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Diverse perceptions of ecosystem (dis)services in a Himalayan protected area

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A R T I C L E I N F O

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A B S T R A C T

Protected areas are essential for balancing biodiversity conservation with the delivery of ecosystem services. However, despite extensive research on the economic valuation of these services, understanding local people's perceptions, particularly of ecosystem services and disservices, remains limited. Therefore, we assessed local perceptions and their socio-demographic determinants in Langtang National Park, a protected area in Nepal's Himalayan region. Ecosystem services and disservices were identified through a stakeholder consultation workshop. We conducted semi-structured interviews with 105 respondents. Both quantitative and qualitative analyses combined Fisher's exact test with Monte Carlo simulation (10,000 replicates), Cramer's V, and content analysis. The most highly regarded ecosystem services include drinking water (96 % of respondents), species and habitat conservation (92 %), air quality maintenance (91 %), protecting the environment for future generations (89 %), and water quality maintenance (89 %). The common ecosystem disservices include crop raiding by wildlife (93 %), allergies (58 %), and barriers to development and construction (48 %). Education and occupation are significantly associated with perceptions of ecosystem services, including carbon sequestration, air regulation, tourism, and research. Although ecosystem services are perceived to operate from local to global scales, disservices are mainly experienced at the local level. This emphasizes developing localized solutions in both national and international biodiversity conservation policies and practices, including indicators for ecosystem disservices.

1. Introduction

The global initiative taken by the Kunming-Montreal Global Biodiversity Framework (GBF), which aims to ensure that at least 30 % of terrestrial, inland water, and coastal/marine areas by 2030 as protected areas (Convention on Biological Diversity, 2022), represents a significant step toward biodiversity conservation. As of 2021, 15.3 % of the world's land area is designated terrestrial protected areas (World Bank, 2024a), while 11.9 % of the world's territorial waters are marine protected areas (World Bank, 2024b). The International Union for Conservation of Nature (IUCN) defines a protected area as a demarcated geographic space legally or effectively managed to ensure the long-term

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conservation of nature, along with its ecosystem services and cultural importance (Neugarten et al., 2018). These protected areas hold ecological significance and encompass cultural and socio-economic values (Zeng et al., 2022), addressing dual objectives of biodiversity preservation and ecosystem services (Xu et al., 2017).

The ecosystem services approach is founded on the principle that ecosystems provide a wide range of benefits to humans and that nature contributes directly to human well-being and prosperity (Boćkowski et al., 2024; Pu et al., 2023). This approach is increasingly recognized as a means of addressing biodiversity loss and habitat degradation. By elucidating the complex interrelationships between ecosystems and humans, it facilitates the integration of this dynamic into effective biodiversity conservation strategies (García-Llorente et al., 2018). The incorporation of the ecosystem services approach into international biodiversity conservation policies and programs has become increasingly evident (Karimi et al., 2020; Subedi et al., 2025; Zhang et al., 2020). However, critics argue that the ecosystem services approach may lead to the commodification of nature, exacerbate economic inequalities, or undermine the intrinsic value of nature and biodiversity (Hummel et al., 2019).

Frequently, the ecosystem services approach neglects ecosystems' potential negative impacts on human well-being (Lyytimäki et al., 2008; Vaz et al., 2017; von Döhren and Haase, 2015). These negative effects, known as ecosystem disservices, refer to ecosystem functions, processes, and attributes with real or perceived negative consequences for human well-being (Shackleton et al., 2016). Disservices may arise from the natural functioning of ecosystems or emerge as unintended consequences of human interventions and ecosystem management (Lyytimäki, 2015). These include, for example, indirect economic costs associated with forest management (Escobedo et al., 2011; Pataki et al., 2011) and restrictions on resource use imposed to protect threatened species (Lyytimäki et al., 2008; Lyytimäki and Sipilä, 2009). Thus, ecosystem services cannot be examined without ecosystem disservices as they represent a continuum (Shackleton et al., 2016). There are three key reasons to consider ecosystem disservices with the same rigor as ecosystem services to capture diverse perspectives and better understand human interactions with ecosystems. First, excluding ecosystem disservices can lead to controversies, especially among those negatively impacted by ecosystems (Lyytimäki, 2014). Second, an integrated framework enhances the incorporation of diverse stakeholder perspectives, facilitating more inclusive decision-making processes (Blanco et al., 2019). Third, ecosystem disservices significantly influence how ecosystems are experienced, valued, used, and perceived (Lyytimäki et al., 2008).

Despite the growing body of research on ecosystem services, most studies in mountainous regions are concentrated in the Northern Hemisphere, particularly in Europe and parts of Asia, such as China (Mengist et al., 2020), leaving regions like Nepal underrepresented and limiting understanding of local perspectives on ecosystem services. While substantial attention has been given to economic valuation, there is a notable gap in research on individuals' subjective perceptions of a broader spectrum of ecosystem services (Karimi et al., 2020; Larson et al., 2019; Zhang et al., 2020). Three key justifications underscore the need for further research in this area. First, such studies can deepen our understanding of the relationship between humans and nature, enhancing the planning and management of protected areas (Pu et al., 2023). Second, they can bridge qualitative and quantitative evaluation methods, providing insights into how ecosystem services contribute to human well-being (Elwell et al., 2018; Li et al., 2025). Third, empirical research on public perceptions of ecosystem services can guide conservation strategies and inform governance across various scales, from local initiatives to national and international policy frameworks (Ke et al., 2024).

In Nepal, although research on ecosystem services has been conducted within protected areas, it typically focuses on the economic valuation of provisioning and cultural services. Notable examples include the economic valuation of ecosystem services in the Koshi Tappu Wildlife Reserve (Sharma et al., 2015) and Shivapuri-Nagarjun National Park (Peh et al., 2016), as well as studies on visitors' willingness to pay entrance fees in Chitwan National Park, Langtang National Park, and the Annapurna Conservation Area (Pandit et al., 2015; Thapa et al., 2024; Baral et al., 2008). Conversely, the negative impact of protected areas has been confined mainly to human-wildlife conflict, including the prevalence, magnitude, and mitigation strategies (KC et al., 2023; Ferdin et al., 2024). This indicates a major research gap in exploring the local people's perceptions, as studies often focus either on ecosystem services or disservices but rarely both. Bridging this gap is vital for informing governance mechanisms that support national conservation goals and global agendas, such as the GBF and the Sustainable Development Goals (SDGs).

Therefore, our study addresses this gap through two research questions: 1) How do local people perceive ecosystem services and disservices, and what underlying reasons shape these perceptions? 2) Are socio-demographic characteristics significantly associated with local perceptions of ecosystem services and disservices? To answer these questions, we conducted semi-structured interviews with local people, primarily residing in the buffer zone of Langtang National Park, a protected area in the Himalayan region. A notable contribution of our study is its integrated examination of how local people simultaneously assess the benefits and costs of protected areas, an approach rarely undertaken in Nepal or the broader South Asian context. This integrated lens is essential for capturing the complexity of human-nature interactions, including how ecological processes, landscape dynamics, and conservation interventions shape people's behaviors, dependencies, and responses. Such comprehensions can inform the design of conservation policies and practices that are both ecologically robust and socially responsive, advancing sustainability and participatory governance. These insights are also relevant to supporting the broader goals of SDGs and global initiatives to designate 30 % of the world's land and territorial waters as protected areas by 2030.

2. Materials and methods

Our study followed a structured methodological framework (Fig. 1), providing a comprehensive overview of the research design. The framework includes the study area, sampling strategies, instrument validation, data collection methods, and data analysis, outlining the process from field observations to analytical procedures that used a mixed-methods approach combining qualitative and quantitative techniques.

2.1. Study area

Langtang National Park (hereafter called Langtang), established in 1976, covers a core area of 1710 sq. km, with an additional 418.30 sq. km declared a buffer zone in 1998 (Fig. 2). Situated within the coordinates 85°15′ E to 86° E and 28°–28° 20′ N (LNP, 2020a), Langtang stretches across the districts of Nuwakot (7 %), Rasuwa (57 %), and Sindhupalchowk (36 %) (LNP, 2024). Its highest point is Mount Langtang Lirung, standing at 7234 m.

The park encompasses a variety of bioclimatic zones, ranging from upper tropical (501–1000 m) to nival (above 5000 m), supporting a rich diversity of life (Bhuju et al., 2007). It is home to unique plants (1,043), mammals (46), birds (380), reptiles (4), fish (40), spiders (10), and butterfly species (58) (LNP, 2020a; LNP, 2023). Notable wildlife includes Red Panda (*Ailurus fulgens*), Snow Leopard (*Panthera uncia*), and Himalayan Musk Deer (*Moschus chrysogaster*). Land use within Langtang is equally diverse, with forest land covering 29.87 %, pasture land 4.94 %, shrub land 2.76 %, cropland 1.7 %, and the remaining 60.73 % consisting of barren land, ice, rock, and wetlands (LNP, 2024).

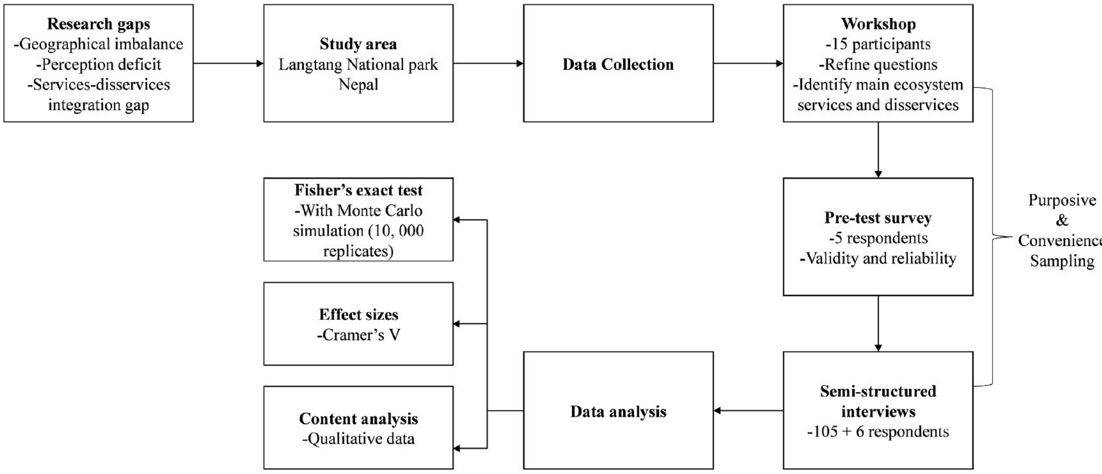

Fig. 1. Methodological framework. It shows an overview of the research gaps, study area, sampling methods, data collection, and data analysis.

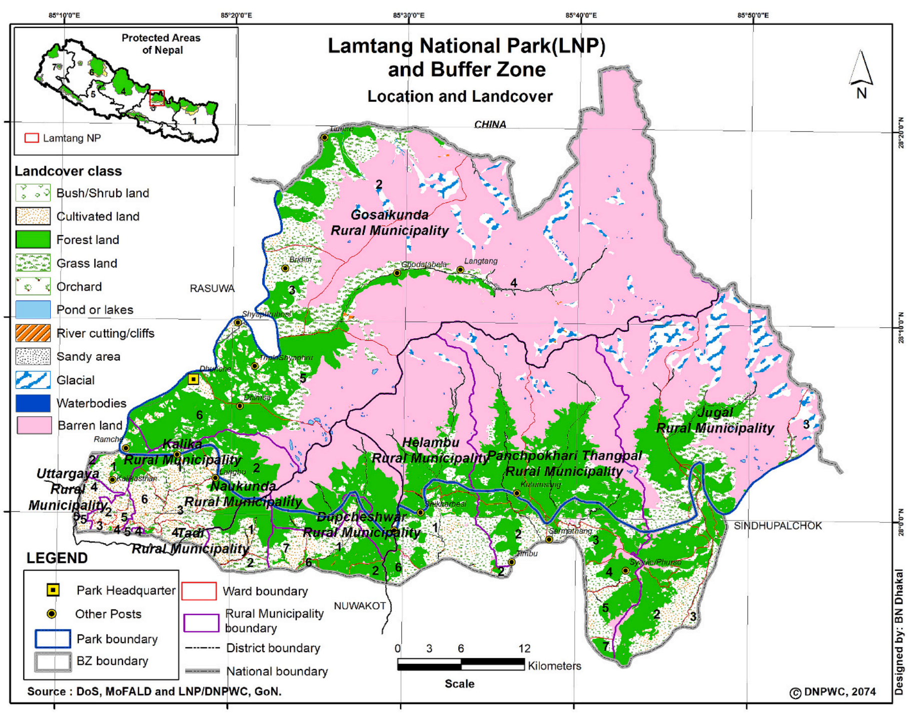

Fig. 2. Location map of Langtang National Park. "Langtang" and "Lamtang" are used interchangeably. Reproduced from "Lamtang National Park (LNP) and buffer zone: location and land cover", Government of Nepal, Ministry of Forests and Environment, Department of National Parks and Wildlife Conservation (DNPWC), 2018 (https://dnpwc.gov.np/media/others/Lamtang_location_landcover.jpg).

2.2. Interview questions setup

Initially, we designed interview questions to assess which ecosystem services are most important to local people and which ecosystem disservices are of greatest concern in Langtang (Text S1). The interview questions were divided into four sections. The first section comprised socio-economic information about the respondents, including age, gender, ethnicity, educational background, and income. The second section focused on respondents' knowledge of the national park. The third section included the local importance of ecosystem services and the reasons behind their choices. Similarly, the fourth section addressed the local perceptions of ecosystem disservices and the mechanisms behind them.

We used a rapid appraisal method to identify the ecosystem services and disservices, which informed the third and fourth sections of the interview questions. This method involved stakeholder consultations through a workshop (Peh et al., 2013) on March 26, 2024, in Dhunche, Rasuwa District. The workshop aimed to compile a comprehensive list of ecosystem services and disservices, which subsequently guided the refinement of the interview questions and provided insights into the local context of the national park. Fifteen purposively selected participants represented diverse perspectives, including members of the buffer zone user committee, conservation activists, entrepreneurs, farmers, hoteliers, journalists, local political leaders, members of non-governmental organizations, and representatives of mothers' groups. A list of 23 ecosystem services and six ecosystem disservices was compiled by combining the workshop results (Table 1).

A 5-point Likert scale was employed to assess the perceived importance of ecosystem services among local people, with response options: 1 (very unimportant), 2 (unimportant), 3 (neither unimportant nor

Table 1
Ecosystem services and disservices in Langtang National Park. The list was compiled through stakeholder consultations conducted during a workshop attended by 15 participants from diverse professional backgrounds.

Category	Services	Disservices
Provisioning Services	1) Timber, 2) firewood, 3) edible food, 4) litter, 5) herbs, 6) drinking water, 7) irrigation, 8) fishing and fish farming, 9) animal husbandry and grazing, 10) hydropower and, 11) stone, sand and gravel	1) Wildlife attacks on humans resulting in injuries and deaths 2) Wildlife attacks on livestock resulting in injuries and deaths 3) Crop raiding by wildlife
Regulating Services	1) Carbon sequestration, 2) water quality maintenance, 3) air quality maintenance, 4) pollination, 5) disease and pest control, and 6) flood, landslide and soil erosion control	4) Allergies such as dizziness, infection, skin irritation, sneezing and others 5) Barriers to development and construction 6) Legal complications and poor management
Supporting Services	1) Soil quality maintenance, and 2) species and habitat conservation	
Cultural Services	1) Tourism and recreation, 2) education and research, 3) conservation of cultural and religious sites, 4) protecting the environment for future generations	

important), 4 (important), and 5 (very important). The respondents were also asked to provide a rationale for their choices. A similar 5-point Likert scale was used to evaluate concerns related to ecosystem disservices, with response options: 1 (very low), 2 (low), 3 (neither low nor high), 4 (high), and 5 (very high).

We conducted a pretest to assess the clarity, relevance, and reliability of the interview and Likert-scale questions. Five respondents representing diverse local perspectives, including a farmer, an hotelier, a herder, a local political leader, and a buffer zone user committee member, were purposively selected for the pretest. The pretest was carried out in Gosainkunda Rural Municipality, Rasuwa District, on March 27 to 28, 2024, with each interview lasting 30–60 min. Insights and feedback from the pretest was used to refine the wording, sequencing, and contextual appropriateness of the questions, thereby enhancing their validity and reliability prior to the main data collection.

2.3. Sampling and data collection

Our study was conducted in the buffer zones of Langtang between April 3 and May 6, 2024, across three districts: Nuwakot, Rasuwa, and Sindhupalchowk (Table 2). We used a combination of convenience and purposive sampling methods to identify study respondents. We chose the "convenience sampling method" to select data collection sites within the districts, as it allows for identifying accessible cases based on factors such as proximity, ease of access, and participant willingness (Robinson, 2013). This approach was particularly suited to the study's geographic context, which included challenging mountainous terrain, limited access via trekking trails, earthen roads, and a scarcity of accommodations. Given these constraints, data collection was primarily conducted by walking along trekking trails and engaging with participants in human settlements encountered en route. We sometimes used motorbikes to navigate the mountainous earthen roads (where accessible).

Table 2
Overview of study sites. The study was conducted in three districts and nine rural municipalities surrounding Langtang National Park.

Districts	Rural municipalities	Specific study sites
Nuwakot	Dupcheshwor, Tadi, and Suryagadi	Ghyangfedi, Kadeni, Dandagaon, Kalche, and Lachyang
Rasuwa	Gosaikunda, Kalika, and Naukunda	Dhunche, Ramche Bazaar, Syapru Besi, Thulo Bharkhu, Bhridim, Sherpa Gaon, Langtang Valley, Kyanjin Gompa, Thulo Syapru, Brabal, Yarsa, and Arukharka
Sindhupalchowk	Helambu, Panchpokhari Thangpal, and Jugal	Melamchighyang, Tarkeghyang, Sermathang, Baruwa, Chimti, Sindhurche, and Kartike

Further, we chose the "purposive sampling method" to select respondents from the selected sites. This method allows for the deliberate selection of respondents based on the researchers' informed judgment to ensure the inclusion of information-rich cases that are diverse and contextually relevant (Staller, 2021). In total, 105 respondents were interviewed. The sample size was determined by geographical constraints associated with the mountainous terrain; the spatial distribution of respondents across all major settlements surrounding the study area; and the principle of data saturation, whereby interviews continued until no substantially new information emerged. The sample encompassed a wide range of socio-economic and professional backgrounds, including farmers, Langtang Buffer Zone User Committee members, hoteliers, national park employees, political leaders, teachers, local government representatives, social workers, herders, entrepreneurs, and Lamas. This composition provided diverse perspectives, enriching qualitative insights and supporting the analysis of potential associations between respondents' socio-demographic characteristics and their perceptions.

We collected data through face-to-face semi-structured interviews guided by a printed set of predetermined questions. In line with research ethics, informed consent was obtained from all respondents before conducting the interviews. The interviews ranged from 30 to 90 min. For literate respondents, Likert-scale questions were self-administered, allowing respondents to mark their responses independently. For those who were illiterate, the researchers marked the Likert-scale points on their behalf, following explicit consent.

All interviews were recorded through detailed note-taking directly on the printed question sheets. In addition to the primary sample, six supplementary interviews were conducted with industry representatives, three from the water industry and three from the cheese production centers, to explore their production and sales activities. A separate set of questions was prepared for these interviews (Text S2 and S3).

2.4. Data analysis

Our study employed both quantitative and qualitative analytical approaches, integrating Fisher's exact test and content analysis. Fisher's exact test was used to examine the significance of associations between socio-demographic variables and local perceptions of ecosystem services and disservices. To obtain accurate *p-values* for contingency tables with small expected cell counts, Monte Carlo simulations with 10,000 replicates were conducted, as recommended when standard asymptotic assumptions are not met (Kaiser, 2007; Mundform et al., 2011). Cramér's V was computed to quantify the strength of association between socio-demographic variables and local perceptions of ecosystem services and disservices. All statistical analyses were performed using R software (version 4.5.2).

The dependent variables comprised local perceptions of 23 ecosystem services and six ecosystem disservices (Table 1), which were measured on a five-point Likert scale but treated as categorical variables in this analysis. Likert scores were treated as categorical rather than ordinal because we used Fisher's exact test, which, as Bewick et al. (2003) explain, requires categorical data. The independent variables included key socio-demographic characteristics such as geographical location (Rasuwa, Nuwakot, and Sindhupalchowk districts), education (formal or no formal education), ethnicity (Tamang or other groups), and professional background (farmers, park governance actors, and service and governance actors), represented as categorical data. These variables were selected because they capture major spatial, cultural, and socio-economic variations among respondents. Gender, religion, and marital status were excluded from the analysis, as preliminary tests indicated no statistically significant associations with the dependent variables. Among the 105 respondents, the majority (52 %) were from Rasuwa District, followed by 31 % from Sindhupalchowk and 17 % from Nuwakot (Table S1). Regarding ethnicity, 64 % identified as Tamang, while the remaining 36 % represented other groups, including Brahmin/Chhetri, Ghale, Newar, and Sherpa. In terms of education, 61 % had received formal education, while 39 % had none. The professional distribution included farmers (33 %), park governance actors (29 %), and service and governance actors (38 %) (Table S1).

In parallel, a content analysis was conducted on qualitative data from semi-structured interviews. We analyzed data by transcribing the interviews and assigning codes to each respondent to ensure anonymity. Afterward, we organized and refined the collected data. The qualitative interview data were subjected to content analysis to uncover the underlying mechanisms for prioritizing the most important ecosystem services and identifying ecosystem disservices as key concerns. The content analysis involved systematically condensing interview transcripts into smaller units, iteratively reading and labeling them with relevant codes, grouping these codes into broader categories, and conducting thematic interpretation to extract meaningful insights (Sheydayi and Dadashpoor, 2023; Wessels et al., 2021).

3. Results

3.1. Local understanding of ecosystem (dis)services

Respondents mentioned ecosystem services by referring to benefits such as firewood, timber, water sources, tourism, biodiversity conservation, and carbon sequestration. When categorized according to the four ecosystem services categories, i.e., provisioning, regulating, cultural, and supporting, we found that 53.9 % were related to provisioning services, followed by 26.1 % to supporting services, 14.5 % to cultural services, and 5.5 % to regulating services (Fig. 3, Table S2). Timber and firewood, comprising 29 %, were the most frequently mentioned services, followed by biodiversity conservation (26 %) and tourism (12 %) (Table S2).

We observed that the respondents' understanding of ecosystem disservices is generally shaped by the processes or actions that negatively impact their daily lives. When analyzing the mention of ecosystem disservices, we found that 69.7 % of the content identified human-wildlife conflict as disservices, followed by 26.3 % for barriers to development and construction, and 3.9 % for legal complications and poor management (Fig. 3, Table S3). Among the human-wildlife conflicts, the most commonly recognized disservice was the loss and damage to crops caused by wildlife.

3.2. Local importance of ecosystem services

Respondents mainly considered ecosystem services as important or very important, with only a few services falling into the neutral (neither unimportant nor important) or unimportant or very unimportant categories (Fig. 4). These considerations are influenced by their cost-benefit perception, socio-economic conditions, geographical location, and park management practices.

3.2.1. Provisioning services

Most responses mentioned drinking water supply, animal husbandry and grazing, firewood, litter, edible food, hydropower, timber, stone, sand, and gravel as important or very important categories (Fig. 4). In contrast, herbs, irrigation, fishing, and fish farming were considered unimportant or very unimportant categories. Many responses had been recorded, mentioning timber, edible food, hydropower, stone, sand, and gravel as being neither important nor unimportant.

The drinking water supply was regarded as a very important ecosystem service provided by Langtang, as the water originates in the high Himalayas and flows through the park's dense forests. In Rasuwa District, respondents believed the source to be the sacred Gosainkunda Lake, a pilgrimage site for both Buddhist and Hindu devotees. This service extends beyond local needs, with Langtang contributing water to the Melamchi Drinking Water Supply Project that serves the Kathmandu Valley (LNP, 2020a). Three water industries in Rasuwa also market water sourced from the high Himalayas nationally and internationally. Hydropower was likewise recognized as an important service for its contributions to local economies and development through equity share distribution and corporate social responsibility initiatives (Text S4).

Respondents considered animal husbandry and grazing as important ecosystem services, as most people have relied on rangelands for livestock grazing for centuries in Langtang (LNP, 2020a). Additionally, the tradition of yak herding continues within the park, serving as a primary source of income for herder families. Cheese production centers utilize the milk produced by these herders (Text S5). The practice of yak herding also sustains a culture that supports the livelihoods of herders and the ecosystem through nutrient flow, natural vegetation restoration, and improved pasture quality (Rai et al., 2024).

Firewood was categorized as important or very important, as it is used for cooking, room heating in winter, preparing feasts during festivals and family functions, and making semi-liquid food for cattle from water, flour, and food waste. Similarly, timber is used for building houses and cowsheds. In *Hyolmo* (an indigenous people residing in the Helambu region of Nepal) culture and tradition, timber holds religious significance. It is used to construct *Chhyathi*, a wooden shelf for placing statues of Buddha, Guru Rinpoche, and related traditional items. It is also essential for making *Soolju*, a reading table used by Lamas to recite Buddhist texts.

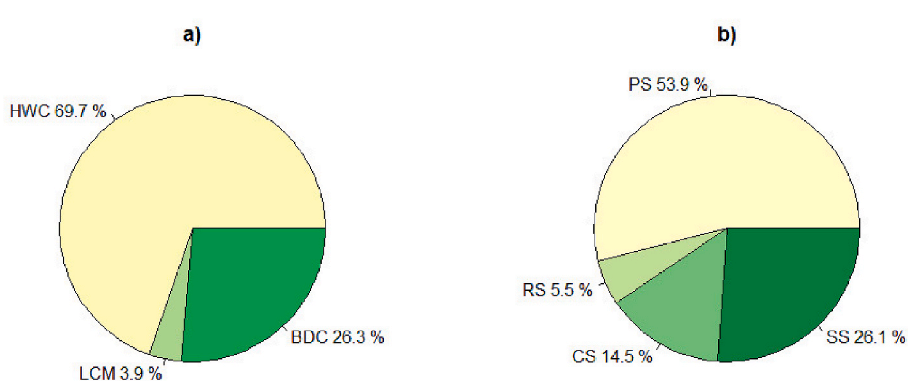

Fig. 3. Categorization of locally defined ecosystem services and disservices. a) Ecosystem disservices are grouped into human-wildlife conflict (HWC), barriers to development and construction (BDC), and legal complications and poor management (LCM). b) Ecosystem services are categorized into provisioning services (PS), regulating services (RS), supporting services (SS), and cultural services (CS). Percentages indicate the proportion of respondents citing each category.

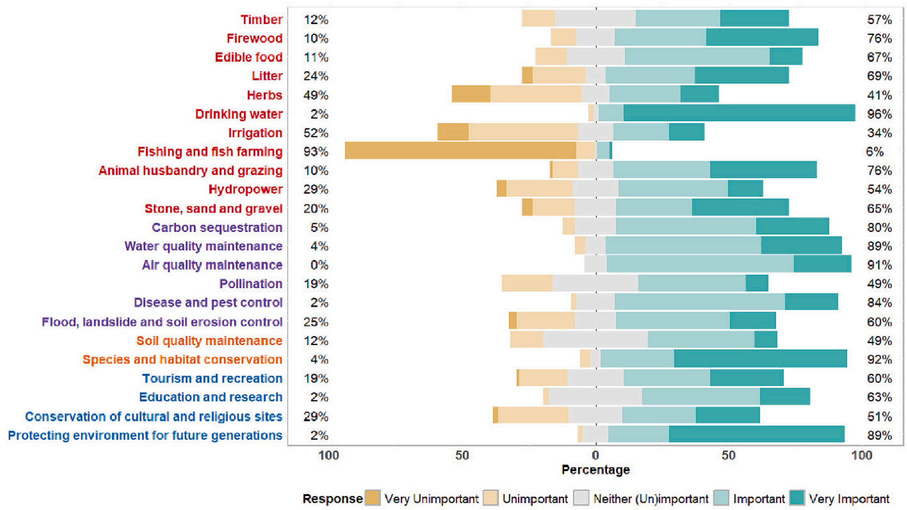

Fig. 4. Local perceptions of ecosystem services. Green and dark green indicate "important" and "very important," respectively; grey denotes "neither unimportant nor important"; and yellow and dark yellow indicate "unimportant" and "very unimportant," respectively. Y-axis labels are color-coded by ecosystem service type: red for provisioning, purple for regulating, orange for supporting, and blue for cultural services. Percentages on the left represent the combined "unimportant" and "very unimportant" responses, while those on the right represent the combined "important" and "very important" responses.

3.2.2. Regulating and supporting services

Most responses mentioned species and habitat conservation, air and water quality maintenance, disease and pest control, carbon sequestration, and flood, landslide, and soil erosion control as important or very important (Fig. 4). Soil quality maintenance and pollination were considered unimportant and neutral (neither unimportant nor important).

Respondent's perception illuminated the complex nature of ecosystem service interactions, highlighting synergies among different services. Many described how the provision of supporting services, particularly species and habitat conservation, led to simultaneous ecological benefits and locally experienced disservices. Species and habitat conservation was widely regarded as very important, primarily because it was associated with visible signs of ecological recovery, such as increased wildlife populations and expanded forest cover. Respondents inferred wildlife population growth based on heightened wildlife activity in their location, which is often described as crop raiding by wildlife. However, such reports of increased crop raiding likely reflect not only perceived increases in wildlife numbers but also a set of underlying ecological drivers. These include variations in the abundance and behavioral traits of specific wildlife species (Shrestha et al., 2025), seasonal declines in natural forage that drive wildlife toward croplands (Pant et al., 2023), and the expansion of monoculture forests that reduce diverse food resources within natural habitats (Koirala et al., 2021).

Strict park regulations limiting unsustainable forest harvesting, as perceived by respondents, have contributed to increased forest cover. This expansion provides multiple co-benefits, including carbon sequestration, improved air and water quality, and prevention of landslides and soil erosion. Several studies similarly underscore the multifunctional role of forest ecosystems in sustaining ecological and socio-environmental benefits (Jo et al., 2024; Peng et al., 2025). Structural attributes like tree height, canopy closure, and leaf area index synergistically regulate key functions, including carbon sequestration, air purification, temperature and humidity moderation, and microclimate regulation, highlighting forests' inherent capacity to optimize ecosystem functions (Lv et al., 2025).

While explaining the importance of species and habitat conservation, respondents highlighted its connection not only to regulating services but also to cultural services. For example, they noted that tourists primarily visit Langtang to experience nature, and any degradation of species or habitats would likely reduce tourist numbers, negatively impacting the tourism industry. Similarly, respondents identified mechanisms for species and habitat conservation, as well as opportunities for research and education.

3.2.3. Cultural services

Most responses categorized protecting the environment for future generations, education and research, tourism and recreation, and conservation of cultural and religious sites as important or very important (Fig. 4). Also, the percentage of responses indicating unimportance or neutrality is notably high for education and research, tourism and recreation, and conservation of historical, cultural, and religious sites. Respondents chose to protect the environment for future generations as very important ecosystem services because they believed that conservation efforts are driven by the desire to preserve nature for their descendants, ensuring they are not responsible for its degradation.

Tourism has become a major source of income for the region, providing employment opportunities for locals in sectors such as hotels, tour operations, travel guides, porter services, and more. It is also a main source of revenue for the national park. Consequently, respondents considered tourism and recreation as an important category. Langtang has seen a steady rise in tourists yearly, contributing significantly to the park's revenue through royalties. In the fiscal year 2013/14, the national park welcomed 17,050 tourists, generating approximately $425,781 in royalties (LNP, 2024). By 2023/24, the number of visitors had increased to 32,597, though royalties amounted to around $391,811 in 2023/24 (LNP, 2025).

Respondents viewed education and research as valuable ecosystem services. The park's importance in these areas stems from its representation of the Himalayan region, its biodiversity hotspots, easy accessibility, available accommodation, and the presence of indigenous and ethnic communities. In the fiscal year 2023/24, the national park granted permission for 16 research and educational activities involving national and international institutions (LNP, 2025). Moreover, respondents perceived that the park's conservation efforts for religious, historical, and cultural sites are primarily focused on the maintenance and repair of monasteries and temples. For instance, 65 monasteries, chortens, and temples were maintained and repaired between 2013 and 2017 (LNP, 2020a).

3.2.4. Variations in local perceptions

Fisher's exact test with Cramér's V revealed significant associations between socio-demographic variables and respondents' perceptions of ecosystem services. Geographical location (district), education, and professional background showed significant associations across multiple services, whereas ethnicity was associated with only a few (Table 3).

Perceptions of provisioning services (such as edible food, herbs, irrigation, hydropower, and materials like stone, sand, and gravel), regulating and supporting services (including air quality maintenance, pollination, disease and pest control, and species and habitat conservation), and cultural services (like tourism and recreation, education and research, and environmental protection for future generations) varied significantly across geographical locations. Additionally, respondents with formal education were more strongly associated with regulating services, particularly carbon sequestration, and with cultural services, notably education and research.

Significant associations were also evident across professional backgrounds. These included provisioning services such as litter management, animal husbandry and grazing, and hydropower; regulating and supporting services like carbon sequestration, air quality improvement, pollination, disease and pest control, as well as species and habitat conservation; and cultural services including tourism and recreation, education and research, the preservation of cultural and religious sites, and environmental protection for future generations. In contrast, ethnicity exhibited limited influence, with significant associations found only in perceptions of hydropower, soil quality maintenance, and species and habitat conservation.

3.3. Local perception of ecosystem disservices

Respondents identified ecosystem disservices, such as crop raiding and allergies, as the most common concerns, while incidents of wildlife attacks on humans and livestock were less frequent in Langtang (Fig. 5). Moderate-level concerns included barriers to development and construction, legal complications, and poor management. The perception of these disservices is shaped by several factors, including the respondents' professional backgrounds, cost-benefit considerations, the frequency of incidents, and the level of authority exercised by park officials.

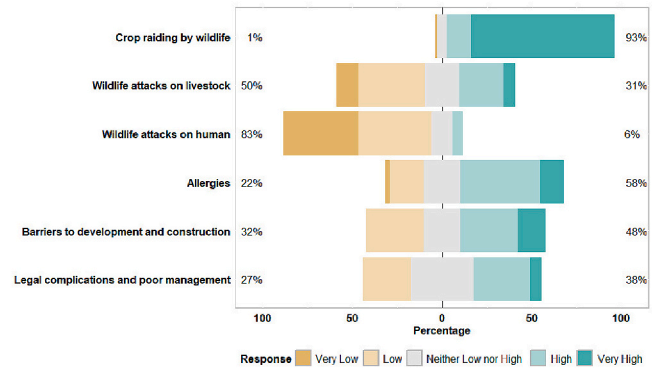

Fig. 5. Local perceptions of ecosystem disservices. Green and dark green indicate "high" and "very high", respectively; grey denotes "neither low nor high"; and yellow and dark yellow represent "low" and "very low", respectively. Percentages on the left show the combined "low" and "very low" responses, while those on the right show the combined "high" and "very high" responses.

3.3.1. Human-wildlife conflict

Human-wildlife conflict encompasses issues such as crop raiding and attacks on humans and livestock by wildlife. Respondents perceived crop raiding as more prevalent in Langtang than direct wildlife attacks on humans or livestock. This is also supported by data from the national park's annual reports over six fiscal years (Table 4), which reflect a similar trend. Main crops such as maize, wheat, potatoes, millet, rice, and green vegetables are frequently raided by wild boar, porcupines, Assamese monkeys, Hanuman langurs, and Himalayan black bears. Respondents identified wild boars and Assamese monkeys as the primary cause. They adopted three strategies to address this issue: building stone walls around croplands, patrolling the lands, and leaving them

Table 3

Associations between socio-demographic variables and local perceptions of ecosystem services, assessed using Fisher's exact test with Monte Carlo simulation (10,000 replicates). Effect sizes are reported as Cramér's V, with the strength of association interpreted as Negligible (N, <0.1), Weak (W, 0.1–0.2), Moderate (M, 0.2–0.4), Relatively Strong (RS, 0.4–0.6), and Strong (S, ≥0.6). Statistical significance levels are denoted as $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***), corresponding to 95 %, 99 %, and 99.9 % confidence levels, respectively.

Ecosystem service	Geographical location [p-value, Cramér's V(label)]	Education [p-value, Cramér's V(label)]	Ethnicity [p-value, Cramér's V(label)]	Professional background [p-value, Cramér's V(label)]
Timber	0.57, 0.15(W)	0.22, 0.20(M)	0.34, 0.18(W)	0.90, 0.10(W)
Firewood	0.65, 0.14 (W)	**0.02***, 0.30(M)	0.17, 0.21(M)	0.25, 0.20(M)
Edible food	**<0.001*****, 0.32 (M)	0.72, 0.10(W)	0.97, 0.05(N)	0.54, 0.15(W)
Litter	0.20, 0.23(M)	0.33, 0.21(M)	0.34, 0.21(M)	**0.03***, 0.26(M)
Herbs	**<0.001*****, 0.34(M)	0.51, 0.17(W)	0.11, 0.26(M)	0.25, 0.21(M)
Drinking water	0.36, 0.15(W)	0.11, 0.21(M)	0.56, 0.15(W)	0.42, 0.17(W)
Irrigation	**0.002****, 0.31(M)	**0.04***, 0.29(M)	0.64, 0.15(W)	0.26, 0.22(M)
Fishing and fish farming	0.46, 0.17(W)	**0.007****, 0.32(M)	0.69, 0.15(W)	0.52, 0.18(W)
Animal husbandry and grazing	0.55, 0.17(W)	**0.03***, 0.30(M)	0.97, 0.09(N)	**0.02***, 0.29(M)
Hydropower	**<0.001*****, 0.34(M)	0.19, 0.24(M)	**0.04***, 0.29(M)	**0.007****, 0.30(M)
Stone, sand, and gravel	**0.03***, 0.27(M)	0.88, 0.11(W)	0.68, 0.15(W)	0.11, 0.23(M)
Carbon sequestration	0.16, 0.19(W)	**<0.001*****, 0.49(RS)	0.28, 0.18(W)	**<0.001*****, 0.33(M)
Water quality maintenance	0.13, 0.18(W)	0.17, 0.21(M)	0.69, 0.10(W)	0.11, 0.21(M)
Air quality maintenance	**0.02***, 0.20(M)	**0.002****, 0.33(M)	1.00, 0.03(N)	**0.002****, 0.26(M)
Pollination	**<0.001*****, 0.32(M)	0.12, 0.23(M)	0.92, 0.06(N)	**0.02***, 0.27(M)
Disease and pest control	**0.03***, 0.22(M)	0.39, 0.18(W)	0.41, 0.17(W)	**0.02***, 0.25(M)
Flood, landslide, and soil erosion control	0.74, 0.16(W)	0.67, 0.14(W)	0.48, 0.18(W)	0.99, 0.08(N)
Soil quality maintenance	0.11, 0.20(M)	0.09, 0.25(M)	**0.04***, 0.28(M)	0.10, 0.22(M)
Species and habitat conservation	**0.02***, 0.23(M)	**0.002****, 0.37(M)	**0.002****, 0.34(M)	**0.04***, 0.23(M)
Tourism and recreation	**0.012***, 0.27(M)	**0.03***, 0.29(M)	0.43, 0.19(W)	**<0.001*****, 0.34(M)
Education and research	**0.02***, 0.23(M)	**<0.001*****, 0.48(RS)	0.07, 0.25(M)	**<0.001*****, 0.36(M)
Conservation of cultural and religious sites	0.78, 0.14(W)	**0.003****, 0.36(M)	0.55, 0.18(W)	**0.002****, 0.31(M)
Protecting the environment for future generations	**0.02***, 0.23(M)	**0.009****, 0.32(M)	0.56, 0.15(W)	**<0.001*****, 0.31(M)

Table 4
Reported cases of human–wildlife conflict and compensation distributed. Data were compiled from Langtang National Park annual reports covering six fiscal years: 1 (LNP, 2020b), 2 (LNP, 2021), 3 (LNP, 2022), 4 (LNP, 2023), 5 (LNP, 2024), and 6 (LNP, 2025).

Fiscal Year	Wildlife attacks on humans (No. of reported cases)	Wildlife attacks on livestock (No. of reported cases)	Crops raided by wildlife (No. of reported cases)	Amount of distributed compensation (US $)
2018/19[1]	07	08	25	3, 756
2019/20[2]	09	15	409	30, 034
2020/21[3]	02	17	356	15, 694
2021/22[4]	04	32	408	27, 222
2022/23[5]	06	67	261	14, 834
2023/24[6]	NA	34	356	5, 890

uncultivated. Most respondents preferred the third option—abandoning cultivation—due to the significant financial losses caused by the raids.

Additionally, Himalayan black bears and leopards are responsible for causing injuries and fatalities to both humans and livestock. Livestock species particularly affected include Himalayan cattle (chauri, yak, and their calves), goats, horses, pigs, dogs, and chickens. In a notable incident during the fiscal year 2021/22, a snow leopard killed 54 goats belonging to Sahara Agriculture and Livestock Firm in Amachhodingmo Rural Municipality, Rasuwa District (LNP, 2023).

3.3.2. Allergies

Respondents perceived that allergic reactions, particularly skin irritations like redness, itching, and swelling, are common. The most frequently reported cause is the larvae found in *Alnus nepalensis*, which trigger skin reactions like itching and redness. These allergies typically occur during the spring season, from March to May. When collecting forest products, respondents often experienced allergic symptoms when entering the forest. For example, they reported that plants such as *Schima wallichii* and *Semecarpus anacardium* cause skin irritations. The bark of *Schima wallichii* can act as a skin irritant (Lalhminghlui, 2018). Likewise, close contact with *Semecarpus anacardium* can lead to skin irritation or allergic contact dermatitis (Neema et al., 2023).

3.3.3. Barriers to development and construction, legal complications, and poor management

The respondents perceived barriers to development and construction as highly prevalent in their area. Major challenges included delays or restrictions in road construction and repair, electricity supply, telecommunications infrastructure, access to drinking water, and the maintenance of trekking trails—all reportedly hindered by national park regulations. Three key points of contention between local people and national park officials centered on the use of stone or rock for development projects, tree felling, and the initiation of projects without approved Environmental Impact Assessment reports. While park authorities argued that such projects violate regulations by proceeding without proper authorization, respondents contended that these resources are used for public purposes and benefit the wider community.

Two issues had made respondents consider the national park's laws complicated. First, they must obtain permits and pay fees to access natural resources that their communities have used for generations. Second, the process of receiving compensation for crop losses or injuries and fatalities to humans and livestock caused by wildlife is lengthy and expensive. Additionally, the national park management was criticized for inadequate tourism management and weak forest fire control.

3.3.4. Variations in the disservice perspective

Compared to ecosystem services, the associations between socio-demographic variables and respondents' perceptions of ecosystem disservices were relatively limited. Geographical location emerged as the most influential factor, with four of the six disservices showing significant associations across districts (Table 5). These included wildlife attacks on livestock, crop raiding, allergies, and barriers to development and construction. Education and professional background were also significantly associated with perceptions of certain wildlife-related disservices, particularly crop raiding and health issues such as allergies. In contrast, ethnicity was associated with governance-related disservices, as perceptions of legal complications and poor management varied significantly across ethnic groups.

4. Discussion

Our study investigated local people's perceptions of ecosystem (dis) services, the underlying reasons for these perceptions, and the associations between socio-demographic characteristics and local perceptions. Overall, most ecosystem services were perceived as highly important or important, consistent with findings by Thiemann et al. (2022) and Elwell et al. (2018). However, perceptions of several ecosystem (dis)services were significantly associated with location, education, and profession. Notably, our study introduces four key novelties that advance understanding of ecosystem (dis)services in protected area management and promote more inclusive and adaptive protected area governance.

First, our study reveals that regulating and supporting services were perceived as more important than cultural and provisioning services. This finding is consistent with previous research (Bai et al., 2024; Thapa et al., 2023; Thiemann et al., 2022), indicating that local people tend to prioritize regulating services. However, our results contrast with findings from the Hindu Kush Himalaya (Bhatt et al., 2024), Darjeeling-Sikkim Himalaya (Pradhan and Khaling, 2023) and Kashmir Himalaya (Islam et al., 2023) in India, the Western Himalayas of Pakistan (Saeed et al., 2022), and the central and eastern mountainous region of Bhutan (Wangchuk et al., 2021), where provisioning services were considered highly important. What sets our findings apart is that rural communities in Langtang placed greater emphasis on regulating and supporting services, in contrast to studies such as Bai et al. (2024), which found that urban areas favored regulating services and rural areas favored provisioning services.

This pattern in Langtang is likely driven by two primary factors. The first factor relates to residents' ability to articulate interactions among ecosystem services, synergies between supporting and regulating services, and between supporting and cultural services, aligning with the findings of Ke et al. (2024), Peh et al. (2016), and Zhang et al. (2020). Such understanding implies that biodiversity conservation can simultaneously generate ecological and socio-economic benefits, supporting both livelihoods and human well-being, and linking material and non-material benefits. The second factor relates to changing livelihood patterns and the ongoing energy transition in the study area. The increasing migration of young people to urban centers and abroad in search of better employment and education opportunities has intensified the abandonment of traditional agriculture and animal husbandry, consistent with Paudel et al. (2020) and Smith et al. (2024). This migration has also reduced the collection of firewood, litter, edible food, and other resources. Simultaneously, Nepal's energy transition has advanced rapidly in recent years, driven by increased access to liquefied petroleum gas and a substantial expansion of small, medium, micro, and mega hydropower installations across the country (Khatiwada et al., 2024). This shift has further reduced local reliance on firewood and other solid fuels.

Second, our results show that education and professional background significantly influence how people perceive ecosystem services, especially regulating and cultural services like carbon sequestration, air quality improvement, tourism, and research. Individuals with higher

Table 5
Associations between socio-demographic variables and local perceptions of ecosystem disservices, assessed using Fisher's exact test with Monte Carlo simulation (10,000 replicates). Effect sizes are reported as Cramér's V, with the strength of association interpreted as Negligible (N, <0.1), Weak (W, 0.1–0.2), Moderate (M, 0.2–0.4), Relatively Strong (RS, 0.4–0.6), and Strong (S, ≥0.6). Statistical significance levels are denoted as $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***), corresponding to 95 %, 99 %, and 99.9 % confidence levels, respectively.

Ecosystem disservice	Geographical location [p-value, Cramér's V(label)]	Education [p-value, Cramér's V(label)]	Ethnicity [p-value, Cramér's V(label)]	Professional background [p-value, Cramér's V(label)]
Wildlife attacks on humans	0.06, 0.23(M)	0.91, 0.06(N)	1.00, 0.02(N)	0.70, 0.13(W)
Wildlife attacks on livestock	**<0.001*****, 0.35(M)	0.11, 0.26(M)	0.94, 0.08(N)	0.37, 0.20(M)
Crop raiding by wildlife	**<0.001*****, 0.33(M)	**0.007****, 0.27(M)	0.53, 0.11(W)	0.07, 0.21(M)
Allergies	**<0.001*****, 0.39(M)	0.10, 0.21(M)	0.65, 0.16(W)	**0.02***, 0.29(M)
Barriers to development and construction	**0.03***, 0.26(M)	0.21, 0.31(M)	0.78, 0.13(W)	0.24, 0.19(W)
Legal complications and poor management	0.35, 0.17(W)	0.33, 0.18(W)	**0.03***, 0.28(M)	0.053, 0.25(M)

education levels or jobs in conservation fields tend to recognize and value ecosystem services that are less visible or experienced indirectly. This pattern aligns with earlier studies (Ahononga et al., 2020; Quintas-Soriano et al., 2018; Wangchuk et al., 2021; Xia et al., 2025), which suggest that education improves environmental literacy and fosters pro-environmental values, thereby increasing appreciation for regulating and cultural ecosystem services. Similarly, people whose livelihoods are closely linked to natural systems demonstrate greater awareness of ecosystem functions and the importance of ecosystem services (Ke et al., 2024). The variation seen across different professional backgrounds likely reflects differences in livelihood dependence and value preferences, as individuals tend to prioritize ecosystem services that meet their immediate needs, interests, and socio-economic contexts, in line with the findings of Koko et al. (2020).

Third, our findings reveal that geographical location strongly shapes perceptions of both provisioning services, such as edible food, herbs, and hydropower, and ecosystem disservices, including crop and livestock damage by wildlife and allergies. These spatial differences likely reflect the interaction between local ecological conditions and socio-economic contexts, consistent with Bai et al. (2024) and Zhang et al. (2016), who emphasize that perceptions of ecosystem services are context-dependent. The availability and prevalence of specific provisioning services within a given area are likely to contribute to these perceptual differences. Likewise, variations in forest cover across districts, which influence access to and reliance on forest resources, help explain differences in how provisioning services are perceived. For instance, Sindhupalchowk, with 53,903 ha of forest, has substantially more than Rasuwa, with 33,118 ha, or Nuwakot, with 11,457 ha (DFRS, 2018). Forest cover may also shape perceptions of ecosystem disservices, particularly human–wildlife conflicts, as communities near forests and protected areas face greater wildlife-related risks (Mbise and Senkondo, 2024; Ram et al., 2022; Tiller et al., 2021). In addition, variations in wildlife densities and behavioral adaptations, including higher predator–herbivore densities (Dunnink et al., 2019; Movasaghi et al., 2025) and increased tolerance to human presence (Pandey et al., 2016; Shrestha et al., 2025), are likely to influence perceptions of disservices. Similarly, spatial variations in local perceptions may be driven by differences in crop types and agricultural practices, as wildlife are often attracted to certain crops (Magar et al., 2024; Yeshey et al., 2024).

Fourth, our study highlights notable differences in how ecosystem services and disservices are perceived and distributed across spatial scales. Illustrating this, Langtang provides a wide range of ecosystem services whose benefits operate at local, national and global levels. As Birch et al. (2014) observed, ecosystem services operate across these multiple scales—from localized forest products that sustain livelihoods to regional watershed functions to global benefits such as climate change mitigation through carbon sequestration. Yet, local communities in our study expressed a clear sense of paradox: while they bear the immediate costs of biodiversity conservation in the form of ecosystem disservices, national and global actors largely enjoy the benefits of ecosystem services without facing the associated burdens. Prior research corroborates this tension, showing that the poorest communities often incur the greatest conservation costs, which can absorb a substantial portion of their household income (Poudyal et al., 2018). This imbalance between local costs and global benefits echoes the findings of Green et al. (2018), Neudert et al. (2016), and Platts et al. (2023), who all documented that while conservation generates benefits at broader scales, its costs are predominantly localized.

These local–global dynamics are particularly salient in the context of the global commitment to protect 30 % of the planet's terrestrial and marine areas by 2030. As Geldmann (2024) cautions, the expansion of protected areas can heighten tensions between biodiversity conservation goals and the rights and livelihoods of local communities. Without adequate compensation or equitable benefit-sharing mechanisms, such expansion risks reproducing historical injustices, imposing high costs on resource-dependent populations, and eroding public support for conservation (Rakotonarivo et al., 2025). In Nepal, for instance, the successful recovery of tiger populations has been accompanied by a worrying increase in human casualties from tiger attacks (Dhungana et al., 2024). Unless ecosystem disservices are explicitly recognized and addressed, these persistent imbalances could foster local resentment and ultimately jeopardize the long-term sustainability of conservation initiatives.

Our study also had some limitations. First, the sampling strategy, combining convenience and purposive approaches, and the number of respondents were designed to capture diverse perspectives but may not fully represent the broader community, which could limit the generalizability of our findings. However, this sampling bias does not undermine the internal validity because our objective was to assess respondents' perceptions rather than to estimate population-level parameters. To mitigate this limitation, we conducted semi-structured interviews with local people from diverse socio-economic and professional backgrounds to capture a wide range of perspectives. Data collection was undertaken across multiple locations within the national park, considering geographical accessibility to ensure spatial representation. We also adhered to the principle of data saturation, continuing interviews until no new themes or insights emerged, consistent with qualitative research standards for purposive sampling (Hennink and Kaiser, 2022). Moreover, we recognized that local people living adjacent to the national park possess valuable experiential knowledge of both the ecosystem services and disservices associated with the park. Incorporating these local perspectives is therefore essential for fostering long-term sustainability and effective management of protected areas.

Second, Likert scales in data collection are subject to several biases, including central tendency bias, social desirability bias, and acquiescence bias, which may compromise data validity (Douven, 2018; Magdolen et al., 2024; Westland, 2022). The interview questions were pretested to address these biases (see methods section). Additionally, respondents were asked to review and justify their Likert-scale scores to further reduce potential data distortion. Third, our study could have more thoroughly examined the ecological mechanisms underlying the increasing abundance and behavioral shifts of conflict-prone species. We recommend that future ecological research investigate the factors driving these dynamics, including habitat recovery, altered food availability, and changes in predator–prey relationships. Furthermore, future studies should explore how climate change influences human–wildlife interactions and shapes local perceptions of ecosystem services and disservices.

Our findings highlight that local communities' perceptions of ecosystem (dis)services are shaped by the interaction of social factors, spatial contexts, and ecological realities. These insights reveal an emerging social-ecological-policy connection, indicating that protected area management must adopt governance structures that integrate ecological functions with spatial dynamics and societal needs. As part of this integrated approach, aligning governance with ecological processes can enhance communities' benefits, safeguard ecosystem integrity, and maintain ecological resilience by leveraging synergies and minimizing tradeoffs among ecosystem services and between services and disservices. Accordingly, we propose four practical recommendations for strengthening biodiversity conservation and promoting sustainable protected area management: 1) incorporating ecosystem services and disservices indicators into monitoring, planning, and reporting frameworks, with clear objectives, actionable measures, verification mechanisms, financial planning, and risk assessment; 2) initiating payment for ecosystem services mechanisms to compensate communities engaged in conservation and ecosystem restoration; 3) establishing robust, timely, and equitable compensation systems for communities experiencing conservation-related losses; and 4) implementing governance reforms to embed ecosystem (dis)services into protected area management plans, operational policies, and relevant legislation, guided by pluralistic values and ensuring the protection of indigenous and local communities (Subedi et al., 2025).

Beyond the national level, our findings have wider policy significance. Internationally, we highlight the need to integrate locally grounded solutions into global biodiversity governance. This involves advocating for biodiversity conservation policies and initiatives that explicitly include indicators for both ecosystem services and disservices. Policy actions based on these insights—whether at the national or international level—can create synergistic opportunities to help achieve the GBF and the SDGs. Specifically, they can support the GBF's 2030 Mission to halt and reverse biodiversity loss and its 2050 Vision of living in harmony with nature (Convention on Biological Diversity, 2022). Sustainable ecosystem management in protected areas is a vital pathway toward achieving life on land (SDG 15). However, this requires careful consideration of indicators for ecosystem disservices and strategies to address them. Therefore, the post-2030 agenda, a follow-up to the SDGs, should include targets and indicators that address ecosystem disservices while fostering life on land (SDG 15) and life under water (SDG 14).

5. Conclusions

Local communities in Langtang demonstrate a sustainability-oriented perspective rooted in an implicit understanding of the interconnectedness between ecological processes and human well-being. This orientation is reflected in the high value placed on regulating and supporting ecosystem services, which communities consider essential for maintaining ecological integrity, sustaining livelihoods, and enhancing both ecological and social resilience. Individuals with formal education or in conservation-related professions tend to recognize the importance of these indirect benefits, particularly regulating and cultural services. A key contribution of our study is elucidation of conservation trade-offs, specifically the extent to which globally distributed benefits rely on localized social and ecological costs. This is evident in the pronounced spatial asymmetry between ecosystem services and disservices: although Langtang provides services whose benefits extend to regional, national, and global scales, the burdens of ecosystem disservices remain intensely local and are disproportionately borne by communities adjacent to the protected area. These findings underscore the need to incorporate local perceptions and lived experiences into conservation governance through an ecosystem services lens, including indicators for ecosystem disservices. Future research should further explore how socio-demographic groups categorize the importance of ecosystem services and the severity of disservices, and the factors driving these priorities. In addition, it should examine how the ecosystem services approach can effectively be applied in conservation policy and practices, in ways that align with both the transformative goals of the 2030 Agenda for Sustainable Development and the GBF, including the commitment to protect 30 % of the world's land and marine areas by 2030. Finally, our study recommends systematically integrating ecosystem (dis)service indicators into planning and monitoring processes, establishing payments for ecosystem services, ensuring timely and fair compensation to communities bearing ecological costs, and advancing governance reforms that embed these priorities within protected area management and policy frameworks.

CRediT authorship contribution statement

Daya Raj Subedi: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Qijing Liu:** Writing – review & editing, Supervision, Conceptualization. **Dinesh Raj Bhuju:** Writing – review & editing, Methodology, Conceptualization. **Shrijana Vaidya:** Writing – review & editing. **Yam Bahadur KC:** Writing – review & editing. **Prajal Pradhan:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.indic.2026.101130.

Data availability

Data will be made available on request.

References

Ahononga, F.C., Gouwakinnou, G.N., Biaou, S.S.H., Biaou, S., Sonounameto, R.C., 2020. Socioeconomic factors determining ecosystem services local perceptions in two ecological zones in Benin (west Africa). Int. J. Biol. Chem. Sci. 14 (5), 1716–1733. https://doi.org/10.4314/ijbcs.v14i5.18.

Bai, Y., Huang, Q., Inostraza, L., Xu, H., Yin, D., Liu, Z., Zhang, L., Xu, F., 2024. Residents' perceptions of ecosystem services in an urbanizing basin: a case study in the guanting Reservoir basin, China. Geogr. Sustain. 5, 430–444. https://doi.org/10.1016/j.geosus.2024.04.004.

Baral, N., Stern, M., Bhattarai, R., 2008. Contingent valuation of ecotourism in Annapurna conservation area, Nepal: implications for sustainable park finance and local development. Ecol. Econ. 66 (2–3), 218–227. https://doi.org/10.1016/j.ecolecon.2008.02.004.

Bewick, V., Cheek, L., Ball, J., 2003. Statistics review 8: qualitative data – tests of association. Crit. Care 8 (1), 46–53. https://doi.org/10.1186/cc2428.

Bhatt, H., Verma, D., Jugran, H.P., Kumar, V., Pandey, R., 2024. Community perception about ecosystem services assessment from forests managed under different regimes in Hindu kush himalaya. Environ. Sustain. Indic., 100463 https://doi.org/10.1016/j.indic.2024.100463.

Bhuju, U.R., Shakya, P.R., Basnet, T.B., Shrestha, S., 2007. Nepal Biodiversity Resource Book: Protected Areas, Ramsar Sites, and World Heritage Sites. International Centre for Integrated Mountain Development (ICIMOD) and Ministry of Environment, Science and Technology (MOEST), Government of Nepal (GoN). https://doi.org/10.53055/ICIMOD.475.

Birch, J.C., Thapa, I., Balmford, A., Bradbury, R.B., Brown, C., Butchart, S.H.M., Gurung, H., Hughes, F.M.R., Mulligan, M., Pandeya, B., Peh, K., Stattersfield, A.J., Walpole, M., Thomas, D.H.L., 2014. What benefits do community forests provide, and to whom? A rapid assessment of ecosystem services from a Himalayan forest, Nepal. Ecosyst. Serv. 8, 118–127. https://doi.org/10.1016/j.ecoser.2014.03.005.

Blanco, J., Dendoncker, N., Barnaud, C., Sirami, C., 2019. Ecosystem disservices matter: towards their systematic integration within ecosystem services research and policy. Ecosyst. Serv. 36. https://doi.org/10.1016/j.ecoser.2019.100913.

Boćkowski, M.D., Tusznio, J., Rechciński, M., Blicharska, M., Akshik, A., Grodzińska-Jurczak, M., 2024. Ecosystem services approach in Turnicki national park planning: factors influencing the inhabitants' perspectives on local natural resources and protected areas. Environ. Manage. 74, 547–563. https://doi.org/10.1007/s00267-024-02016-x.

Convention on Biological Diversity, 2022. Nations adopt four goals, 23 targets for 2030 in landmark UN biodiversity agreement [Press release]. https://prod.drupal.www.infra.cbd.int/sites/default/files/2022-12/221219-CBD-PressRelease-COP15-Final_0.pdf.

DFRS, 2018. Forest Cover Maps of Local Level (753) of Nepal. Department of Forest Research and Survey (DFRS). https://www.nnrfc.gov.np/uploads/resources/2024-05-10/07_Summary_of_Forest_Cover_Maps_of_Local_Levels_of_Nepal_as_published_by_Department_of_Forest_Research_and_Survey.pdf.

Dhungana, R., Maraseni, T., Allen, B.L., Kandel, R.C., Koirala, P.N., Pant, G., Ranabhat, R., 2024. Multi-stakeholder identification and prioritization of human–tiger conflict reduction measures in Chitwan National Park, Nepal. Oryx 1–9. https://doi.org/10.1017/s0030605323001734.

DNPWC, 2018. Lamgtang National Park (LNP) and buffer zone: location and land cover. Government of Nepal, Ministry of Forest and Environment, Department of National Park and Wildlife Conservation [Map]. https://dnpwc.gov.np/media/others/Lamtang_location_landcover.jpg.

Douven, I., 2018. A Bayesian perspective on Likert scales and central tendency. Psychon. Bull. Rev. 25, 1203–1211. https://doi.org/10.3758/s13423-017-1344-2.

Dunnink, J.A., Hartley, R., Rutina, L., Alves, J., Franco, A.M.A., 2019. A socio-ecological landscape analysis of human–wildlife conflict in northern Botswana. Oryx 1–9. https://doi.org/10.1017/s0030605318001394.

Elwell, T.L., Gelcich, S., Gaines, S.D., López-Carr, D., 2018. Using people's perceptions of ecosystem services to guide modeling and management efforts. Sci. Total Environ. 637–638, 1014–1025. https://doi.org/10.1016/j.scitotenv.2018.04.052.

Escobedo, F.J., Kroeger, T., Wagner, J.E., 2011. Urban forests and pollution mitigation: analyzing ecosystem services and disservices. Environ. Pollut. 159 (8–9), 2078–2087. https://doi.org/10.1016/j.envpol.2011.01.010.

Ferdin, A., Aryal, U.C., Dhungana, N., Lamichhane, B.R., Chook, J.W., Lee, C., 2024. Prioritizing human-wildlife conflict management strategies through importance-performance analysis: insights from Chitwan National Park, Nepal. J. Nat. Conserv. 81. https://doi.org/10.1016/j.jnc.2024.126675.

García-Llorente, M., Harrison, P.A., Berry, P., Palomo, I., Gómez-Baggethun, E., Iniesta-Arandia, I., Montes, C., García del Amo, D., Martín-López, B., 2018. What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. Biodivers. Conserv. 27, 1575–1597. https://doi.org/10.1007/s10531-016-1152-4.

Geldmann, J., 2024. Protected areas: biodiversity or people — or both? Curr. Biol. 34 (13), R633–R635. https://doi.org/10.1016/j.cub.2024.05.040.

Green, J.M.H., Fisher, B., Green, R.E., Makero, J., Platts, P.J., Robert, N., Schaafsma, M., Turner, R.K., Balmford, A., 2018. Local costs of conservation exceed those borne by the global majority. Glob. Ecol. Conserv. 14, e00385. https://doi.org/10.1016/j.gecco.2018.e00385.

Hennink, M., Kaiser, B.N., 2022. Sample sizes for saturation in qualitative research: a systematic review of empirical tests. Soc. Sci. Med. 292. https://doi.org/10.1016/j.socscimed.2021.114523.

Hummel, C., Poursanidis, D., Orenstein, D., Elliott, M., Adamescu, M.C., Cazacu, C., Ziv, G., Chrysoulakis, N., van der Meer, J., Hummel, H., 2019. Protected area management: fusion and confusion with the ecosystem services approach. Sci. Total Environ. 651, 2432–2443. https://doi.org/10.1016/j.scitotenv.2018.10.033.

Islam, T., Nawchoo, I.A., Khuroo, A.A., 2023. Community perception and management of ecosystem services in a protected area in Kashmir Himalaya. Hum. Ecol. 51 (4), 769–779. https://doi.org/10.1007/s10745-023-00439-4.

Jo, J.-H., Choi, M., Kweon, D., Son, Y.-G., Lim, E.M., 2024. Regulating ecosystem services in a local forest: navigating supply, trade-offs, and synergies. Trees, Forests and People 15, 100466. https://doi.org/10.1016/j.tfp.2023.100466.

Kaiser, J., 2007. An exact and a monte carlo proposal to the fisher–pitman permutation tests for paired replicates and for independent samples. STATA J. 7 (3), 402–412. https://doi.org/10.1177/1536867x0700700307.

Karimi, A., Yazdandad, H., Fagerholm, N., 2020. Evaluating social perceptions of ecosystem services, biodiversity, and land management: Trade-offs, synergies and implications for landscape planning and management. Ecosyst. Serv. 45. https://doi.org/10.1016/j.ecoser.2020.101188.

Kc, B., Baniya, R., Singh, H.B., Chapagain, B., 2023. Human-wildlife conflicts in a Nepalese protected area: conservation challenges, mitigation strategies, and policy implications. Geojournal 88, 5997–6010. https://doi.org/10.1007/s10708-023-10953-z.

Ke, Y., Bai, Y., Ali, M., Ashraf, A., Li, M., Li, B., 2024. Exploring resident's perceptions of ecosystem services in nature reserves to guide protection and management. Ecol. Indic. 158. https://doi.org/10.1016/j.ecolind.2023.111535.

Khatiwada, P.P., Subedi, D.R., Gurung, Y.B., Pradhan, M.S., Pradhan, P., 2024. Challenges to leave no one behind in Nepal for achieving sustainable development goals. In: Leal Filho, W., Ng, T.F., Iyer-Raniga, U., Ng, A., Sharifi, A. (Eds.), Sdgs in the Asia and Pacific Region: Implementing the UN Sustainable Development Goals – Regional Perspectives. Springer, pp. 1137–1168. https://doi.org/10.1007/978-3-030-91262-8_105-1.

Koirala, S., Garber, P.A., Somasundaram, D., Katuwal, H.B., Ren, B., Huang, C., Li, M., 2021. Factors affecting the crop raiding behavior of wild rhesus macaques in Nepal: implications for wildlife management. J. Environ. Manage 297, 113331. https://doi.org/10.1016/j.jenvman.2021.113331.

Koko, I.A., Misana, S.B., Kessler, A., Fleskens, L., 2020. Valuing ecosystem services: stakeholders' perceptions and monetary values of ecosystem services in the Kilombero wetland of Tanzania. Ecosyst. People 16 (1), 411–426. https://doi.org/10.1080/26395916.2020.1847198.

Lalhminghlui, K., Jagetia, G.C., 2018. Evaluation of the free-radical scavenging and antioxidant activities of Chilauni, Schima wallichii Korth in vitro. Future Sci. OA 4 (2). https://doi.org/10.4155/fsoa-2017-0086.

Larson, K., Corley, E., Andrade, R., Hall, S.J., York, A., Meerow, S., Coseo, P., Childers, D.L., Hondula, D., 2019. Subjective evaluations of ecosystem services and disservices: an approach to creating and analyzing robust survey scales. Ecol. Soc. 24 (2). https://doi.org/10.5751/ES-10888-240207.

Li, J., Warchold, A., Pradhan, P., 2025. Revisiting social foundations and well-being indicators for sustainability: insights from a systematic literature review. Ecol. Indic. 178, 113890. https://doi.org/10.1016/j.ecolind.2025.113890.

LNP, 2020a. Management plan of Langtang national park and its buffer zone (2077/78-2081/82). https://langtangnationalpark.gov.np/media/download_documents/लङटङ_रषटरय_नकञजक_वयवसथपन_यजन_२०८२.pdf.

LNP, 2020b. Langtang national park (LNP) annual progress report for the fiscal year 2018/19. https://langtangnationalpark.gov.np/media/download_documents/Annual_Report_2075-076.pdf.

LNP, 2021. Langtang National Park Annual Progress Report for the Fiscal Year 2019/20. Langtang National Park.

LNP, 2022. Langtang National Park Annual Progress Report for the Fiscal Year 2020/21. Langtang National Park.

LNP, 2023. Langtang National Park Annual Progress Report for the Fiscal Year 2021/22. Langtang National Park.

LNP, 2024. Langtang national park annual progress report for the fiscal year 2022/23. https://langtangnationalpark.gov.np/media/download_documents/लङटङ_रषटरय_नकञजक_आ.व._2079-०८०_परतवदन.pdf.

LNP, 2025. Langtang national park annual progress report for the fiscal year 2023/24. https://langtangnationalpark.gov.np/media/download_documents/Langtang_Annual_Report_2080_81.pdf.

Lv, H., Wang, G., Chen, W., Zou, T., Zhou, Y., Shi, Y., 2025. Impacts of stand structure characteristics of three forest types on the internal environment and carbon sink functions of forests. Ecol. Indic. 179. https://doi.org/10.1016/j.ecolind.2025.114199, 114199–114199.

Lyytimäki, J., 2015. Ecosystem disservices: embrace the catchword. Ecosyst. Serv. 12, 136. https://doi.org/10.1016/j.ecoser.2014.11.008.

Lyytimäki, J., 2014. Bad nature: newspaper representations of ecosystem disservices. Urban For. Urban Green. 13, 418–424. https://doi.org/10.1016/j.ufug.2014.04.005.

Lyytimäki, J., Petersen, L.K., Normander, B., Peter Bezak, P., 2008. Nature as a nuisance? Ecosystem services and disservices to urban lifestyle. Environ. Sci. 5 (3), 161–172. https://doi.org/10.1080/15693430802055524.

Lyytimäki, J., Sipilä, M., 2009. Hopping on one leg – the challenge of ecosystem disservices for urban green management. Urban For. Urban Green. 8 (4), 309–315. https://doi.org/10.1016/j.ufug.2009.09.003.

Magar, Y.G., Pant, B., Regmi, S., Katuwal, H.B., Belant, J.L., Sharma, H.P., 2024. Economic effects of wild boar damage to crops in protected areas of Nepal. Glob. Ecol. Conserv. 56, e03301. https://doi.org/10.1016/j.gecco.2024.e03301.

Mbise, F.P., Senkondo, N.F., 2024. Socio-demographic factors influencing locals' responses to human-wildlife conflicts in societies living adjacent to Swagaswaga Game Reserve. Tanzania. Discov. Conserv. 1 (7). https://doi.org/10.1007/s44353-024-00008-w.

Magdolen, M., Behren, S., Vallee, J., Chlond, B., Vortisch, P., 2024. Response bias in Likert-style psychological items – an example from a large-scale travel survey in China. Transp. Res. Procedia 76, 349–360. https://doi.org/10.1016/j.trpro.2023.12.060.

Mengist, W., Soromessa, T., Legese, G., 2020. Ecosystem services research in mountainous regions: a systematic literature review on current knowledge and

research gaps. Sci. Total Environ. 702, 134581. https://doi.org/10.1016/j.scitotenv.2019.134581.
Movasaghi, Y., Khosravi, R., Mohammady, M., Pourghasemi, H.R., Ghoddousi, A., Kuemmerle, T., 2025. Exploring spatial patterns of human–bear conflict in southwestern Iran due to future land-use change. Biol. Conserv. 311, 111459. https://doi.org/10.1016/j.biocon.2025.111459.
Mundform, D.J., Schaffer, J., Kim, M.-J., Shaw, D., Thongteeraparp, A., Supawan, P., 2011. Number of replications required in Monte Carlo simulation studies: a synthesis of four studies. J. Mod. Appl. Stat. Methods 10 (1), 19–28. https://doi.org/10.22237/jmasm/1304222580.
Neema, S., Dabbas, D., Pathania, V., Vasudevan, B., 2023. Marking nut dermatitis: a case series on factitious dermatitis. Med. J. Armed Forces India 79 (4), 470–473. https://doi.org/10.1016/j.mjafi.2020.11.022.
Neudert, R., Ganzhorn, J.U., Watzold, F., 2016. Global benefits and local costs – the dilemma of tropical forest conservation: a review of the situation in Madagascar. Environ. Conserv. 44 (1), 82–96. https://doi.org/10.1017/s0376892916000552.
Neugarten, R.A., Langhammer, P.F., Osipova, E., Bagstad, K.J., Bhagabati, N., Butchart, S.H.M., et al., 2018. Tools for measuring, modelling, and valuing ecosystem services: guidance for key biodiversity areas. Natural World Heritage Sites, and Protected Areas. International Union for Conservation of Nature (IUCN). https://doi.org/10.2305/IUCN.CH.2018.PAG.28.en.
Pandey, P., Shaner, P.-J.L., Sharma, H.P., 2016. The wild boar as a driver of human-wildlife conflict in the protected park lands of Nepal. Eur. J. Wildl. Res. 62 (1), 103–108. https://doi.org/10.1007/s10344-015-0978-5.
Pandit, R., Dhakal, M., Polyakov, M., 2015. Valuing access to protected areas in Nepal: the case of Chitwan National Park. Tour. Manag. 50, 1–12. https://doi.org/10.1016/j.tourman.2014.12.017.
Pant, B., Sharma, H.P., Dahal, B.R., Regmi, S., Belant, J.L., 2023. Spatio-temporal patterns of human-wildlife conflicts and effectiveness of mitigation in Shuklaphanta National Park, Nepal. PLoS One 18 (4), e0282654. https://doi.org/10.1371/journal.pone.0282654.
Pataki, D.E., Carreiro, M.M., Cherrier, J., Grulke, N.E., Jennings, V., Pincetl, S., Pouyat, R.V., Whitlow, T.H., Zipperer, W.C., 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. Front. Ecol. Environ. 9 (1), 27–36. https://doi.org/10.1890/090220.
Paudel, B., Wu, X., Zhang, Y., Rai, R., Liu, L., Zhang, B., Khanal, N.R., Koirala, H.L., Nepal, P., 2020. Farmland abandonment and its determinants in the different ecological villages of the Koshi river basin, central himalayas: synergy of high-resolution remote sensing and social surveys. Environ. Res. 188, 109711. https://doi.org/10.1016/j.envres.2020.109711.
Peh, K.S.H., Thapa, I., Basnyat, M., Balmford, A., Prakash, G., Bradbury, R.B., et al., 2016. Synergies between biodiversity conservation and ecosystem service provision: lessons on integrated ecosystem service valuation from a Himalayan protected area, Nepal. Ecosyst. Serv. 22, 359–369. https://doi.org/10.1016/j.ecoser.2016.05.003.
Peh, K.S.H., Balmford, A., Bradbury, R.B., Brown, C., Butchart, S.H.M., Hughes, F.M.R., et al., 2013. TESSA: a toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance. Ecosyst. Serv. 5, 51–57. https://doi.org/10.1016/j.ecoser.2013.06.003.
Peng, D., Zhang, B., Zheng, S., et al., 2025. Newly established forests dominated global carbon sequestration change induced by land cover conversions. Nat. Commun. 16, 6570. https://doi.org/10.1038/s41467-025-61956-y.
Platts, P.J., Schaafsma, M., Turner, R.K., et al., 2023. Inequitable gains and losses from conservation in a global biodiversity hotspot. Environ. Resour. Econ. https://doi.org/10.1007/s10640-023-00798-y.
Poudyal, M., Jones, J.P.G., Rakotonarivo, O.S., Hockley, N., Gibbons, J.M., Mandimbiniaina, R., Rasoamanana, A., Andrianantenaina, N.S., Ramamonjisoa, B.S., 2018. Who bears the cost of forest conservation? PeerJ 6, e5106. https://doi.org/10.7717/peerj.5106.
Pradhan, A., Khaling, S., 2023. Community priorities, values, and perceptions associated with ecosystem services provided by the socio-ecological landscapes of Darjeeling-Sikkim Himalaya. Reg. Environ. Change 23 (1). https://doi.org/10.1007/s10113-023-02028-z.
Pu, X., Ding, W., Ye, W., Nan, X., Lu, R., 2023. Ecosystem service research in protected areas: a systematic review of the literature on current practices and future prospects. Ecol. Indic. 154. https://doi.org/10.1016/j.ecolind.2023.110817.
Quintas-Soriano, C., Brandt, J.S., Running, K., Baxter, C.V., Gibson, D.M., Narducci, J., Castro, A.J., 2018. Social-ecological systems influence ecosystem service perception: a Programme on Ecosystem Change and Society (PECS) analysis. Ecol. Soc. 23 (3). https://doi.org/10.5751/es-10226-230303.
Rai, R.K., Joshi, S., Dorji, T., Pant, B., 2024. Herder's preference for maintaining Yak herding in the eastern Himalayas. Rangel. Ecol. Manag. 94, 20–28. https://doi.org/10.1016/j.rama.2024.01.009.
Rakotonarivo, O.S., Shyamsundar, P., Kramer, R., Hockley, N., 2025. Conservation practice must catch up with commitments to local people for 30 × 30 success. Nat. Rev. Biodivers 1 (2), 84–85. https://doi.org/10.1038/s44358-025-00021-4.
Ram, A.K., Yadav, N.K., Subedi, N., Pandav, B., Mondol, S., Khanal, B., Kharal, D.K., Acharya, H.B., Dhakal, B.K., Acharya, K.P., Baral, H.S., Dahal, B.R., Mishra, R., Naha, D., Pradhan, N.M.B., Natarajan, L., Lamihhane, B.R., 2022. Landscape predictors of human elephant conflicts in Chure Terai Madhesh landscape of Nepal. Environ. Chall. 7, 100458. https://doi.org/10.1016/j.envc.2022.100458.
Robinson, O.C., 2013. Sampling in interview-based qualitative research: a theoretical and practical guide. Qual. Res. Psychol. 11 (1), 25–41. https://doi.org/10.1080/14780887.2013.801543.
Saeed, U., Arshad, M., Hayat, S., Morelli, T.L., Nawaz, A.M., 2022. Analysis of provisioning ecosystem services and perceptions of climate change for indigenous communities in the Western Himalayan Gurez Valley, Pakistan. Ecosyst. Serv. 56, 101453. https://doi.org/10.1016/j.ecoser.2022.101453.
Shackleton, C.M., Ruwanza, S., Sinasson Sanni, G.K.S., Bennett, S., De Lacy, P., Modipa, R., et al., 2016. Unpacking Pandora's Box: understanding and categorizing ecosystem disservices for environmental management and human well-being. Ecosystems 19, 587–600. https://doi.org/10.1007/s10021-015-9952-z.
Sharma, B., Rasul, G., Chettri, N., 2015. The economic value of wetland ecosystem services: evidence from the Koshi Tappu Wildlife Reserve, Nepal. Ecosyst. Serv. 12, 84–93. https://doi.org/10.1016/j.ecoser.2015.02.007.
Shrestha, U.B., Shrestha, S., Khanal, S., Baral, N., Dhungel, U., Shrestha, A., Neupane, D., Dahal, B.R., Thapa, S.K., 2025. People's perceptions on the effectiveness of human-wildlife conflict mitigation measures in Nepal's Tarai Arc Landscape. J. Environ. Mange 395, 127944. https://doi.org/10.1016/j.jenvman.2025.127944.
Sheydayi, A., Dadashpoor, H., 2023. Conducting qualitative content analysis in urban planning research and urban studies. Habitat Int. 139. https://doi.org/10.1016/j.habitatint.2023.102878.
Smith, A.C., Hajjar, R., Kanel, K.R., Fox, J., Tuladhar, S., Den, V., 2024. Out-migration, agricultural abandonment, and community forest management: drivers of afforestation in privately managed land in Nepal. Appl. Geogr. 167, 103275. https://doi.org/10.1016/j.apgeog.2024.103275.
Staller, K.M., 2021. Big enough? Sampling in qualitative inquiry. Qual. Soc. Work 20 (4), 897–904. https://doi.org/10.1177/14733250211024516.
Subedi, D.R., Liu, Q., Bhuju, D.R., Pradhan, P., 2025. Ecosystem (dis)services matter for conservation policies: insights from Nepal. Earth Syst. Governance 26, 100303. https://doi.org/10.1016/j.esg.2025.100303.
Thapa, K., Ntanos, S., Kyriakopoulos, G.L., Skordoulis, M., Getzner, M., 2024. Visitors' environmental attitudes and willingness to pay for nature conservation: the case of Langtang national park in the Himalayas. Glob. NEST J. 26 (3). https://doi.org/10.30955/gnj.005717.
Thapa, P., Torralba, M., Bhaskar, D., Nagendra, H., Plieninger, T., 2023. Green in grey: ecosystem services and disservices perceptions from small scale green infrastructure along a rural-urban gradient in Bengaluru, India. Ecosyst. People 19 (1). https://doi.org/10.1080/26395916.2023.2223307.
Thiemann, M., Riebl, R., Haensel, M., Schmitt, T.M., Steinbauer, M.J., Landwehr, T., et al., 2022. Perceptions of ecosystem services: comparing socio-cultural and environmental influences. PLoS One 17 (10). https://doi.org/10.1371/journal.pone.0276432.
Tiller, L.N., Humle, T., Amin, R., Deere, N.J., Lago, B.O., Leader-Williams, N., Sinoni, F. K., Sitati, N., Walpole, M., Smith, R.J., 2021. Changing seasonal, temporal and spatial crop-raiding trends over 15 years in a human-elephant conflict hotspot. Biol. Conserv. 254, 108941. https://doi.org/10.1016/j.biocon.2020.108941.
Vaz, A.S., Kueffer, C., Kull, C.A., Richardson, D.M., Vicente, J.R., Kühn, I., et al., 2017. Integrating ecosystem services and disservices: insights from plant invasions. Ecosyst. Serv. 23, 94–107. https://doi.org/10.1016/j.ecoser.2016.11.017.
von Döhren, P., Haase, D., 2015. Ecosystem disservices research: are view of the state of the art with a focus on cities. Ecol. Indic. 52, 490–497. https://doi.org/10.1016/j.ecolind.2014.12.027.
Wangchuk, J., Choden, K., Sears, R.R., Baral, H., Yoezer, D., Tamang, K.T.D., et al., 2021. Community perception of ecosystem services from commercially managed forests in Bhutan. Ecosyst. Serv. 50. https://doi.org/10.1016/j.ecoser.2021.101335.
Wessels, N., Sitas, N., Esler, K.J., O'Farrell, P., 2021. Understanding community perceptions of a natural open space system for urban conservation and stewardship in a metropolitan city in Africa. Environ. Conserv. 48, 244–254. https://doi.org/10.1017/S0376892921000345.
Westland, J.C., 2022. Information loss and bias in Likert survey responses. PLoS One 17 (7), e0271949. https://doi.org/10.1371/journal.pone.0271949.
World Bank, 2024a. Terrestrial protected areas (% of total land area). Retrieved September 23, 2024 from. https://data.worldbank.org/indicator/ER.LND.PTLD.ZS.
World Bank, 2024b. Marine protected areas (% of territorial waters). Retrieved September 23, 2024 from. https://data.worldbank.org/indicator/ER.MRN.PTMR.ZS?end=2022&start=2016&view=chart.
Xia, P., Zheng, H., Hu, T., Xu, Z., Peng, J., 2025. Linking perceptions of ecological restoration projects' impacts on ecosystem services and human well-being for achieving regional sustainability. Appl. Geogr. 178, 103570. https://doi.org/10.1016/j.apgeog.2025.103570.
Xu, W., Xiao, Y., Zhang, J., Yang, W., Zhang, L., Hull, V., et al., 2017. Strengthening protected areas for biodiversity and ecosystem services in China. Proc. Natl. Acad. Sci. U. S. A 114 (7), 1601–1606. https://doi.org/10.1073/pnas.1620503114.
Yeshey, Keenan, R.J., Ford, R.M., Nitschke, C.R., 2024. Social and Ecological Dimensions are Needed to Understand Human-Wildlife Conflict in Subsistence Farming Context. People and Nat. https://doi.org/10.1002/pan3.10740.
Zeng, Y., Koh, L.P., Wilcove, D.S., 2022. Gains in biodiversity conservation and ecosystem services from the expansion of the planet's protected areas. Sci. Adv. 8 (22). https://doi.org/10.1126/sciadv.abl9885.
Zhang, W., Yu, Y., Wu, X., Pereira, P., Borja, M.E.L., 2020. Integrating preferences and social values for ecosystem services in local ecological management: a framework applied in Xiaojiang Basin Yunnan province, China. Land Use Policy 91. https://doi.org/10.1016/j.landusepol.2019.104339.
Zhang, W., Kato, E., Bhandary, P., Nkonya, E., Ibrahim, H.I., Agbonlahor, M., Ibrahim, H. Y., Cox, C., 2016. Awareness and perceptions of ecosystem services in relation to land use types: evidence from rural communities in Nigeria. Ecosyst. Serv. 22, 150–160. https://doi.org/10.1016/j.ecoser.2016.10.011.