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Assessment of the Development of Geotourism and Ecotourism in the Pokhara Valley, Nepal

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Abstract

This project was conducted in Pokhara, Nepal, to find the potential of geoheritage sites and to supply avenues for sustainable development and education. We assessed five tourist locations on their potential for geotourism and seven sites for their ecotourism practices. The geotourism quantitative assessment and degradational risk assessment used a survey developed by Brilha (2016). A modified version of the questionnaire created by Baral et al., (2012) was used to evaluate locations for their ecotourism ability in combination with the 5 general Principles of Ecotourism. The study appraised Pokhara for its geodiversity, geological heritage, and ecological conservation in line with UNESCO's list of attributes for aspiring Geoparks (aUGGp). These areas had high scores in geological diversity and geosite potential that may benefit from increased resources to support overall geological education and conservation as an aspiring UNESCO Global Geopark. This study aims to provide resources for tourists at these tourist locations with information on relevant geologic morphology, lithology, eco-conscious procedures, and conservation mitigations, as well as geo- and cultural history. The infographics included in the supplemental materials also aims to educate tourists on how to better take part in geotourism and conservation efforts in the Pokhara Valley of Nepal.

Keywords: geotourism, ecotourism, geomorphology, natural resources and conservation, anthropology cultural

Introduction

Hazards of Nepal's geology are at the forefront of public knowledge, scientific research, and media outreach because of their relevance as a threat to human life. However, while the geohazards of Nepal threaten lives and infrastructure, other aspects of geology can be utilized by its people to promote sustainable economic growth. In addition to financial benefits, there is a need for geologic education for Nepal's public and tourists. In a country with such a diversity in altitude, earth processes are further relevant to everyday human life and culture. Scientists, students, and the general public alike can participate in these benefits of knowledge and wealth because of the advantageous location of their home and its geologic exceptionality.

This study will focus on the Pokhara Valley area, the tourist capital of Nepal. This city shows huge geologic diversity, from far-off mountainous views to small-scale variations in strata. The science behind these sites, however, often falls to the tour guide to explain or to tourists to discover on their own. It would be beneficial to the tourist industry and citizens to have

ecotourism has to contribute minimal impact on ecosystems and to the local community's economy, as well as respect for the local culture" (Yuwono, Eko et al., 2020). Conservation of the natural land is only part of ecotourism. Sustaining the local community, such as their cultural and religious sites, is another critical part. These ideals and the five pillars (Table A1) that are expected of an ecotourist location are used in the criteria for analyzing each tourist site. In addition to geotourism potential, this study hopes to evaluate the locations on their current conservatory, sustainable, and eco-friendly applications and mitigation methods and their effectiveness.

Research questions

What are the important geological attributes of each site for tourists and the public's education? How is ecotourism being advertised and upheld on each site? What principles are being utilized and what mitigation methods are performed to ensure the area remains an ecotourist site? Do these locations offer a diversity of amenities to conservation range? What is the geotourism potential in this area and does this area as a whole fit into UNESCO's geopark requirements?

Research method

At each site, geological information such as mineralogy, morphology, and structures was gathered using standard field techniques. Fieldwork was aided by a literature review to create a concise story of the natural history of the site. Geological figures and graphics were created using Microsoft software.

Analytical data for geoheritage potential and risk were found for each site using the quantitative assessment of geosites rubric (Table A2), which was originally published in *Geoheritage*. This allows more objective research about these sites' potential for educational and recreational uses. The researchers generally ranked each of these characteristics from 1 to 5, with 1 being the least optimal for education/tourism and 5 being the most optimal. As Nepal has a particularly strong potential for risks, a degradation Risk Assessment from the same source was included (Table A3).

The information obtained for the ecotourism assessment was how each site performs and adheres to the Principles of Ecotourism. This included evaluation through yes or no questions for amenities offered at the tourist sites (Table A4) and a ranking of 1 through 5 on the availability of certain eco-friendly, tourism-focused criteria (Table A5). Averages were calculated from a list of predetermined questions that encompass the principles of ecotourism and each site's conservation methods. The researchers used a modified rendition of the questionnaire created by Baral, et al., to determine amenities offered and ecotourism criteria met at each location. A modified version was used because there does not appear to be a universal and official scale to determine if an organization, company, or location qualifies as an ecotourist site. It is important to note that the scale and criteria used for all the amenities (Table A4) are weighed equally as either having an amenity (yes) or not having it (no) within the Amenities Rating Scale (ARS). If an area exhibits one method of Leave No Trace principles being used or one accessibility procedure, it is weighed equally to a location that may have two or more procedures implemented at the site.

The criteria within the Ecotourism Rating Scale (ERS) is based on a 1 to 5 scale with a rating of 1 meaning there are poor or no conservation/sustainability aspects, and 5 meaning there

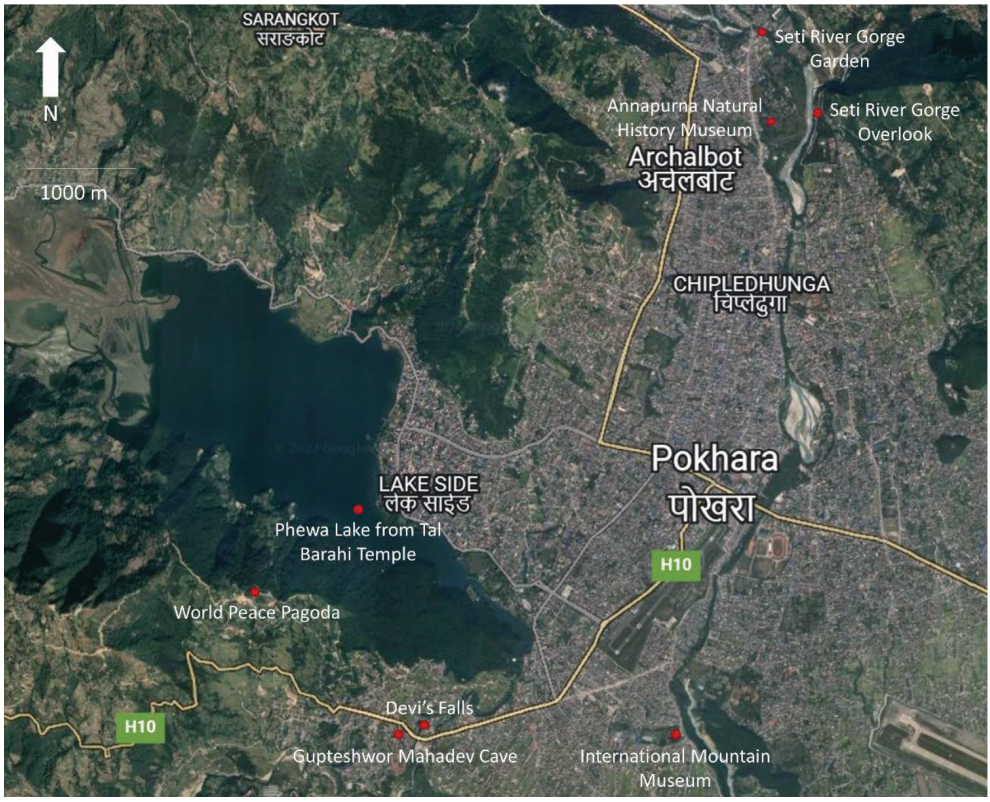
are great or near-perfect sustainability aspects. These location ratings were completed as accurately as possible by the researchers, though it is evident that interpretation and perceptual errors particularly of foreigners in an area can and do occur during analysis.

Results

The intramontane valley of Pokhara draws tourists from around the world with its cultural heritage sites, beautiful mountain views, and active lakeside neighborhood. It also houses a variety of locations that are prime areas for observing sedimentary structures, massive debris deposits, large geomorphologic formations, karstification, and river processes. This variety of geologic features makes geotourism in Pokhara a massive prospect, with the entire region having the potential to be a UNESCO geopark in the future.

Figure 1

Map of the site locations



Note: Google Earth image, 2022

Table 1

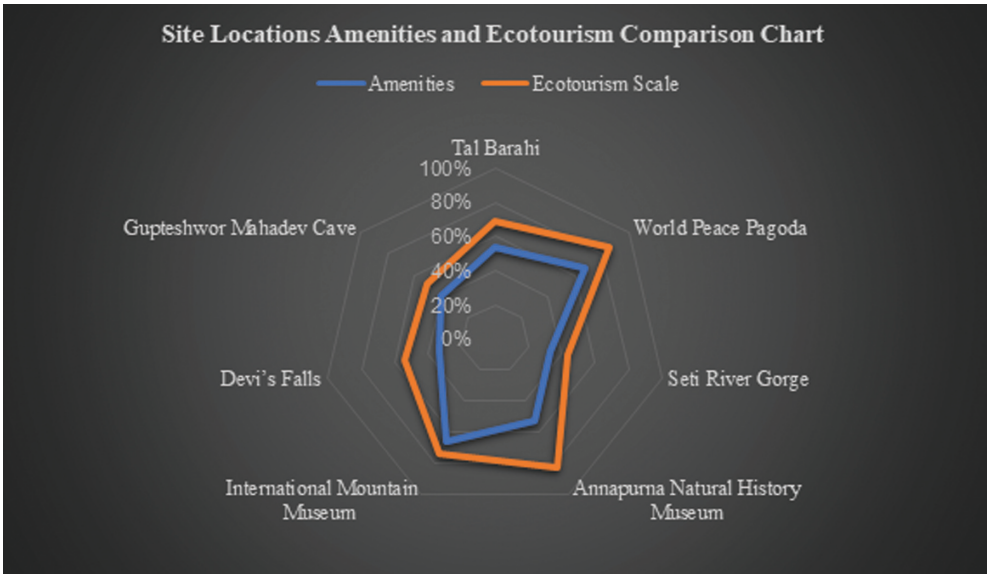
Final scores for each site

Site Name	Geotourism Assessment Score (100 is the most potential, 0 being the least)	Risk Assessment Score (100 as least risk, 0 as most risk)	Amenities Rating Scale (ARS; 0 as least offered, 100 as most)	Ecotourism Rating Scale (ERS; 0 as least eco, 100 as most)
World Peace Pagoda	88%	70%	67%	86%
Phewa Lake/Tal Barhi	79%	40%	53%	69%
Seti River Gorge	78%	66%	33%	43%
Devi's Falls	81%	61%	33%	54%
Gupteshwor Mahadev Cave	82%	51%	40%	51%
Annapurna Museum	N/A	N/A	53%	83%
International Mountain Museum	N/A	N/A	67%	74%

Note: Gilbert and Landsem, 2022

Figure 2

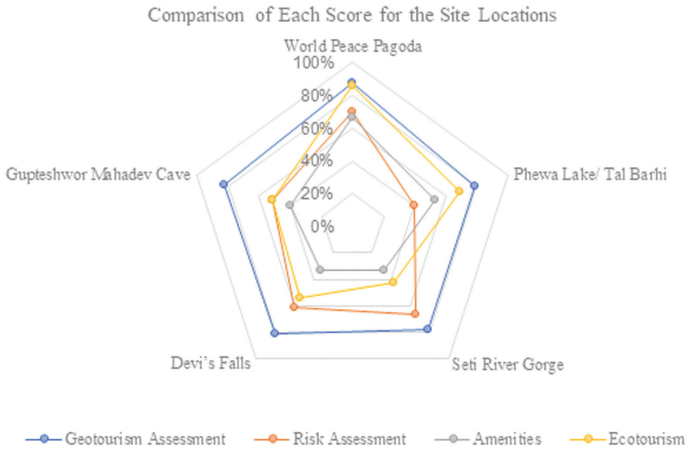
Site locations amenities and ecotourism comparison chart



Note: Gilbert and Landsem 2022

Figure 3

Comparison of each score for the site locations



Note: Gilbert and Landsem, 2022

Locations

World Peace Pagoda

Figure 4

World Peace Pagoda view

Note: Gilbert and Landsem, 2022

The first observed site was the World Peace Pagoda, situated just under 1000 meters on the south side of Phewa Lake. Geologic features noticeable on the hike up to this site are phyllite outcrops and landslide scarps from residual soils. From the top, the glaciated Annapurna Range can be viewed, the Harpan Khola Floodplains near Phewa Lake, terraces, as well as larger-scale landslide scarps. On the Geosite Assessment Scale, the area received 88% (Table 1). The most highly-ranked attribute of this site was the scenery, with a view of the Annapurna Range and many large-scale geomorphological features that surround the Pokhara Valley. In addition, the Pagoda is a well-established site for pilgrimages and tourism as it enshrines relics of Lord Shakyamuni Buddha. This association with cultural values allows for more outreach of tourists, whether they hike to this site for the beautiful pagoda or the overlook of Pokhara and its geology.

While the scenery adds geological heritage to this site, the accessibility of this uphill site will deter tourists, especially elderly or disabled tourists. There is also a risk for deterioration in

each location – in this case, the Risk Assessment Scale was moderate to low at 70% (Table 1). The main risk is landslides in the weathered outcrops and water-logged soils surrounding the hike. The gabion levee mitigation of these slopes and the upkeep of the monument lessens the risk these slopes are to those who visit this site. The majority of the hike up appears to be well preserved and sustained, with minimal urban development, allowing the tourist to be almost fully enveloped by the forest. While this site is difficult to reach by walking, there were aspects of the hike up the mountain that were noted for their accessible attributes. These included some handrails (an ongoing installation) and resting locations. Along the path to the World Peace Pagoda, trashcans were frequently spaced along the durable-surfaced trail that minimized off-trail walking. These were provided and possibly maintained by a local boating company. Once at the top of the Pagoda, signs about the cultural significance and the history of the Lord Buddha were in both English and Nepali. There were also signs displaying Leave No Trace principles, such as enforced observed silence for consideration to pilgrims and signs saying to not pick flowers or otherwise disturb wildlife. The area was free to enter for tourists and locals, though donation boxes were available. Solar panels at the top of the mountain around the pagoda were also observed. These operations made this area a good choice for an ecotourist interested in the cultural tourism of Pokhara. For the Amenities Rating Scale (ARS) average, the World Peace Pagoda scored 67% (Table A4), and the Ecotourism Rating Scale (ERS) averaged 86% (Table A5).

Phewa Lake

Other case studies of the Geosite Assessment Scale of Pokhara brought scores close to 80%. Phewa Lake is incredibly accessible, surrounded by a bustling tourist district on one side, with cultural and recreational areas perched on top of the hills that flank it. This proximity to other sites is a huge benefit to developing tourist areas. The measurement of this development potential is 79% (Table 1). However, the ability to access this site easily makes it more at risk of degradation and pollution from the dense population around it. Phewa Lake is a fragile ecosystem, with many other processes depending on its health, giving it the most amount of degradation and risk potential for the geosite case studies observed. It is important that, if further developed for geological tourism, this site promotes sustainable practices and educates readers on the fragility of the lake.

Figure 5

Phewa Lake

Note: Gilbert and Landsem, 2022

The island that exists within Phewa Lake is home to a temple that is culturally important to many within the Hindu religion. Tal Barahi Temple which was one of the first sites studied for its ecotourism ability is only accessible by boat, and no motorized boats were observed at the time of the study. Some pre-planning procedures may be necessary particularly during

Figure 6

Seti River Gorge overlook

(Gilbert and Landsem, 2022)

peak tourist season to hire a boating company, which may impede locals' ability to participate and worship freely. Tal Barahi Temple had signs about the legend of Phewa Lake, some information regarding the lake, and donors in Nepali. While arrival to the island on a boat may prove difficult for accessibility, the island did attempt to make its location accessible with signs, ramp access, handrails, and benches to rest on. Aside from hiring local companies to boat you to the location, the entrance to the temple and island was free and open to tourists and the public. There was a donation box next to the temple for anyone to give freely, potentially used for the upkeep of the temple and island. The area had some natural elements on the island such as planted trees and shrubs, birds, and a fish-watching area; however, the area was highly developed. All of these elements would benefit cultural tourists and locals, though do not benefit the ecotourism identity of the Tal Barahi Temple island. This leaves the average for the ARS of the island to be 53% (Table A4) by the researchers, and its ERS averaged to be 69% (Table A5).

Seti River Gorge

There are at least two locations that will be labeled as the Seti River Gorge area. The first area is the physical gorge as it relates to geotourism, whereas the second location is the location that many tourists will first approach in their search for the Seti River Gorge. The Seti River Gorge itself is a unique area in Pokhara that shows karstification, river erosional processes, and confluence between the Seti River and the Khola River. This site scored a 78%, with high scores in scenery and geologic diversity in the Geological Assessment Score.

The main risks to tourists of this area concern observing it closely – it is both not very accessible and the sheer sides of the gorge could produce falling rocks and other unsafe conditions for tourists. In regards to the site itself's safety, the degradation risk score was a 66%. This area is classified as high risk of subsidence, low load-bearing capacity, and sinkhole hazards, and the development of it could strain these systems and cause infrastructure or human damage (Koirala et. al, 1998).

Figure 7

Gupteshwor Mahadev Cave staircase

Note: Gilbert and Landsem, 2022

The location that the ecotourism and amenities scale covers is above the Seti River Gorge on Lamachaur Road at Tunnel 3. After paying a small entrance fee, this location was observed to have a small garden with two benches, one flight of stairs with handrails, and a short cement

bridge with water running parallel and in the bridge to Tunnel 3. Looking over the side of the bridge, the Seti River is visible through the gorge. The area does not have many negative impacts on the local people. It provides some funds with fees for the community and the upkeep of the area, as well as donations at the shrine at the end of the short bridge being accepted. This area does not do much towards the conservation of the area; however, it does help the community to keep one of their cultural sites open with the fees paid by tourists. The area was not large, nor did it have a lot of amenities for tourists giving it a lower scale of 33% for the ARS, and the lowest of the ERS at 43%.

Figure 8

Devi's Fall

Note: Gilbert and Landsem, 2022

Devi's Falls and Gupteshwor Mahadev Cave

These two geosites are in close proximity to each other and represent the plethora of formations that can be formed from karstic sediments. Devi's Falls was well-accommodated with optimal viewpoints of the falls, where the Pardi River plunges through the consolidated sediments into a 200-meter-long underground gorge (Fort, 2010).

Beds of 10 to 20 cm thickness are visible in this cave system. Gupteshwor Cave shows a variety of sedimentary structures in the bedrock. There were laminations and wavy bedding observed in the lower part of the cave wall at a thickness of about 30 cm. The middlemost section showed hummocky cross-stratification, with pinching and swelling 5 cm thick beds. Above this was lag gravel deposits of angular to sub-rounded clasts of pebble size. There were instances of wedges and other forms of cross-bedding in this section.

At Devi's Falls, while the erosion of these formations by water creates the unique formations opportune for tourism, their weakness can be a risk as well. The consolidated sediments of the Pokhara and Ghackok formations can be prone to translational slides and rock falls, as well as sinkhole and subsidence hazards (Koirala et al., 1998).

Besides safety for tourists, degradation of the site must be considered in their geoheritage assessment too. Gupteshwor Cave has low ceilings in some places with stalactites that tourists were observed touching. This can greatly damage the growth of stalactites and the overall health of the cave system. The risk of degradation of the Gupteshwor Cave site was found to be 51%, while Devi's Falls, much less accessible to vandalism, scored a 61%.

Upon paying a fee and entering the area, there were many statues and a large winding staircase that leads down to the cave where photography was strongly prohibited. An electric gate at this site showed both the importance of the area and the amount of revenue they generate to uphold this sacred area with visitors - significantly different from the other sites the researchers analyzed. The area above the cave had trashcans and some walking paths that were poorly adhered to, but durable areas both above and within the cave existed. The funds for the ticket and donations at the temple clearly funded sustaining this cave, as well as hiring caretakers and workers for the site. However, in ecological terms there appeared to be a lack of conservation for the cave as a natural site. There were no regulations against touching the

walls and lights were put in place that promoted the growth of plants and moss, potentially disrupting the ecosystem within the cave. It is important to recall it is a religious site, and these aspects that may seem to conflict with eco-conscious conservation may be important to the conservation of their religion and culture. The scaling that the researchers used did not have a way to reflect on these ideas, which could potentially be important for every location visited. Therein, the scaling for the ARS came to be 40% (Table A4) while the ERS averaged 51% (Table A5).

Devi's Falls, often also referred to as Davis Falls, had a few different amenities and ecotourist aspects than Gupteshwor Mahadev Cave. There was a separate entrance fee, and upon walking in there was a small garden that lead to a religious statue of the Lord Buddha, a photo zone, the summer house, and Davi's Fall. The path through the garden was durable and kept tourists on the trail with signs to leave the flowers and stay out of the garden. Once through the garden, the trail became poorly regulated, and large areas of the ground had been cemented over to withstand large crowds of people. There were some benches throughout the park, handrails, and some signage in both Nepali and English. Some signs provided visitors with information about the area, its legends/history, and other local areas such as the Gupteshwor Mahadev Cave to go visit. While the area did have a shrine, it did not appear to be related to the waterfall and was thus suspected not to be a geo-specific cultural site. This area does not appear to be built or regulated as an ecotourism location, based more on its geotourism qualities. This location was averaged to have an ARS of 33% (Table A4) and an average of 54% (Table A5) toward the ERS.

Museum ecotourism

There were two museums that the researchers visited and evaluated. The first museum was the Annapurna Natural History Museum. This location was free to visitors with donations accepted and offered a great amount of education on plants, landscapes, and wildlife of the area. The museum had exhibits for ethnic groups with information about their cultures and religions, with some comparisons of other places primarily within the Annapurna and Nepal area. The majority of this information was in English. This potentially would impede locals from being able to visit and benefit from the information within the museum, though it is located on a college campus and benefits the students there. While no "Green Energy" was observed on site, there were exhibits that had information about different eco-friendly forms of energy and their importance. This location itself may not be considered a natural ecotourism location due to the lack of the literal natural world within the museum, yet the amount of information that is covered to educate locals, students, and tourists gives it an average on the ARS of approximately 53% (Table A4), but with an ERS of 83% (Table A5) due to its vast amount of education.

The International Mountain Museum required an entrance fee. Entering featured a short walk through a garden that led visitors to the main museum. The museum offered information about trekkers and mountaineers but did not offer those amenities themselves. There were trash bags throughout the museum and the garden, which was mostly restrictive to the trail through the garden. While there was not a particular place for nature photography, there were exhibits with lots of nature and wildlife photography and opportunities to rent the garden to film videos. Exhibits within the museum often explained Leave No Trace principles and ideas, such as respecting wildlife, being considerate to others, leaving what you find, proper waste disposal and management, reducing firewood consumption, and staying on the trail.

The museum also talked about the Annapurna Conservation Area Project (ACAP), climate change issues both at local and global levels and Everest trash and Leave No Trace (LNT) issues that mountaineering poses. The ARS was at 67% (Table A4), and the ERS average was recorded by the researchers at 74% (Table A5).

Interpretations

Geological setting

The Pokhara formation that forms these on-site tourist attractions has calcareous gravels with a matrix derived from limestone. The Ghackok formation shows more angular clasts with a higher degree of calcareousness. The clasts are mixed in origin, showing gneisses, quartzites, and sandstones/mudstones of varying degrees of metamorphosis. These outcrops depict rocks eroded from the Lesser Himalaya, Higher Himalaya, and Tethys sequences.

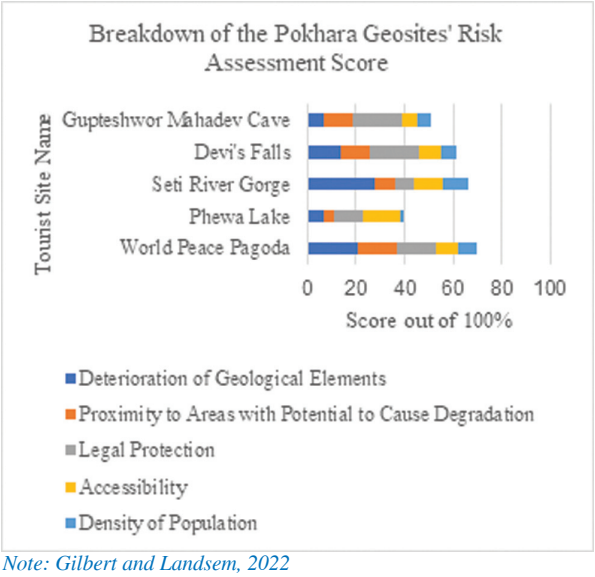
The formation of the Pokhara Valley is interpreted to be from several historical events of debris flows from the steep slopes of Annapurna II and IV (Fort, 2010). Sub-angular to sub-rounded sediments of the Pokhara formation imply debris and muddy flows alternated with river and alluvial fan deposits. The centimeter to decimeter scale of these sub-angular clasts suggests the debris flows could have been caused by an earthquake that would destabilize these slopes enough to dislodge and transport up to 3,000-ton boulders – for example, the famous Bhim Kali Boulder on the Pokhara University Campus. The lake is a drowned valley (Gurung, 1970), forming from the damming of the Seti River by these various catastrophes. This variety of geologic elements makes Pokhara an ideal hub for education in this field.

Geotourism potential

The 5 case studies of geotourism potential averaged to be 81.6%. Overall, these sites excelled in proximity to recreational areas, the density of the population, and the scenery. It seems that in addition to the geology present at this site, these sites benefit from each other and the interconnected tourist network of Pokhara (Figure 9). On the other hand, the weak points tended to be safety and vulnerability. The deterioration Risk Assessment Score (Figure 10) furthers this point, with lower scores that average 57.8% (Table 1). While the dense population aids geosites' interconnected development, it heightens the risk of deterioration by this population. In fact, the degradation or tourist safety risk of these sites had an inverse relationship to their uniqueness and aesthetic value. For example, Phewa Lake scored a 1 in vulnerability and a 5 in scenery (Table A6 and A7), and Seti River Gorge scored a 3 in safety yet a 5

Figure 9

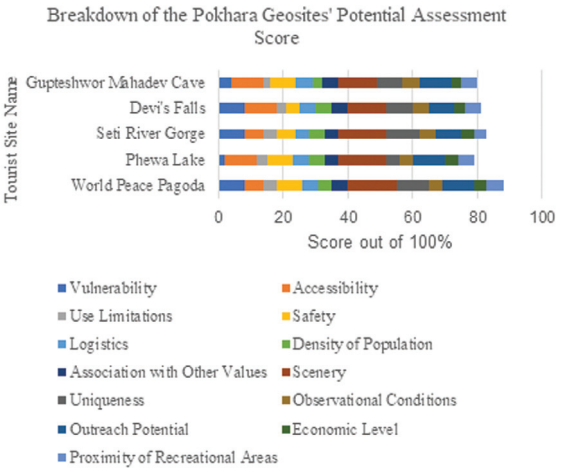
Comparison of geosite assessment scores



Note: Gilbert and Landsem, 2022

Figure 10

Comparison of risk assessment scores



Noe: Gilbert and Landsem, 2022

in both observational conditions and uniqueness. Education is key to alleviating this difference - ideally, a campaign to teach tourists and locals about the geological factors of the sites around Pokhara. This would include how they can keep themselves and the sites safe with ecotourism principles while learning about the geologic features they are seeing and how they came to be.

In addition, the sites that were evaluated for their amenities to their ecotourism potential show that sites that appeared to offer more in the way of amenities correlated with the sites that had more ecotourism aspects and information (Figure 2). When used in conjunction with each other, there is potential for growth in helping create a sustainable area and a place for the education of the community and tourists, as well as for profiting and economically helping the local community.

UNESCO Geopark potential

A UNESCO Geopark offers residents and visitors unique and stimulating earth science processes for educational, recreational, and sustainable purposes. The researchers observed that Pokhara offers a plethora of sites to observe unique geological features, from small-scale up-close sedimentary structures in the Gupteshwor Cave to large-scale geomorphological features in the view from the World Peace Pagoda. Additionally, some areas offered more information about these areas off-site, such as the Annapurna Natural History Museum and the International Mountain Museum. Pokhara's geological heritage ties into cultural values as well as this community's economic welfare. Each of the geosites researched has processes representative and stemming from a variety of geologic areas of Nepal. There are sediments with clasts of varying degrees of metamorphism for observation, lacustral and fluvial geomorphology, and glaciated mountain views in just 5 of the many geological tourist spots of Pokhara. Each of these areas has value in the scientific community and cultural heritage with local stories and religious significance attached to each. This is valuable on an international level as well because of Nepal's diverse geology and culture attached to its steep elevation changes.

As much as geologic importance and heritage is fundamental to UNESCO Geoparks, their development requires a large capacity for educational, conservational, and economic infrastructure. This area lacks some educational tools that would be used by residents, tourists, and students in a Geopark. Very little about the geology of this area exists outside of technical papers or with easy access to tourists at each site. Promotional material and geotourism action plans, outlined by UNESCO in their requirements for a Geopark, are yet to be extensively developed. We have created and provided 4 diagrams for on-site learning

at the geosites visited as a model for geological learning of tourists with no earth science background (Figure A1-Figure A4).

In terms of conservation, many of these tourist locations provided some sort of regulation and upkeep. In areas such as the Tal Barahi, cleaning of the location was actively occurring during the field study, and the museums and Gupteshwor Mahadev Cave showed maintenance occurring. New infrastructure was also being built in locations such as the World Peace Pagoda. There were attempts to mitigate landslides and erosion of this site with the ongoing installation of gabion walls and structures. Some locations provided information about the geology of the area, though this was not common enough throughout our study to thoroughly educate a tourist or local. Many of the locations did not have their own websites, and instead relied on other websites, while others did not even have that. Only 3 of 5 of the on-site locations had small map displays at the site. Still, many of the areas promoted some concept of sustainability either with signs or exhibits with in-depth information about conservation and sustainability. There appears to be potential for these sites, with modifications, to apply for a Geopark status, but further development of these sustainability practices and educational efforts is necessary.

Worldwide travel and tourism-related GDP trends flatlined significantly with the recent COVID-19 pandemic, but travel to Nepal and therefore tourism economic benefits are predicted to increase in the coming years. With this increase in traffic and therefore revenue, it is important that Nepal invests in sustainable and long-lasting plans for the expanding tourist industry. The cost of this sustainable development will ward Pokhara away from potential degradations of geological and cultural sites, pollution to the environment, and the social impact on locals.

There are inevitable uncertainties in this research as Pokhara expands and the climate crisis worsens, including culture shifts, geohazard-related shifts to the sites such as earthquake damage, and land use shifts from urbanization. In addition, foreigners analyzing a location they are not fully accustomed to, with minimal knowledge of all the nuances of the culture and human's relationship to the land has the potential to skew the results of the findings. This study would benefit from incorporating personal accounts from businesses and those living close to the tourist sites, as this was not possible in the research period. According to Bhandara (2013), a key factor for tourism management and development is community awareness in Pokhara. This would entail increasing the participation of residents and local businesses in tourism, creating awareness of the value of their sites to their heritage, and sharing those aspects with visitors. While this study benefits visitors who speak English by providing information in their language (Figure A1-Figure A4), a plan to incorporate the community to have more of a role in the geological education of these sites would add more authenticity to their value as geological heritage.

Conclusion

During the field study, the researchers were able to analyze and evaluate several different tourist locations within the Pokhara Valley of Nepal and extract data about their geotourism and ecotourism capabilities. This information was collected for the Phewa Lake area and the two cultural sites studied there, for the two nearby sites along the Phewa Tal stream, the Seti River Gorge, as well as two different museums. While geotourism, risk, amenities, and ecotourism may not immediately appear to be interrelated, there do appear to be overarching trends when doing comparisons for the data. As found in the results and the interpretations,

geotourism in Pokhara remains a massive prospect, with the region having the potential to be a UNESCO Geopark. This information can help tourists make more informed decisions on locations they wish to visit while traveling to the Pokhara area, and how those locations align with cultural tourism, geotourism, and ecotourism. This study also should prove beneficial to the sites visited and future sites for expanding their information on their location and what features can progress their tourism and local communities. Through this study it is hoped that the people of the Pokhara Valley in Nepal, as well as any future tourists, are better informed about the geo- and ecotourism of the area and how it intermingles with all the factors concluded in this study.

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Conflict of interest

The authors declare no conflicts of interest.

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Supplemental Materials

Figures and Tables

Table A1

Pillars of Ecotourism

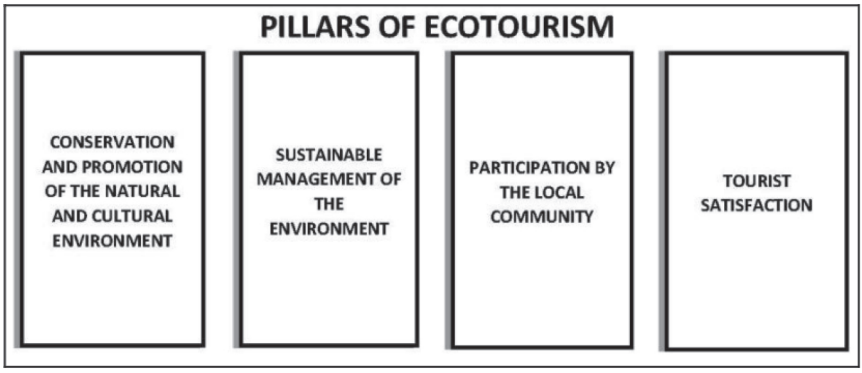

Table A2

Quantitative Assessment of Geosites' use for tourist and recreational and purposes

Criteria	Weight
Vulnerability – existence of geological elements that can be destroyed by students or visitors	10%
Accessibility – the easier and shorter the walk between the means of transportation and the site is, the higher the site's potential use	10%
Use limitations – existence of obstacles that may be problematic for the development of educative or touristic activities	5%
Safety – when the field activity can be carried out under low-risk conditions for students and visitors, the site's potential use increases	10%
Logistics – existence of facilities to receive students and visitors, such as accommodation, food, and toilets	5%
Density of population – existence of a population near the site potentially provides students and visitors who will use the site	5%
Association with other values – the existence of other natural or cultural elements associated with the site may justify interdisciplinary fieldtrips and attract visitors	5%
Scenery – represents the beauty of the geological elements that could stimulate students' and visitors' interest for the site and attract visitors	15%
Uniqueness – concerns the distinctiveness and the rarity of the geodiversity element that could promote students' interest for the site and attract visitors	10%
Observation conditions – the better the conditions for observation of all the geodiversity elements on the site, the higher its potential use	5%
Didactic potential – the use of the site by students of different education levels increases its potential use	0%

Variety of elements – a high number of different geological elements with didactic potential increases its potential use	0%
Outreach potential – related to the capacity of a geodiversity feature to be easily understood by people with no geological background	10%
Economic level – the high level of income of people living near the site suggests a higher probability of it being visited	5%
Proximity of recreational areas – a touristic visit to a site may benefit from the existence of well-known tourist attractions in the surrounding area	5%

Note: Saayman, 2009; Price, 2017

Table A3

Analysis for Degradation

Criteria	Weight
Deterioration of geological elements – reflects the possibility of loss of geological elements in the site as a consequence of: (1) its fragility, namely its intrinsic characteristics (size of geological element, east of obtaining samples, resistance of the rock, etc.) and natural actions (sensitivity to erosion, intensity of erosional agents, etc.) and (2) its vulnerability to anthropic actions (tourism, agriculture, urban development, vandalism, etc.)	35%
Proximity to areas/ activities with potential to cause degradation – mining, industrial facilities, recreational areas, roads, urban area, etc.	20%
Legal protection – related to the location of the site in an area with any type of legal protection (direct or indirect). Access control refers to the existence of obstacles, such as: restrictions by the owner, fences, need to pay entrance fees, mining activities	20%
Accessibility – reflects the conditions of access to the site for the general public (not considering disabled people). A site with easy access is more likely to be damaged by visitors' misuse than one with difficult access	15%
Density of population – reveals the number of persons that live near the site and that can cause potential deterioration due to inappropriate use (vandalism, theft, etc.)	10%

Note: Brilha, 2016

Table A4

List of Amenities for Site Locations Amenities Rating Scale score

Amenities Rating Scale Criteria (Yes or No)	Tal Barahi	World Peace Pagoda	Seti River Gorge	Annapurna Natural History Museum	International Mountain Museum	Devi's Falls	Gupteshwor Mahadev Cave
Trekking/Hiking	No	Yes	No	No	No	No	No
Wildlife viewing or bird watching	Yes	No	No	No	No	No	No
Mountaineering	No	No	No	No	No	No	No
Cultural site	Yes	Yes	Yes	No	No	No	Yes
Ethnic museums	No	No	No	Yes	Yes	No	No
Research/Study	No	No	No	Yes	Yes	No	No

Nature photography	No	No	No	Yes	Yes	No	No
Trash/Recycling Cans	Yes	Yes	No	No	Yes	Yes	Yes
Accessibility (ramps, benches, signage, etc.)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
"Green" energy (solar panels, etc.)	No	Yes	No	Yes	Yes	No	No
Minimization of off-trail walking, maximization of natural spaces	No	Yes	Yes	Yes	Yes	No	No
Designated/No smoking areas	Yes	Yes	No	No	No	No	No
Leave No Trace principles	Yes	Yes	No	Yes	Yes	Yes	Yes
Fees and donations for							
conservation or local benefits	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Natural elements (trees, bushes, water area, animals, etc.)	Yes	Yes	Yes	No	Yes	Yes	Yes
Average (100% being the most fulfilling, 0% being the least)	53%	67%	33%	53%	67%	33%	40%

Note: Brilha, 2016

Table A5

Ecotourism Rating Scale score for Site Locations

Ecotourism Rating Scale Criteria (1 to 5)	Tal Barahi	World Peace Pagoda	Seti River Gorge	Annapurna Natural History Museum	International Mountain Museum	Devi's Falls	Gupteshwor Mahadev Cave
Minimizes negative impacts on the environment and local people.	4	5	3	5	3	3	3
Contributes to the conservation and management of the legally protected area.	3	4	2	4	3	3	2
Promotes participation and empowerment of local people.	4	5	3	4	3	2	4

Satisfies visitors' expectations towards successful ecotourism projects.	2	4	1	4	4	2	2
Increases the awareness of the area's natural and cultural systems.	4	4	2	5	5	3	2
Directs economic and other benefits to local people.	3	3	3	2	3	3	3
Provides adequate information to visitors before and during visits.	4	5	1	5	5	3	2
Average (100% being the most fulfilling, 0% being the least)	69%	86%	43%	83%	74%	54%	51%

Note: Gilbert & Landsem, 2022

Table A6

Quantitative Assessment of 5 Pokhara Geosites' Capacity to Support Geotourism

Criteria	Weight	World Peace Pagoda	Phewa Lake	Seti River Gorge	Devi's Falls	Gupteshwor Cave
Vulnerability	10%	4	1	4	4	2
Accessibility	10%	3	5	3	5	5
Use Limitations	5%	4	3	4	3	4
Safety	10%	4	4	3	2	4
Logistics	5%	5	5	4	5	5
Density of Population	5%	4	5	5	5	3
Association with other Values	5%	5	4	4	5	5
Scenery	15%	5	5	5	4	4
Uniqueness	10%	5	2	5	4	4
Observational Conditions	5%	4	4	5	5	5
Didactic Potential	0%	4	5	4	5	
Variety of Geological Elements	0%	5	3	5	3	5
Outreach Potential	10%	5	5	4	4	5
Economic Level	5%	4	4	4	3	3
Proximity of Recreational Areas	5%	5	5	4	5	5

Note: Gilbert & Landsem, 2022

Table A7

Quantitative Assessment of 5 Pokhara Sites' Degradation Risk

Criteria	Weight	World Peace Pagoda	Phewa Lake	Seti River Gorge	Devi's Falls	Gupteshwor Cave
Deterioration of Geological Elements	35%	3	1	4	2	1
Proximity to Areas with Potential to Cause Degradation	20%	4	1	2	3	3
Legal Protection	20%	4	3	4	5	5
Accessibility	15%	3	5	4	3	2
Density of Population	10%	4	1	5	3	3

Figure A1

Example of Geological Infographic for On-Site Education of Tourists at the World Peace Pagoda

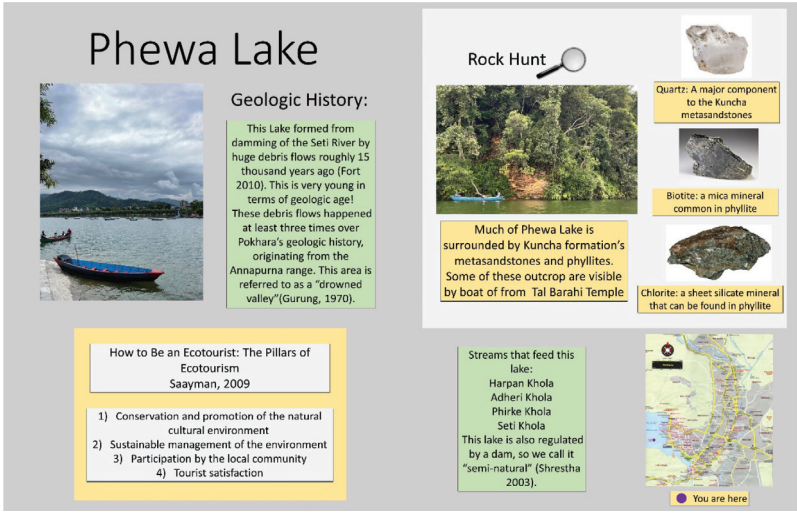

Figure A2

Example of Geological Infographic for On-Site Education of Tourists at the World Peace Pagoda

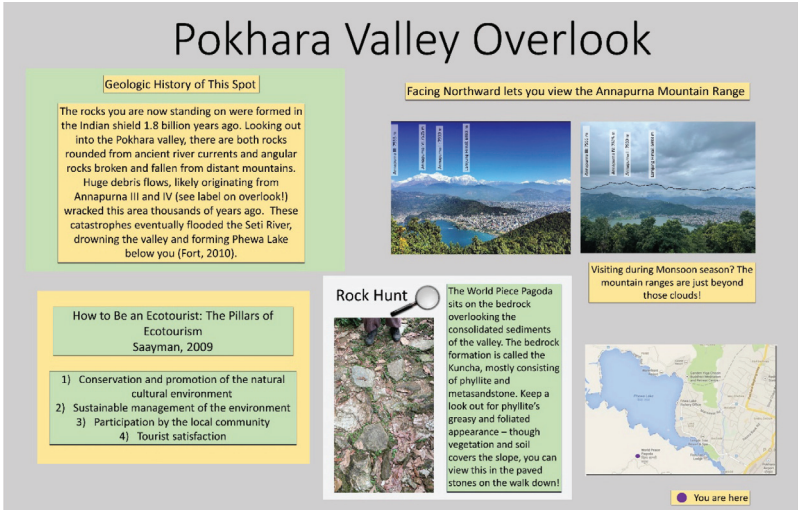

Figure A3

Example of Geological Infographic for On-Site Education of Tourists at the World Peace Pagoda

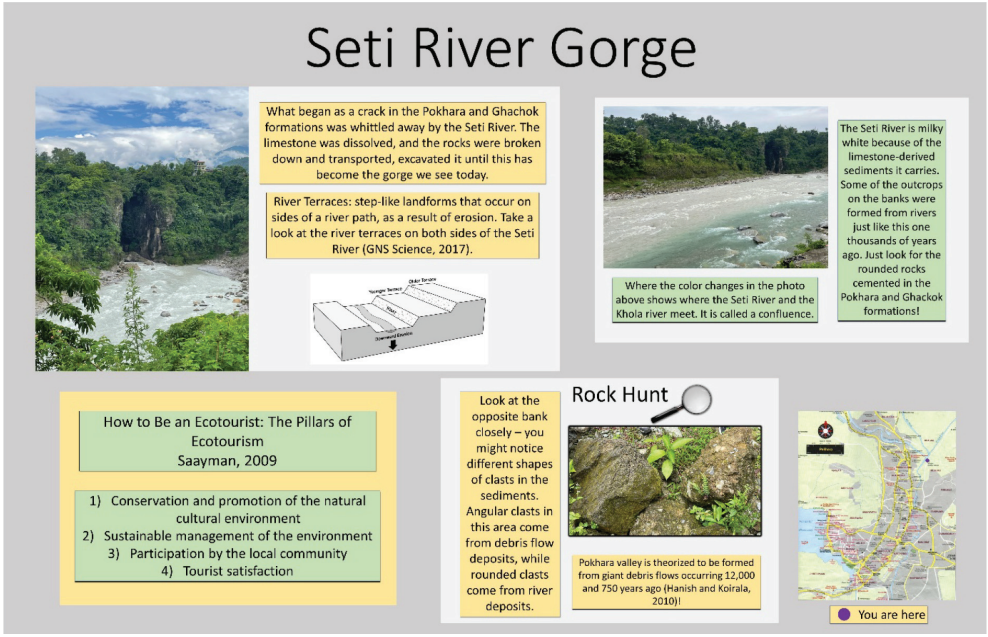

Figure A4

Example of Geological Infographic for On-Site Education of Tourists at Davi's Falls and Gupteshwor Mahadev Cave