapes. Elsevier, New York, p.23-42.

Mace, G., Norris, K., and Fitter, A. (2012) Biodiversity and ecosystem services: a multilayered relationship. Trends in ecology & evolution, 27(1), p.19-26.

Maris, V. and Bé chet, A. (2010) From adaptive management to adjustive management: a pragmatic account of biodiversity values. Conservation biology, 24(4), p.966-973.

Marté n-Lé pez, B., Iniesta-Arandia, I., Garcé a-Llorente, M., Palomo, I., Casado-Arzuaga, I., Del Amo, D.G., Gé mez-Baggethun, E., Oteros-Rozas, E., Palacios-Agundez, I., Willaarts, B., and Gonzé lez, J. (2012) Uncovering ecosystem service bundles through social preferences. PLoS ONE, 7(6), p.e38970.

McCarthy, T., Mallon, D., Sanderson, E.W., Zahler, P. and Fisher, K. (2016) What is a Snow Leopard? Biogeography and status overview. In In McCarthy, T., Mallon, D., and Nyhus, P., Snow Leopards: Biodiversity of the world: Conservation from genes to landscapes. Elsevier, New York, p.23-42.

McCauley, D.J. (2006) Selling out on nature. Nature, 443(7107), p.27-28.

McKenney, B. and Kiesecker, J. (2010) Policy development for biodiversity offsets: a review of offset frameworks. Environmental management, 45(1), p.165-176.

Millennium ecosystem assessment (MA) (2005) Ecosystems and human wellbeing: a framework for

assessment. Island Press, Washington, DC.
Mishra, C., Allen, P., McCarthy, T., Madhusudan, M., Bayarjargal, A. and Prins, H. (2003a) The role of incentive programs in conserving the snow leopard. Conservation Biology, 17(6), p.1512-1520.
Mishra, C., Prins, H., & Van Wieren, S. (2003b) Diversity, risk mediation, and change in a Trans-Himalayan agropastoral system. Human Ecology, 31(4), p.595-609.
Mishra, C., Redpath, S., and Suryawanishi, K. (2016) Livestock predation by Snow Leopards: Conflicts and the search for solutions. In McCarthy, T., Mallon, D. and Nyhus, P. Snow Leopards. Biodiversity of the world: conservation from genes to landscapes. Elsevier, New York, p.59-68.
Mishra, C., Young, J., Fiechter, M., Rutherford, B., and Redpath, S. (2017) Building partnerships with communities for biodiversity conservation: lessons from Asian mountains. Journal of Applied Ecology.
Murali, R., Mishra, C., and Redpath, S. (2017) The value of ecosystem services in the High Altitude Spiti Valley, Indian Trans-Himalaya. Ecosystem services (in press).
Norphel, C. (2012) Artificial glacier: A high altitude cold desert water conservation technique. In Defense of Liberty Conference, New Delhi, India.
Norton, B.G. and Noonan, D. (2007) Ecology and valuation: big changes needed. Ecological economics, 63(4), p.664-675.
Nowell, K. and Jackson, P. (1996) Wild cats: status survey and conservation action plan (Vol. 382). Gland, IUCN.
Pandit, M. and Grumbine, R. (2012) Potential effects of ongoing and proposed hydropower development on terrestrial biological diversity in the Indian Himalaya. Conservation Biology, 26(6), p.1061-1071.
Raymond, C., Singh, G., Benessaiah, K., Bernhardt, J., Levine, J., Nelson, H., Turner, N., Norton, B., Tam, J., and Chan, K. (2013) Ecosystem services and beyond: Using multiple metaphors to understand human–environment relationships. BioScience, 63(7), p.536-546.
Redford, K. and Adams, W. (2009) Payment for ecosystem services and the challenge of saving nature. Conservation Biology, 23(4), p.785-787.
Sen, A. (1999) Development as Freedom. Random House inc., New York, USA
Snow Leopard Working Secretariat (2013) Global Snow Leopard and Ecosystem Protection Program. Bishkek, Kyrgyz Republic.
Snow Leopard Network (2014) Snow leopard survival strategy. Seattle, Washington, USA.
Sunquist, M. and Sunquist, F. (2017) Wild cats of the world. University of Chicago press, IL, USA. p. 377.
Suich, H., Howe, C., and Mace, G. (2015) Ecosystem services and poverty alleviation: a review of the empirical links. Ecosystem Services, 12, p.137-147.
Suzuki, Y. (2013) Conflict between mining development and nomadism in Mongolia. In Suzuki, Y.,The Mongolian ecosystem network. Springer Japan, p. 269-294
Tumurjav, M. (2015) Husbandry techniques practiced by Mongolian nomadic people. Mongolia Today: Science, Culture, Environment and Development, p.86.
Turnhout, E., Waterton, C., Neves, K. and Buizer, M. (2013) Rethinking biodiversity: from goods and services to “living with”. Conservation Letters, 6(3), pp.154-161.
Upton, C., 2012. Mining, resistance and pastoral livelihoods in contemporary Mongolia. Accessed at https://lra.le.ac.uk/bitstream/2381/28072/6/Upton%20Mining%20Resistance%20and%20Pastoral%20Livelihoods.pdf
Vira, B. and Adams, W. (2009) Ecosystem services and conservation strategy: beware the silver bullet. Conservation Letters, 2(4), p.158-162.
Vé ré smarty C., Green P., Salisbury J., and Lammers R. (2000) Global water resources: vulnerability from

climate change and population growth. Science, 289(5477), p.284-288.
Ward, D., (2015) Water requirements of livestock. Ministry of agriculture, food, and rural affairs, Governmnet of Canada. Accessed: http://www.omafra.gov.on.ca/english/engineer/facts/07-023.htm
Wallace, K. (2007) Classification of ecosystem services: problems and solutions. Biological Conservation, 139, 235–246.
Wertime, M., Ostrom, E., Gibson, C., and Lehoucq, F. (2007) International Forestry Resources and Institutions (IFRI) research program: Field manual, version 13. Centre for the Study of Institutions, Population, and Environmental Change, Indiana University, IN, USA.
Wunder, S. and Wertz-Kanounnikoff, S. (2009) Payments for ecosystem services: a new way of conserving biodiversity in forests. Journal of Sustainable Forestry, 28(3-5), p.576-596.
Zedler, J. (1996) Ecological issues in wetland mitigation: an introduction to the forum. Ecological Applications, 6(1), p.33-37.
Zhang, W., Ricketts, T., Kremen, C., Carney, K., and Swinton, S. (2007) Ecosystem services and dis-services to agriculture. Ecological economics, 64(2), p.253-260.

Snow leopards and people have shared Asia's mountain landscapes for millennia. Pastoralism is the predominant land use in Asia's high mountains, and across the range, agro-pastoral and pastoral communities inhabit and use snow leopard landscapes. They rely on ecosystem services – the benefits that humans derive from nature – which in turn depend on well functioning ecosystems.

The threats that the snow leopards face to their survival, such as habitat degradation due to increasing human populations, mining and large-scale infrastructure projects, also impact the well-being of people living in these landscapes. However, till date, there have been no studies that have attempted to quantify peoples' dependence on ecosystem services in snow leopard landscapes, or understand the impacts that alternate land-use decisions such as mining or infrastructure can have on the ecosystem services and on the local people who are dependent on them.

In this report, we evaluate the economic value of provisioning ecosystem services – the material goods from ecosystems – used by local people in five sites from four GSLEP landscapes: Spiti Valley and Changtang in India's Hemis-Spiti Landscape, the Gurez Valley in the Himalayan Landscape of Pakistan, the Tost Nature Reserve in the South Gobi Landscape of Mongolia, and the Sarychat region in the Central Tien Shan Landscape of Kyrgyzstan.