The Geographical Journal of Nepal
Vol. 18: 32-56, 2025
DOI: https://doi.org/10.3126/gjn.v18i1.77056
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Spatial Distribution of Caves and Cave Species in Nepal: A Review

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Received: 27 October, 2024; Accepted: 07 January, 2024; Published: March, 2025

Abstract

A cave is a natural underground hollow with a dark passage accessible to humans, naturally made by rock erosion or melting ice over a long period. Caves have fascinated humans for centuries for their appearance and biological diversity. Caves have played essential roles in various cultures, mythology and history. Many caves in Nepal are cultural sites for many societies. They are also significant for habitats for various cave-dwelling vertebrate and non-vertebrate species. The country has several caves that are used for tourism activities. This study found 222 caves known from within 56 districts of Nepal. Surkhet, Mustang, and Salyan districts possess the highest number of caves, totaling 21, 15, and 12 caves, respectively. Spatially, caves are largely found in the country's Hill and Middle Mountain regions. The Hill region found the highest number of caves (n= 136). Similarly, 34, 26 and 1 caves are located in the Middle Mountain, Siwalik, High Mountain and Tarai regions,respectively. This study has analyzed the caves in various importance. About 36.7% of caves in Nepal have cultural and religious significance, about 17.7% are important for flora and about 15.5% are significant for wild species. *We looked into the spatial distribution of caves based on various secondary sources mentioned in reports, research papers, books, and municipality profiles. Based on the existing literature, most of the caves are roosting sites for bats, and some caves are used as cultural sites and tourist sites. Caves and cave management for cultural,*

tourism, and fauna conservation have emerging challenges in Nepal due to a lack of proper management, which requires establishing cave policies and adequate planning for wild species.

Keywords: *Spatial distribution of cave, cave species, review, Nepal*

Introduction

A cave is a natural opening in the ground extending beyond the zone of light and large enough to permit the entry of human (Davies & Morgan, 1980). Caves contain records of archeological, paleontological and palaeo-environmental change (Das *et al.,* 2007). Caves can be developed in different lithologies, which are determined by their structure and characteristics (Barros & Bernard, 2023). Humans used caves not only as shelters but for multipurpose uses, such as military purposes (shelter, food storage, and training), water storage, agriculture (mushroom farming, cheese making), wine-making, tourism, recreation and religious observance (Watson *et al.,* 1997).

Caves have been formed by various processes, such as mechanical erosion, volcanic erosion, glacier erosion, and solutions. The erosional processes include mainly corrosion and abrasion. Corrosion or solution is a chemical action that involves the dissolution of soluble materials on rocks. Likewise, abrasion breaks down rocks and removes loosened materials from the rocks with the help of erosional tools such as boulders, pebbles, cobbles, etc. (Das *et al.,* 2007). Caves can be classified as solution caves (formed in carbonate and sulfate rocks such as limestone, marble, and gypsum), glacier caves (formed by melt ice), sea caves (geological formations shaped by the forces of erosion and geological processes along coastlines) and lava cave (created by the flow of molten lava during a volcanic eruption) (Davies & Morgan, 1980). However, most caves are commonly found in limestone, as acidic water slowly dissolves the rock and creates big holes (Das *et al.,* 2007). Based on chemical action, commonly CO_2 found in all surface water (H_2O), when water reacts with limestone, results in calcium carbonate ($CaCO_3$), which is highly soluble and gets readily removed by water (Equation 1) (Das *et al.,* 2007).

$$H_2O + CO_2 + CaCO_3 \rightarrow Ca(HCO_3) \qquad \text{Equation 1.}$$

Caves vary in shape, size, and formation in different geographic and geological areas. The large size caves are called caverns (Das *et al.,* 2007). Nepal's diverse geography and geology makes it a fascinating destination for cave enthusiasts, explorers, and researchers. Nepal has hundreds of natural caves, which provide habitats for a large variety of wild fauna, such as mammals, birds, fishes, crustaceans, and many terrestrial and aquatic vertebrates (Adhikari, 2008; Koju & Chalise, 2012; Sharma *et al.,* 2020; Yin *et al.,* 2015). Caves hold both scientific and cultural importance. In recent years, caves have been

important for explorers, academicians and scientists. Many caves are related to culture in societies, where people believe that they are holy places for worship (Wasti & Acharya, 2011). However, killing bats for fun and cave tourism activities in the caves have also been found to threaten bats and cave environments in Nepal (Acharya *et al.,* 2010; Bhattarai *et al.,* 2022; Sharma *et al.,* 2020). In addition, deforestation of the primary forest was also observed as the key driving factor in reducing the suitable habitat of several bat species in the country (Jnawali *et al.,* 2011).

In recent years, studies on bats have largely been neglected (Jnawali *et al.,* 2011). Some studies have been carried out on bat species and a few popular caves in the country. However, there are several hundreds of caves that need to be studied to preserve caves, cave species, and the environment and to promote them for various purposes such as geological study, ecosystems, biodiversity and conservation, discovery of the past, etc. In order to find cave-dwelling species, a study mapped the distribution of caves and animals in the United States. About 45,000 caves and 924 cave species were found in the 48 contiguous states of the United States (Culver *et al.,* 1999). Caves are not a negligible part of our environment; however, they are comparatively less studied in various parts of the globe (Watson *et al.,* 1997). Likewise, in Nepal, caves provide several habitats for bats, however, they have very limited studies conducted on cave and cave species (Adhikari, 2009; Sharma *et al.,* 2020). Thus, this study reviews caves, cave species,and mapping of caves using ArcGIS software with the help of various secondary literatures and data published in journals and official web portals.

Materials and Methods

Study Area

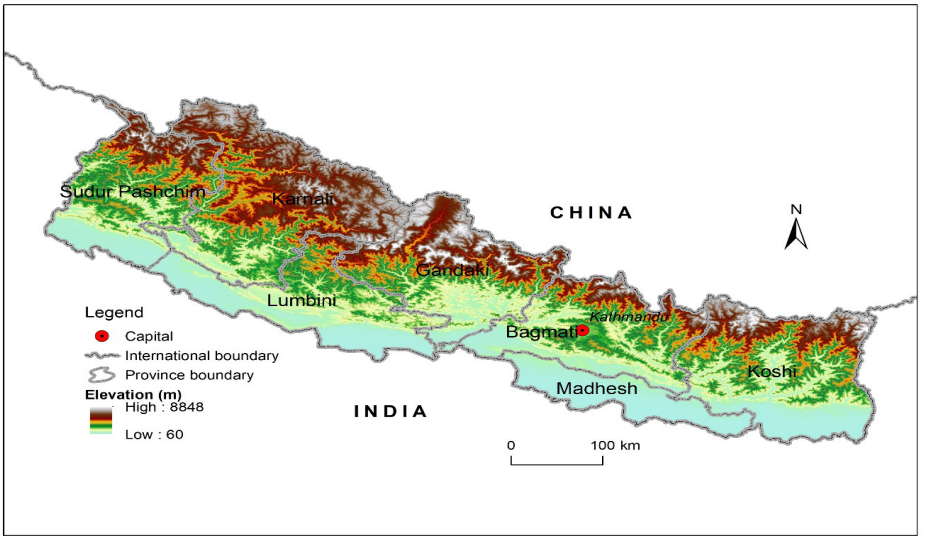
This study covers the caves across Nepal. The country has stunning mountain landscapes, including various mountains and hills. It is situated mainly in the Himalayas, bordered by China to the north and India to the east, south, and west. Administratively the country is divided into seven provinces, 77 districts, and 753 municipalities (rural and municipality). Based on physiography, the country is classified as High Mountain, Middle Mountain, Hill, Siwalik, and Tarai (east-west low land) region (LRMP, 1986).

The physiographic division is based mainly on landform, climate, and altitudinal differences between valley and ridge (Paudel *et al.,* 2011). The elevation in Nepal ranges from 60m to 8848.86m (Mt. Everest, the highest peak in the world) in the country. Due to diverse topography such as mountains, river valleys, gorges, and flat lands, it offers habitats for several wild species within a small geographic area (Paudel *et al.,* 2011).

Geologically, the country is divided into five tectonic zones from south to north, which are the Indo-Gangetic Plain (Tarai), Siwaliks, Lesser Himalayas, Higher Himalayas, and Tibetan-Tethys zones. These zones are developed with different types of rocks, including igneous, sedimentary, and metamorphic, distributed throughout the Nepal Himalayas, which describes the depositional environment and history of the Himalayan range (Adhikari & Ojha, 2021).

Figure 1

Location of Nepal



Source of Data

This study is based on secondary sources such as published municipality and rural municipality profiles in their official web portal. This study referred to the official website (https://sthaniya.gov.np/gis/website/)of the 753 local governments for their municipality profiles. Likewise, published research papers were searched and collected from various internet portals such as GoogleScholar, Google Search, Research Gate,and Web of Science. Related literature was searched with keywords such as cave, bats, cave environment, cave species, and Nepal. In total, 54 related literature published between 1975 and 2023 in local, national and international journals were referred and cited in the study. Similarly, the spatial data (100 cave location data) of caves were collected from the Nepal Tourism Board (NTB). NTB was surveyed tourism sites in the country in 2022.

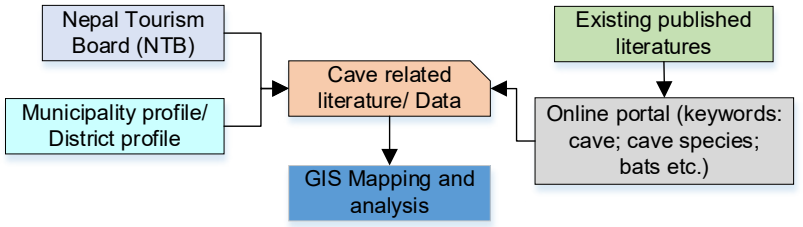
GIS Mapping

ArcGIS Version 10.8 software was used to map the cave locations mentioned in the municipality profile, research papers, and books. The cave distribution wasre-classed

and analyzed based on the country's province, physiographic regions, elevation zones, climatic zones, and geological types. The overall methods of the study has presented in Figure 2.

Figure 2

Overall Methods of the Study



Cave classification

Based on the importance of the cave mentioned in the municipality profile and existing literature, this study has categorized into seven classes of caves as follows;

1. Cultural and religious: The cave that already has cultural significance such as Halesi Cave, Gupteshor Cave, Siddha Cave, etc.
2. Flora and fauna: The class includes the very small size of the plant and wild species including spiders, bats, lizards, snakes, etc.
3. Wild animals: The class includes small to large size wild animals focusing on mammals animals such as tigers, leopards, bears, etc.
4. Cultural, religious, and tourism: The class includes the caves that have cultural, religious, and tourism significance.
5. Geology and wild animals: It includes the caves that are significant for both geological as well as wild animals (small to big size wild animals such as bats).
6. Tourism and wild animals: The caves include which has been mentioned as significant for tourism and wild species (such as bats), such as Bat Cave.
7. Cultural, religious, and geology: Such caves have importance for multipurpose such as cultural beliefs, religious significance, and geological importance.

Results and Discussion

Spatial Distribution of Caves

Solutional caves are formed in limestone,dolomite,or similar types of soluble rock by the action of water (Das *et al.,* 2007; Davies & Morgan, 1980), these types of caves are also found in various parts of Nepal (Pokharel, 2017).While other caves are formed in non-soluble rocks through other processes like erosion and tectonic activity(Davies & Morgan, 1980).

There are various caves found within the country, mainly Pokhara, Mustang, and Tanahu districts. Some of them are well known, such as Gupteshor Mahadev Cave, Mahendra Cave, Chamare Cave (Bat Cave), Siddha Cave, Sky Caves (Upper Mustang).The limestone caves in Pokhara Valley is interesting for geological research (NTB, 2011; Pokharel, 2017). Predominantly, the Hill and Middle Mountain regions have more caves than other regions of the country. Due to its unique geography and indigenous cultural heritage, numerous caves are located in the Upper Mustang region (Darnal, 2017).

In total, 222 caves are documented within 56 districts of Nepal. A total of 112 caves' locations were extracted from the municipality profile and previous literature. Surkhet, Mustang, and Salyan districts have the highest number of caves, with a total of 21, 15, and 12 caves distributed, respectively (Figure 3). Likewise, based on province, Gandaki province has found 66 caves which is the highest number of caves. Similarly, Karnali, Koshi, Bagmati, Lumbini, and Sudur Pashim provinces have found a total of 45, 35, 30, 29, and 17 caves, respectively. Based on the physiography, the Hill region has the highest number of caves, with 136 caves. Likewise, Middle Mountain, Siwalik, High Mountain, and Tarai regions have 34, 26, 25, and one caves, respectively (Figure 3). Among these caves, many caves such as Chamere Cave, Mahendra Cave, Siddha Cave, Manjushree Cave, etc., are already established as show caves. A study has underscored that still there is much potential for the opening of new show caves for economic development, mainly in developing countries (Chiarini *et al.,* 2022). In addition, another study also concluded that show caves play a significant role in economic development by conducting tourism activities, however, the natural karst environment transforms into show caves, which damages the cave environment (Cigna *et al.,* 2000). Therefore, a study has pointed out that show cave should address on environmental protection as well as safety for the cave visitors. In the case of Nepal, there are still several caves that need to open for show caves to promote sustainable tourism, scientific research, geological study, recreation, job creation, and income generation. A study has highlighted that to get aforesaid benefits from show caves about 9 caves were observed as eligible and they were initiated to be established for show caves in Pokhara Valley, Nepal (Wasti & Acharya, 2011).

Figure 3

Spatial Distribution of Caves in the Different Districts and Provinces.

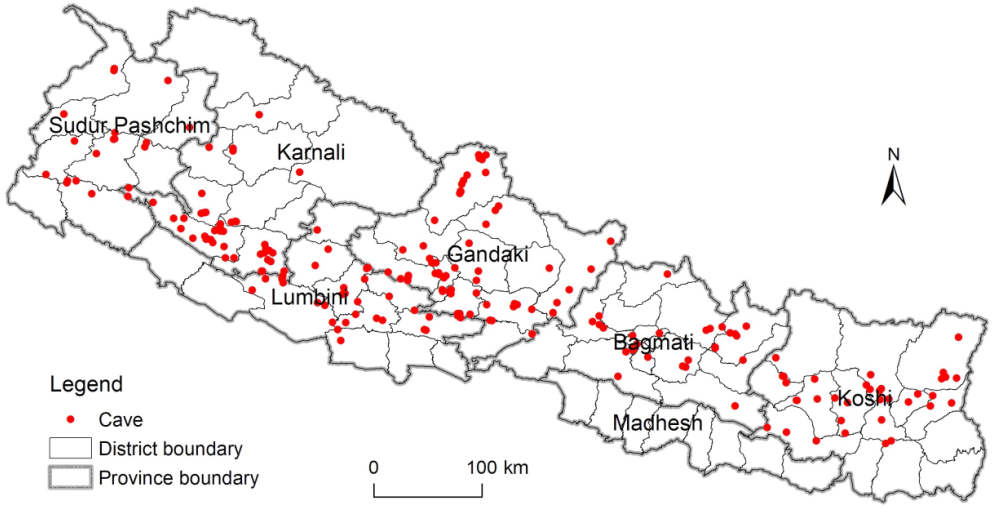
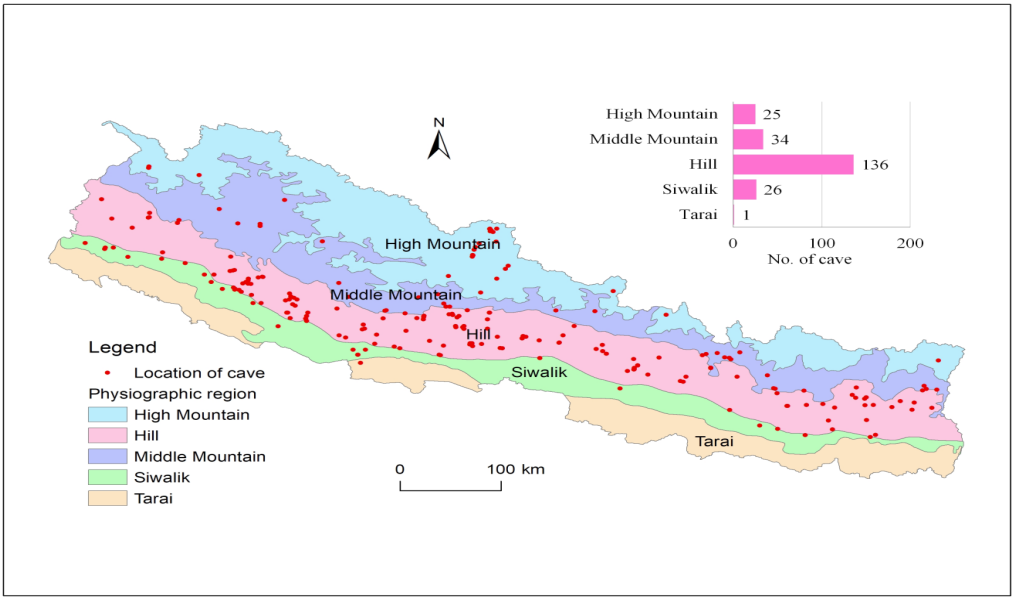


Figure 4

Spatial Distribution of Caves in the Different Physiographic Regions.



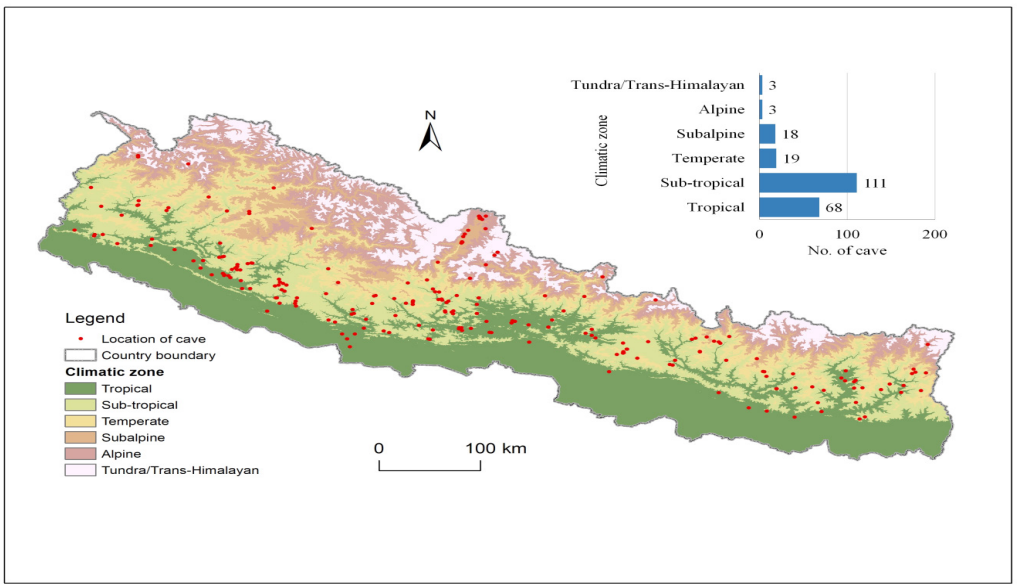
Climatic Zone

The climatic condition of a cave is determined by several factors such as rock type, elevation, the cave's size and structure, entrances, and the cave's geometry and aspect. However, the microclimate of a cave is affected by surface-level climate changes (Baniya *et al.,* 2023). In the temperate region, caves provide roosting and hibernating sites in the winter season and breeding places for some species in summer.

In reference of elevation, temperature and precipitation, the climatic zone of the country has been classified into six categories, such as tropical (land below 1000m elevation) (Nayava, 1975), sub-tropical (1000-2000m), temperate (2000-3000m), subalpine (3000-4000m), alpine (4000-5000m) and tundra/trans-Himalayan zone (more than 5000m) (LRMP, 1986; Paudel *et al.,* 2021). Predominantly, caves are(a total of 111) distributed in sub-tropical climatic zones with an elevation of 1000 to 2000 meters. Only 19, 18, 3, and 3 are distributed in temperate, subalpine, alpine, and tundra/ trans-Himalayan climatic zones, respectively (Figure 5).

Figure 5

Spatial Distribution of Caves in the Different Climatic Zones.

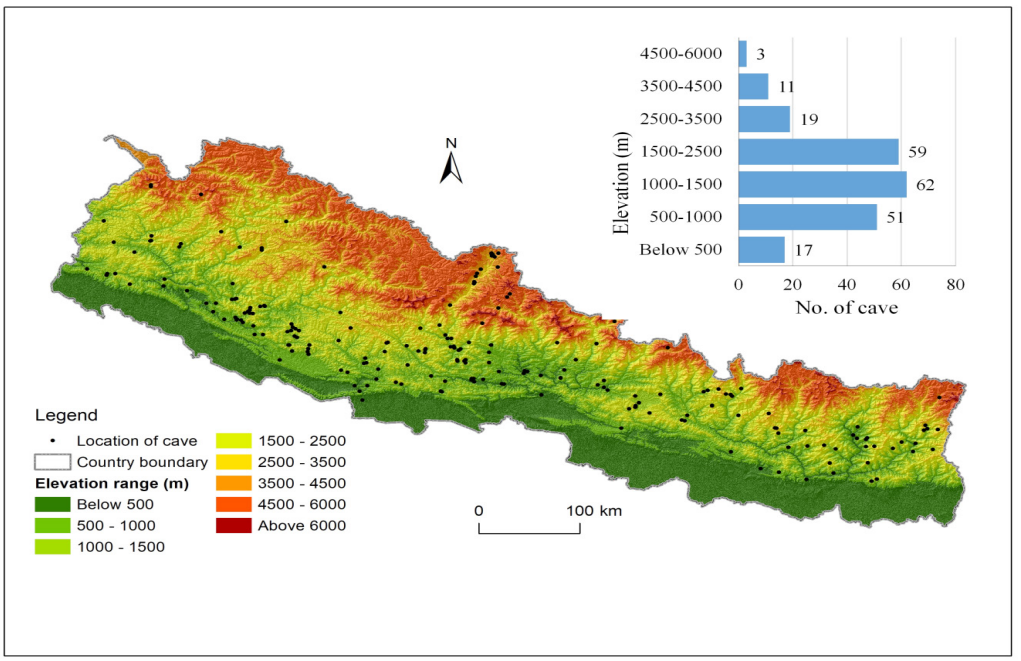


This study has analyzed the distribution of caves in each 500m elevation zone. Based on elevation, the caves are predominantly found between 500m to 2500m elevation zones.

A total of 62 caves are found in the 1000m to 1500m elevation zone. Only a few caves are noted from 2500m to 4500 m elevation zones in the country (Figure 6).

Figure 6

Spatial Distribution of Caves in the Different Elevation Ranges.



Geology of caves: Based on rock types, the caves are found in 15 different categories of rocks. Based on cave mapping over the geology of Nepal, predominantly, caves are found in slate, shale, siltstone, sandstone, and graphitic schist rock types within the country (Table 1). Likewise, based on geological formation, the Lesser Himalayan Sequence has more caves than other formations (Dhital, 2015). However, based on chemical action (Equation 1), caves were mainly formed in Carbonate band, Bhainsakati Fm, Markhu Fm or lime-silicate bands, Phulchouki group of KTM rock types.

Types of cave: Based on Davies and Morgan (1980), caves are classified into four types: solution cave, lava cave, sea cave, and glacier/ice cave. Solution caves are formed in carbonate and sulfate rocks such as limestone,dolomite, marble, and gypsum. Likewise, lava caves are formed by volcanic processes. A lava cave is formed when the outer surface of a lava flow cools and hardens. Similarly, a sea cave is a type of cave that is formed by the web action of the sea regularly hitting the weak parts of rocks of oceans

and large lakes. Erosion is the primary action forming a sea cave. The sea caves are still forming along the coastlines. Due to the landlocked country, there are no sea caves in Nepal.

Table 1

Number of Caves in Different Geology (Rock Type and Formation)

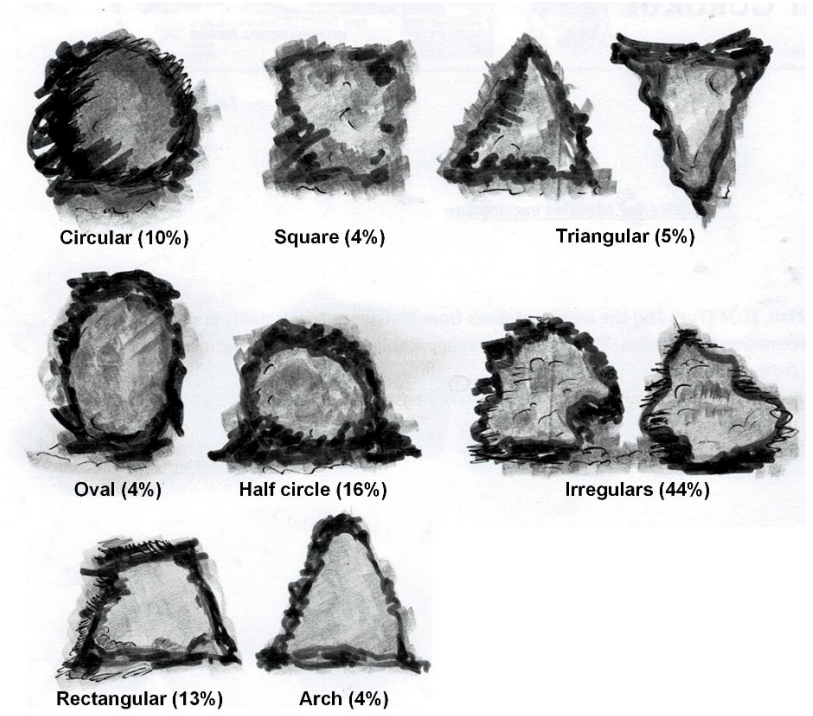
SN	Rock type	No. of cave
1	Carbonate band	19
2	Bhainsakati Fm	3
3	Tistung Fm	5
4	Higher Himalayan Gneiss	2
5	MarkhuFm or lime-silicate bands	1
6	Mesozoic	3
7	Phulchouki group of KTM	14
8	Phyllite, amphibolite, metasandstone, schist	42
9	Quartzite band	9
10	Schist, quartzite, gheiss and migmatite	23
11	Sediments of Tarai and Intermontane basin Fill	17
12	Siwaliks	30
13	Slate, shale, siltstone, sandstone, graphitic schist	45
14	Two-mica leucogranite	2
15	Ulleri and other Lesser Himalayan gneisses	7
	Total	222
SN	Geological formation	No. of cave
1	Higher Himalayan Crystallines	33
2	Intermontane Basin	17
3	Lesser Himalayan Sequence	125
4	Siwaliks	30
5	Tethyan Himalayan Sequence	17
	Total	222

The glacier/ice caves are formed within the ice of a glacier by melting water,which excavates drainage tunnels through the ice. Based on the above categories of caves by Davies and Morgan (1980), only solution and glacier/ ice caves are found in Nepal. Glacier caves can be found in Annapurna, Gokyo, Khumbu, Imja, and other Himalayan regions. An explorer also observed some ice glacier caves as large as 15m × 25m with considerable snow and water in the Kanchanjungha region (Mendez, 2009).

Cave Opening Shape: Based on the previous study, this study also classified caves into eight types of opening shapes such as circular, square, triangular, oval, half circle, irregular, rectangular, and arch (Mane & Manchi, 2017; Pambudi *et al.,* 2018). In this study, about 44% of caves look like irregular shapes; that have no actual geometrical shape. Likewise, about 16% of caves look like half-circle shapes followed by rectangles 13%, circular 10%, triangles, 5%, and arch 4%, oval 4%, and square 4%, respectively (Figure 7).

Figure 7

Cave Opening Shape (Based on Mane and Manchi, 2017)

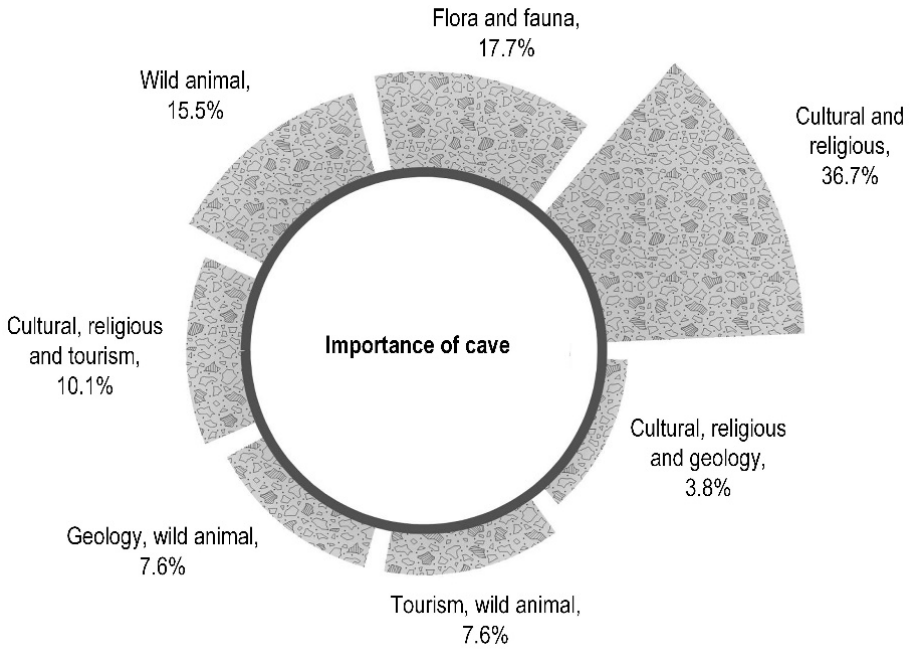


Importance of Caves: Every cave is important for various purposes including wild species, tourism, geological, cultural, and religious. About 36.7% of caves are analyzed for cultural and religious significance within the country. Likewise, about 17.7% of caves are important for flora and fauna. Similarly, other caves are important for various purposes, including wild animals, cultural, religious, tourism, and geological studies (Figure 8). Among them, some caves are important for spiritual and meditation, especially for Buddhist tourism. Spiritual tourism may help in economic growth and sustainability in countries like Nepal (Acharya & Rimpoche, 2023). Caves are traditionally accepted

as religious and cultural practices as well as adventure and wildlife study (Wasti & Acharya, 2011). In addition, caves are presently the foremost geotourism activity and an important economic source for several developing countries (Cigna & Forti, 2013). Supporting Cigna and Forti (2013), several caves in Nepal are being used for tourist purposes (Acharya *et al.,* 2010). Pokhara Valley has many popular caves and already started cave tourism activities (Wasti & Acharya, 2011). Siddha Cave, Sky Cave, Mahendra Cave, Chamare Cave (Bat Cave), and Gupteshor Cave are also performing cave tourism and supporting the economic source of these localities (Pokharel, 2017; Wasti & Acharya, 2011). Similarly, Ajanta, Ellora, Khandagiri-Udayagiri, and many famous caves in India also have been established as tourist destinations (Das *et al.,* 2007). Likewise, in Brazil, some caves are under destruction due to urban development and the exploitation of mineral resources (Ferreira *et al.,* 2022).

Figure 8

Classified of the Importance of Cave.



Popular Caves in Nepal

Sky Cave: The Sky Cave, also called Mustang Sky Caves, is located in the Upper Mustang along with Kali Gandaki River, near Kagbeni village. Long abandoned human-made caves are found on very steep cliffs, where it is dangerous to reach them. Some

researchers have already caved and found murals, statues, and manuscripts, which provide historical signs of people who lived in these caves. It is said that about 10000 artificial caves were constructed in the Upper Mustang area in the past. Many previous studies found that most of the caves of the Upper Mustang area were used as burial sites (Darnal, 2017; Mishra, 1994). Nowadays, some popular caves are being used as religious sites, museums,and show caves in this area (Khattri, 2023).

Siddha Cave: Siddha Cave is located in Tanahu district, which is the largest cave in the country and the second largest cave in South Asia (NTB, 2011; Sigdel, 2012) (Photograph 1). Visitors can see the rock formations, stalactites, and stalagmites, underground waterfalls, and streams inside the cave. The cave is also home to many bats and other creatures, which provides a unique ecosystem inside the caves. This cave hasa dark environment with several sub-trails, holes, and gorges resulting from the dissolution of limestone (Sigdel, 2012). The cave is about 0.5 km long and nearly 50m high. It can hold about 2400 people together inside. Around half an hour's walking distance can be found inside the cave (NTB, 2011). It offers the opportunity to observe dark environments and bats chattering. This cave also has a combination of natural beauty, adventure, and cultural significance.

Figure 9

Photograph1. Siddha Cave, Tanahu district(left) and Bat Cave, Pokhara (right).

Mahendra Cave: According to history, this cave was discovered by shepherds in the 1950s. After visiting King Mahendra Bir Bikram Shah, this cave was named Mahendra Cave. This is a popular cave developed below the course conglomerate of the cap-rock. The cave has two main alleys at the west and northeast,which are narrow and very dark(Koju & Chalise, 2012). The cave has recorded Hipposideros Pomona, Hipposideros armiger, Rhinolophusaffin is Rhinolophusmarcotis and Rhinolophusaffinis bat speciesatvarious times (Koju & Chalise, 2012).

Chamere Cave: Chamere Cave (Bat Cave) is located in Batulechaur of Pokhara Valley, which is about 800m west of Mahendra Cave, which provides watching bats and adventure cave walk (Adhikari & KC, 2008). It is 25m in length, about 9 mwide, and about 5m high. In this cave, Hipposideros armiger and Rhinolophusmarcotis were observed. In the roosting sites, the gap between the two bats was about 35 cm (Koju & Chalise, 2012).

Gupteswor Cave: This cave is located about 3km southwest of Pokharacity. The cave was developed by erosional processes such as chemical weathering on soluble limestone through outlet water from the Phewa Lake (Pokharel, 2017). It is known as the largest cave in Asia, which is 2959m long. In addition, the cave is also known as the longest cave in Nepal (Koju & Chalise, 2012). Among the present bats, only two species Hipposideros armiger and Rousettusleschenaulti were reported from the cave (Koju & Chalise, 2012). Likewise, Sita cave is also located in Pokhara Valley, which is near by Begnas Lake, 15km northeast(Koju & Chalise, 2012). The total length of the largest cave (Gupteshwor Mahadev cave, Pokhara) is 2959m long and which has five different entrances. The cave can be found in plain, stalactite and stalagmite (shelving) structures with some large and small circular pits can be found in the cave (Pokharel, 2017). A study has revealed that the cave size is determined by rock layer type, vegetation type and number of openings (Mane & Manchi, 2017). Likewise, in Nepal, the caves' sizesare varied based on their location.

Life in Cave

According to history, early humans lived during the Paleolithic(Old Stone Age)before 9000 B.C. Even today, some people are living in caves, such as in the Georeme Valley of central Turkey, Bushman of Africa, Veddas of Sri Lanka, and Tasadays of the Philippines (Das *et al.,* 2007). Likewise, early humans also used caves as shelter sites, human activity places and cultural sites in various places of Andes Mountain (Chile) (Dransart, 1997). Therefore, we also call them "cavemen" because they were our old ancestors who lived in the caves in ancient times (Das *et al.,* 2007). We can find human and animal footprints in some of the caves of Nepal. Some previous studies have observed that most of the caves were used by people as burial and religious sites in the Upper Mustang region (Darnal, 2017; Mishra, 1994). Even today, some caves are being used as museums and show caves in that region (Khattri, 2023).

Temporary Tenants in Cave

Caves provide suitable habitats for several plants and wild animals (Das *et al.,* 2007). Among the species, bats have largely been used as roosting sites in caves. However, some wild animals, such as lions, bears, wild cats, leopards, wolves, hyenas, etc., live near the

entrance to sleep, hibernate, and eat. In addition, some animals live in the daytime to clean claws and some birds, like South American oil-birds, owls,and jackdaws,also live in the caves (Das *et al.,* 2007). Besides these animals, civets also used limestone caves in Andaman and Nicobar Island, India, where a total of 13 civets' signs were found in 314 surveyed caves from the Islands (Mane & Manchi, 2018).

Permanent Inhabitants in Cave

Many wild animals, such as salamanders, crayfish, insects, and spiders, also live permanently in caves. Caves provide important benefits to bats, which protect against extreme weather, reduce predation risk, and manage thermoregulation due to gathering in large numbers. The cave animals are primarily carnivorous, and they prey on each other. The bodies of cave animals are modified in various ways to make suitable habitats in the cave. Only a few fungus plants can survive underground without sunlight (Das *et al.,* 2007). Most studies have been carried out on bat species in Nepal rather than other animals and plants.

A study has found the best seasonal roosting site for fruit bats in Karuna Bat Cave of Baglung district of Nepal, with probably the largest population observed,around 400 individuals from mid-summer to autumn (Bhattarai *et al.,* 2022). Likewise, Kaligandaki Canyon (the deepest gorge in the world) also studied the various small 20 caves by roosting count surveys for bat species. A total of 13 individual bats were counted from 20 caves (Sharma *et al.,* 2020). Similarly, a study was also carried out in Kailash cave (located in 1130m elevation) of Syangja district. The cave is famous for Hindus for holy bathing during the Shivaratri festival. In addition, this cave also found the roosting site for three species of bats: *Hipposideros armiger, Miniopterusschreibersii* and *Myotiscsorbai,* with 240 individuals (Thapa & Thapa, 2010).

Actually, Pokhara Valley is a suitable habitat for bats due to topographical features and climatic conditions(Adhikari, 2008; Koju & Chalise, 2012), where Chamero Cave observed 94.57 per square meter population of *Pteropusgiganteus* (Koju & Chalise, 2012).A study has recorded a total of 11 bat species (fruit bats and insectivorous bats) from Pokhara Valley in 2005, such as *Pipistrellusjavanicus, Pteropusgiganteus, Megadermalyra, Hipposiderospomona, Cynopterus sphinx, Rhinolophuspusillus, Rousettusleschenaulti, Scotophilusheathii, Myotisformosus, Myotismuricola, Myotissiligorensis, and* (Adhikari, 2008). Likewise, a study also identified eight species with 116 bat individuals in Kaski and Palpa districts in 2009 (Adhikari, 2010). Likewise, Palpa district has recorded eight species such as *Hipposideros armiger, Miniopterusschreibersii, Rhinolophusaffinis, Rhinolopuspearsonii, Rhinolophusferrumequinum, Pisistrellus tenuis, Pteropusgiganteus*and *Cynopterus*

sphinx (Adhikari & Karki, 2010). A historical study already reported 30 subspecies of bats from *Pteropodidae, Emballonuridae, Magadermatidae, Rhinolophidae, and Hipposideriadae* from Nepal (Csorba *et al.,* 1999). A recent study studied in bats in Nepal,out of 53 species of bats, 44 species were found in 12 protected areas of the country, where the Annapurna conservation area reported the highest species richness; there are 22 species. The study concluded that the protected area covers only 12% of the national bat (Thapa *et al.,* 2021). Not only bat species, other species are also recorded from the caves of the country. A newspecies of *Pseudophanias* Raffray was recorded from the Mahendra Cave in 2015 (Yin *et al.,* 2015).

Importance and Challenges for Cave Species

Bats are permanent tenants of caves. They are also known as pest and disease controllers (Acharya *et al.,* 2010; Riccucci & Lanza, 2014). They are very useful because they feed several harmful agricultural pests as their diet (Riccucci & Lanza, 2014). They also help to minimize the spread of some diseases, such as Dengue, Encephalitis, Malaria, Japanese Encephalitis, and Kala-azar by feeding mosquitoes and flies. In addition, carnivorous bats (Megadermalyra) eat rats, which helps to minimize the economic loss of grains during harvesting time (Acharya *et al.,* 2010). Moreover, they have an important role in ecosystems and they are a prey species for other animals. Fruits-eating bats such as *Pteropusgiganteus*, *Cynopterus sphinx* and *Rousettusleschanaultii have played a role as* Pollinators and seed dispersers for several fruits such as Papaya, Banana, Mango, Litchi, Amla, Kathar, Palm, etc. In addition, they also pollinate and disperse seeds of several plants such as Peepal, Kadam, Eucalyptus, Neem, Chiuri, Rudrakshya and many more (Acharya *et al.,* 2010). Likewise, a study has analyzed that bats have been playing an important role in ecosystem services, such as controlling pests in Brazil (Ferreira *et al.,* 2022). In Nepal, bat species represent almost a quarter of all mammal species. About 10% of bat species are considered as Threatened, with a further 6% being Near Threatened (Jnawali *et al.,* 2011). Bat is also used as medicine, such as making bat oil to ear drops to expel ear bugs and restore lost hair and paralyzed limbs, which is used by the Newar community in Nepal (Tuladhar-Douglas, 2008).

This study found caves with suitable habitats for bats in 56 districts of the country. However,bat conservation is a rare practice in Nepal. The bat habitat is threatened due to the deforestation of primary forests, which are also suffering from a lack of protection of roosting sites (Jnawali *et al.,* 2011). In addition, structural construction such as buildings above the cave, vibrate of heavy vehicles near cave, water erosion, and lack of proper management of waste management around the caves including Chhorepatan Cave, Gupteshor Cave and Mahadevsthan Cave area are challenging to the Cave environment (Pokharel, 2017).

Likewise, global climate change and anthropogenic activities have also resulted in the primary causes of the decline of cave bats in Europe and North America, which has alarmed serious concerns. In Nepal, some organizations have been working on bat research, such as the Natural Resources Research and Conservation Center, Small Mammals Conservation and Research Foundation, Bat Friends, Nature,and others. In addition, conservation awareness programs on the radio and in the newspaper have been launched in some local areas. However, extensive research and studies on awareness need to be carried out in various parts of the country (Adhikari, 2009).

Caves are used by adventures, scientists and speleologists (cave scientists) to understand the earth's geological process. Likewise, the study of caves may help to scientists to understand the biodiversity, conservation and ecosystems of the cave. Caves provide habitats for several important organisms and creatures. Still, thousands of cave species have lack of proper description and they are waiting for discovery (Ferreira *et al.,* 2022). Nowadays,in Nepal and several other countries such as India (Debata, 2021; Pandey, 2018), Korea (Kim *et al.,* 2008), and China (Jin *et al.,* 2012) the cave is being used for tourism activities. Several caves in the world are used for tourism purposes and established as tourist destinations (Acharya *et al.,* 2010; Das *et al.,* 2007). However, the bat habitat is under threat by habitat loss and disturbance by humans for the development process and their activities in Nepal (Koju & Chalise, 2012) and Brazil (Ferreira *et al.,* 2022). In addition, climate change and hunting for meat by some communities also pose an important threat to bat habitats in the world. Thus, studies on caves, bats, and cave environments have not been sufficiently studied (Jnawali *et al.,* 2011).

Conclusion

This study analyzed the spatial distribution of caves in Nepal and the cave species. There are 222 caves located within the country. Predominantly, caves are found in the Gandaki province of Nepal, where about 60 caves are located with various bat species. Among them, some are show caves specifically for tourism purposes. Based on the physiographic region, the Hill region has the highest number of caves, with 136 caves. Caves are not only attractive to people; some caves have significant meaning and they have played an important role in human history that needs to be studied in detail.

Gupteshor Mahadev Cave, Mahendra Cave, Chamare Cave (Bat Cave), Siddha Cave, and Sky Caves are the most famous for show caves that have been made habitat by various bat species and conducting tourism activities. Still, there may be several caves within the country that need to be researched and explored for bat-friendly cave conservation actions and study of geological formation. In addition, caves are needed to be spatially mapped to promote and explore the caves. The increasing tourism activities in caves are

challenging to bat species and protection. The proper cave policy and management are needed for the cave environment. Thus, this study recommends the regulation of cave tourism and a halt to tourism-related development in and around the caves. In addition, the caves need to be studied based on geological formation, such as rock type, cave size, and cave type for a better understanding of the biotic and abiotic factors inside caves.

References

Acharya, P. R., Adhikari, H., Dahal, S., Thapa, A., & Thapa, S. (2010). Bats of Nepal. *A Field Guide*, 1-63.

Acharya, S., & Rimpoche, C. N. (2023). Sustainability of Buddhist tourism in Nepal: A case study of Asura Cave. *Journal of Tourism and Sports Management*, *5*(2), 1444-1455.

Adhikari, B. R., & Ojha, R. B. (2021). Geology and physiography. *In:* R. B. Ojha, Panday, D. (ed.), *The soils of Nepal.* Springer, Cham, pp. 29-39.

Adhikari, H. (2008). Bat species richness and their distribution in Pokhara valley of Nepal. *The Initiation*, *2*(1), 43-48.

Adhikari, H. (2009). Bats of Nepal. *Small Mammal Mail*, *1* (Aug-Dec), 9-16.

Adhikari, H. (2010). Species richness, distribution, and threats of bats in Palpa and Kaski District of Western Nepal. *Small Mammal Mail*, *2*(2), 14-22.

Adhikari, H., & Karki, L. (2010). Research and conservation awareness of bats in Palpa district of Nepal. *Small Mammal Mail*, *2*(1), 33-35.

Adhikari, H., & KC, M. (2008). One day training programme on bats, organized at Bat Cave, Pokhara, Nepal. *BAT NET- CCINSA Newsletter*, *9*(Jan-July), 1-3.

Baniya, S., Neupane, K., Thaker, M., Goswami, V. R., & Ramachandran, V. (2023). Springing into caves: The dynamics of cave roost use by bats in the Central Himalayas of Nepal. *Research Square*, 1-26.

Barros, J. S., & Bernard, E. (2023). Species richness, occurrence and rarity of bats in Brazilian caves. *Austral Ecology*, 1-27.

Bhattarai, P. K., Sharma, B., Ghimire, S., Sharma, S., & Bhattarai, B. (2022). A note on bat faunal assessment in Karuna bat cave, Baglung, Nepal. *Mammalia*, *86*(6), 585-590.

Chiarini, V., Duckeck, J., & De Waele, J. (2022). A global perspective on sustainable show cave tourism. *Geoheritage*, *14*(3), 14-82.

Cigna, A., Cucchi, F., & Forti, P. (2000). Engineering problems in developing and managing show caves. *Journal of Nepal Geological Society*, *22*, 85–94.

Cigna, A. A., & Forti, P. (2013). Caves: The most important geotouristic feature in the world. *Tourism Karst Areas*, *6*(1), 9-26.

Csorba, G., Kruskop, S., & Borissenko, A. (1999). Recent records of bats (Chiroptera) from Nepal, with remarks on their natural history. *Mammalia*, *63*(1), 61-67.

Culver, D. C., Hobbs III, H. H., Christman, M. C., & Master, L. L. (1999). Distribution map of caves and cave animals in the United States. *Journal of Cave Karst Studies*, *61*(3), 139-140.

Darnal, P. (2017). Significant heritages of Upper Mustang and issue of conservation. *Dhaulagiri Journal of Sociology Anthropology*, *11*, 1-23.

Das, M., Goswami, S., & Guru, B. (2007). Caves and Caverns. *Everyman's Science*, *XLI*(6), 392-396.

Davies, W. E., & Morgan, I. M. (1980). *Geology of Caves*. U. S. Department of the Interior.

Debata, S. (2021). Bats in a cave tourism and pilgrimage site in eastern India: Conservation challenges. *Oryx*, *55*(5), 684-691.

Dhital, M. R. (2015). *Geology of the Nepal Himalaya: Regional perspective of the classic collided orogen*. Springer.

Dransart, P. (1997). Rockshelters and ritual activities in the Atacama desert of Northern Chile. *Bar International Series*, *667*, 207-216.

Ferreira, R. L., Bernard, E., da Cruz Júnior, F. W., Piló, L. B., Calux, A., Souza-Silva, M., Mammola, S. (2022). Brazilian cave heritage under siege. *Science*, *375*(6586), 1238-1239.

Jin, P., Fu, Z., & Ban, M. (2012). Karst cave tourism system in Zhejiang Province based on resource regional analysis. *Chinese Geographical Science*, *22*, 496-506.

Jnawali, S., Baral, H., Lee, S., Acharya, K., Upadhyay, G., Pandey, M., . . . Admin, R. (2011). *The Status of Nepal Mammals: The National Red List Series*.

Khattri, M. B. (2023). The trans-himalayan livelihood: Opportunities and challenges in tourism development in Upper Mustang, Nepal. *Journal of Tourism and Adventure*, *6*(1), 18-38.

Kim, S. S., Kim, M., Park, J., & Guo, Y. (2008). Cave tourism: Tourists' characteristics, motivations to visit, and the segmentation of their behavior. *Asia Pacific Journal of Tourism Research*, *13*(3), 299-318.

Koju, N. P., & Chalise, M. K. (2012). A brief study on bats of Pokhara Valley. *Journal of Science and Engineering*, *1*, 33-37.

LRMP. (1986). *Land systems report*. Land Resource Mapping Project; Government of Nepal and Government of Canada.

Mane, A. M., & Manchi, S. S. (2017). Physical and environmental characteristics based classification of the caves of the Andaman Islands. *Ambient Science*, *4*(1), 82-87.

Mane, A. M., & Manchi, S. S. (2018). Civets in the Limestone Caves of Andaman Islands: Notes on the Distribution and Natural History. *Ambient Science*, *05*(1), 6-10.

Mendez, J. (2009). *Glacier caves.* ICIMOD, Kathmandu, Nepal. https://lib.icimod.org/record/14442

Mishra, T. N. (1994). The archaeological research in the High Mountains of Mustang district: An assessment of the situation. *Ancient Nepal*, *136*, 147-160.

Nayava, J. L. (1975). Climates of Nepal. *The Himalayan Review*, *VII*, 9-12.

NTB. (2011). *Paradise Pokhara*. Nepal Tourism Baord.

Pambudi, R. A., Damayanti, A., & Marko, K. (2018). Distribution pattern of cave entrance based on morphometry in Gunung Sewu karst landscape. E3S Web of Conferences, EDP Sciences.

Pandey, U. (2018). Cave tourism in the heart of India: A study of Madhya Pradesh. *Journal of Emerging Technologies Innovative Research*, *5*, 831-840.

Paudel, B., Pandey, D., & Dhakal, K. (2021). Climate. *In:* R. Ojha & D. Pandey (eds.), *The soils of Nepal*. Springer, Cham.

Paudel, P. K., Bhattarai, B. P., & Kindlmann, P. (2011). An overview of the biodiversity in Nepal. *In:* P. Kindlmann (ed.), *Himalayan biodiversity in the changing world*. Netherlands: Springer Verlag, pp. 1-40.

Pokharel, R. P. (2017). Possibility of overall utilization of mysterious Gupteshwor Cave in Chhorepatan, Pokhara and its management strategies. *Kalika Journal of Multidisciplinary Studies*, *I*, 39-48.

Riccucci, M., & Lanza, B. (2014). Bats and insect pest control: A review. *Vespertilio*, *17*, 161-169.

Sharma, B., Subedi, A., Baniya, S., Ghimire, P., Bist, B., Bahadur, B., Acharya, P. (2020). A preliminary assessment of the caves and bats in Kaligandaki Canyon. *Bat Research & Conservation*, *13*(1), 74-87.

Sigdel, T. P. (2012). Prospects of ecotourism in Bandipur. *The Third Pole*, 50-55.

Thapa, A., & Thapa, S. (2010). A short note on chiropteran status from Kailash cave, Syangja district, Western Nepal. *Lifescience Journo-Magazine*, *2*(1), 1-7.

Thapa, S., Dahal, D. R., Ghimire, R., Baral, R., Yadav, B., Lamichhane, B. R., Yi, W. (2021). Occurrence of bats in protected areas of Nepal: An update on species richness and distribution records. *Nepalese Journal of Zoology*, *5*(2), 68-85.

Tuladhar-Douglas, W. (2008). The use of bats as medicine among the Newars. *Journal of Ethnobiology*, *28*(1), 69-91.

Wasti, D., & Acharya, P. R. (2011). Cave tourism an emergent opportunity: A case study in caves of Pokhara Sub Metropolitan City, Nepal. Asian trans-disciplinary karst conference 2011,

Watson, J., Hamilton-Smith, E., Gillieson, D., & Kiernan, K. (1997). *Guidelines for cave and karst protection*. IUCN- The World Conservation Union, Cambridge, UK.

Yin, Z.-W., Coulon, G., & Bekchiev, R. (2015). A new species of Pseudophanias Raffray from a cave in central Nepal (Coleoptera: Staphylinidae: Pselaphinae). *Zootaxa*, *4048*(3), 446-450.

Annex 1
Some Famous Caves in Nepal

Ice cave of Himalaya region, (Mendez, 2009)

Khumbu glacier ice cave: source; https://www.travelblog.org/Photos/714825

Sky Cave, Mustang

Replace with

बराहा गुफा, वडा नं. १, अर्जुन चौपारी गाँउपालिका

Baraha Cave, Syanja

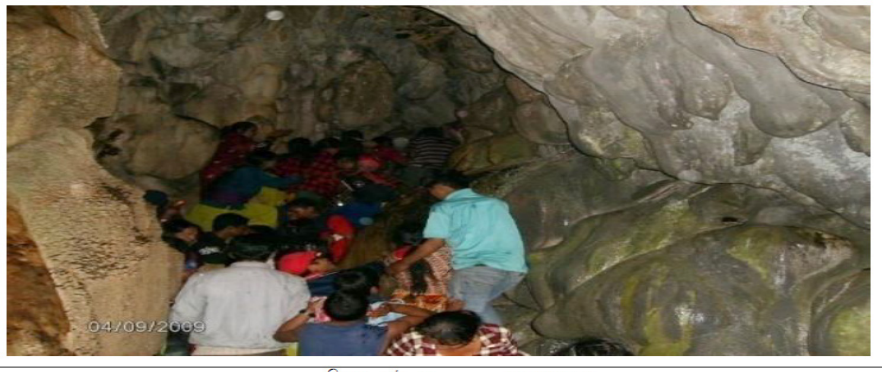
चित्र नं. २ : अकालदेवी मन्दिर, डेढगाउँ

चित्र नं. ३ : अकालादेवी गुफा, डेढगाउँ

Akaldevi Cave, Nawalparasi East

क) गौमुखी

गौमुखी गाउँपालिकाको पर्यटकीय स्थलहरु मध्ये गौमुखी पनि एक महत्वपुर्ण स्थल हो । झिम्रुक धर्मावती) नदीको उद्गमस्थल समेत रहेको यस स्थानमा एउटा गुफामा रहेको गाईको मुखजस्तो भू- आकृतिबाटप्राकृतिकरुपमा अनवरत पानी निक्लीधर्मावती नदीकोरुप लिने गर्दछ । गाईको मुख जस्तो भू- आकृतिबाट पानी निस्कने भएकोले पनि यसलाई गौमुखि भन्ने गरिएको जनश्रुति छ ।



चित्र नं. १. गौमुखी गुफा

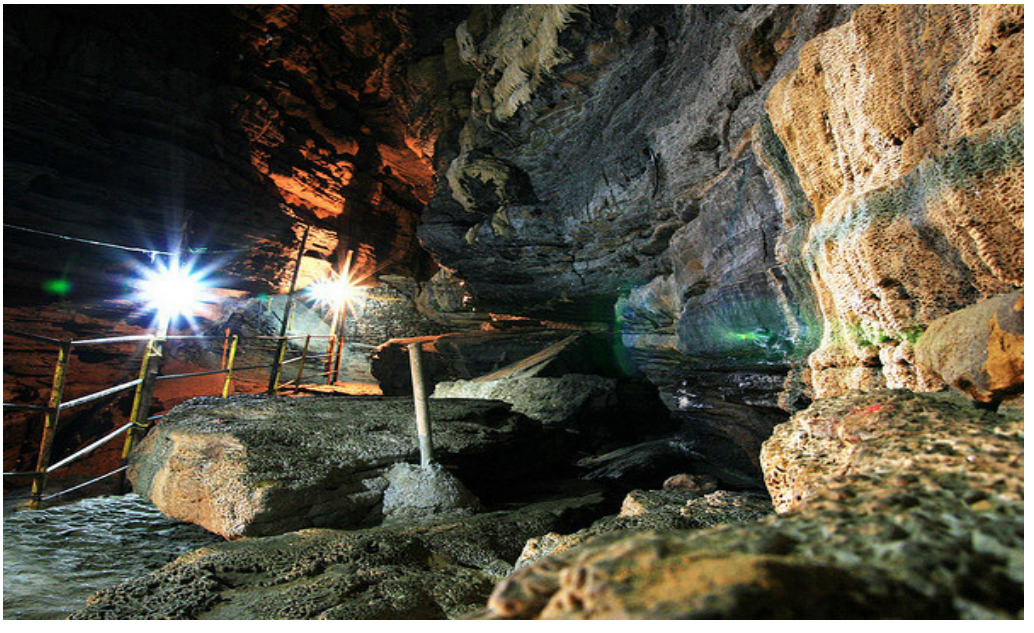
लक्ष्मीको प्रतीक मानिने गाईको आदर सम्मान गर्ने हिन्दू परम्परा रहेकोले यस स्थानलाई पवित्र

Gaumukhi Cave, Pyuthan

उत्खनन् एवम् प्रचलनमा आएको गाउँलेहरूको श्रुतिकथाबाट बुझ्नमा आएको छ ।

सिद्ध गुफा भित्रको तस्बिर

Siddha Cave, Salyan



Mahendra Cave, Pokhara