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Unplanned Urban Expansion and Natural Sensitivity in Chhorepatan, Pokhara

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Abstract

Chhorepatan, one of the geologically sensitive tourist hubs in Pokhara Valley, has undergone rapid and unplanned urbanization in the last five decades, changing its topography significantly. This research paper explores the unplanned urban expansion and natural sensitivities in Chhorepatan, Pokhara Metropolitan City. This paper uses satellite data, field surveys, and historical data to assess the impact of urban expansion on the area's geologically sensitive landscape using RS, GIS tools. The finding based on the satellite images of 1990-2020 reveals that rapid expansion of built-up sensitive areas increases subsidence risks, particularly in sinkhole and cave zones. Urban growth of Chhorepatan area, exacerbated by population growth and infrastructure development over the geologial sensitive area, poses a significant threat to environmental stability and human life. It is suggested that the policy should incorporate geological assessments into urban planning for sustainable development and disaster reduction in geologically sensitive regions.

Keywords: Built-up area, natural sentivity, urban expansion, satellite images, natural resources

Introduction

The global issue of uncontrolled urban growth is closely tied to the increasing human population and the trend toward urbanization (Esfandeh et al., 2022). Urbanization has been on a rapid rise; in 1950, 30% of the world's population was urban, and by 2014, it had reached 50%. Predictions indicate that by 2030, urban populations will account for 60% of the world's population, approximately five billion out of eight billion people (UN, 2018) reaching as much as 70% in 2050. It is relevant to point out that our future depends on solving urbanization patterns (Taiema & Ramadan, 2021). As the global population expands, cities worldwide are experiencing heightened demand for land, particularly for residential use. These are specific issues that reveal a lack of understanding with respect to the contribution of cities both to climate change and technological hazards. Apart from creating different kinds of vulnerabilities, unplanned urban growth generates a set of new human-made hazards. The unplanned urbanization process should be considered as part of factors that exacerbate risk-especially for the vulnerable developing world-but as a local and global hazard. Otherwise, efforts to reduce disaster risk will continue to fall short (Bhattarai & Conway, 2010).

Nepal is among the top ten fastest urbanizing countries (UN, 2018), and understanding this phenomenon is crucial. The urban population in Nepal was 3.61% of the total population in 1971, doubling by 1981 (6.39%), increasing to 9.2% in 1991, reaching 13.9% in 2001, and further growing to 17.1% in 2011 (Subedi, 2014). After the declaration of Nepal's new constitution in 2015, new administrative councils were established under the federal state provision. As of 2021, the number of urban municipalities increased from 58 in 2013/2014 to 293 in 2017/18, with an increase in urban municipal population from 17 to 66 percent (NSO, 2024). This led to an urban population of 59 Percent.

In Nepal, urbanization commenced in the 1950s (Gurung, 2005), and data on urbanization have been available since the 1952–1954 census (Sharma, 2003; Subedi, 2014). Nepal has experienced one of the highest rates of urban population growth in South Asia, with an annual growth rate of approximately 6% since the 1970s (Muzzini & Aparicio, 2013). Previous research primarily focused on urbanization in terms of the number of towns, regional and economic comparisons, the population fraction of the nation, and the availability of essential urban services (Chapagain, 2018; Devkota, 2012; Khanal, 2001; Poudel, 2008; Subedi, 2014). Prior to 1990, urban growth studies in Nepal mainly concentrated on economic and political aspects, functional analysis, town hierarchies, and urban-rural connections (Bajracharya, 1995; Haack, 2009). Over the last 28 years (1990 to 2018), urban built-up areas of Nepal's Hill and Tarai cities increased rapidly, with Pokhara seeing a threefold increase and Bharatpur seeing a fivefold increase. This increase was mostly ascribed to strong urban population expansion, which was fuelled by rural migration from surrounding regions (Rai et al., 2020).

Geological structures are primarily natural, while land use, especially built-up areas, is generally anthropogenic. However, the span of human history is insignificant compared to geological history. Humans utilize natural resources in various ways to meet their needs (Sharma, 1975). In the Chhorepatan area of Pokhara Metropolitan City-17, geological sensitivity and unplanned land use have become major concerns in the past few decades. The situation has been worsened by rapid and unplanned urbanization associated with so-called modern development. Therefore, this research aims to answer the following questions: What is the geological sensitivity of the Chhorepatan area? How is land use occurring? What are the associated concerns? What should be done? And how can potential risks be mitigated in the future? These questions are the main focus to evaluate the concerns raised by the geological sensitivity and land use especially urban built-up area, and propose fact-based measures to minimize potential risks.

The Chhorepatan area, known for its caves, sinkholes, and underground streams, is a good example of the challenges posed by urbanization in geologically sensitive areas. Koirala (1998) highlights that the gravels brought from Ghachok Formation make an unstable platform for construction and hence the area is very unsuitable for heavy infrastructure. However, the rapid urbanization in Chhorepatan continues due to population increase and economic importance of the area as a touristic zone.

The present study is thus expected to go a long way in the understanding and mitigation of geological sensitivity and intensive land use risks in the Chhorepatan area. It is expected that practical recommendations for risk mitigation will be proffered based on the evaluation of such risks. This will, in sum, foster proper planning, strategic development, and proper utilization of geologically sensitive areas before land use. Further, this study will help extend the life of such lands through the identification and correction of procedural errors in the current practices in land use.

Methods and Materials

The study area

Pokhara Valley, situated in western Nepal, is the second-biggest valley in the hilly part of the nation. The present work, however, deals with the Chhorepatan area of the Pokhara Metropolitan City-17. The investigated area lies between 28°10'55" to 28°11'40" N latitude and 83°56'50" to 83°57'45" E longitude. Some familiar sites present within this area are the Gupteshwor Mahadev Cave and the Patale Chhango or Devis Fall (Upreti et al., 2013) . The Chhorepatan area is bounded on the east by the western fringe of the Birauta plains, on the west by the foothills of Kudi in Pumdibhumdi, on the north by Simaltuda of Ward No. 17 of Pokhara, and on the south by Fursekhola. The altitude in the area under study ranges from 730 meters as low as to a maximum height of 793 meters at the confluence of Furse and Pardi rivers and near Saaney Paani stream, respectively. Over the past five decades, the population in this area has significantly increased. Previously, the area had a minimal population due to the prevalence of malaria. However, in 1964, a Tibetan refugee camp was established. Chhorepatan is located along the historic main road that connects western districts such as Syangja and Palpa to Pokhara, Kathmandu, and Mustang (Muktinath). Moreover, this region is hub to popular tourist destinations like Gupteshwar Mahadev Cave and Patale Chhango. Additionally, the Pardi River, which serves as an outlet for water from Phewa Lake, flows openly and underground through deep gorges before merging into Furse khola in this particular area (Fig. 1).

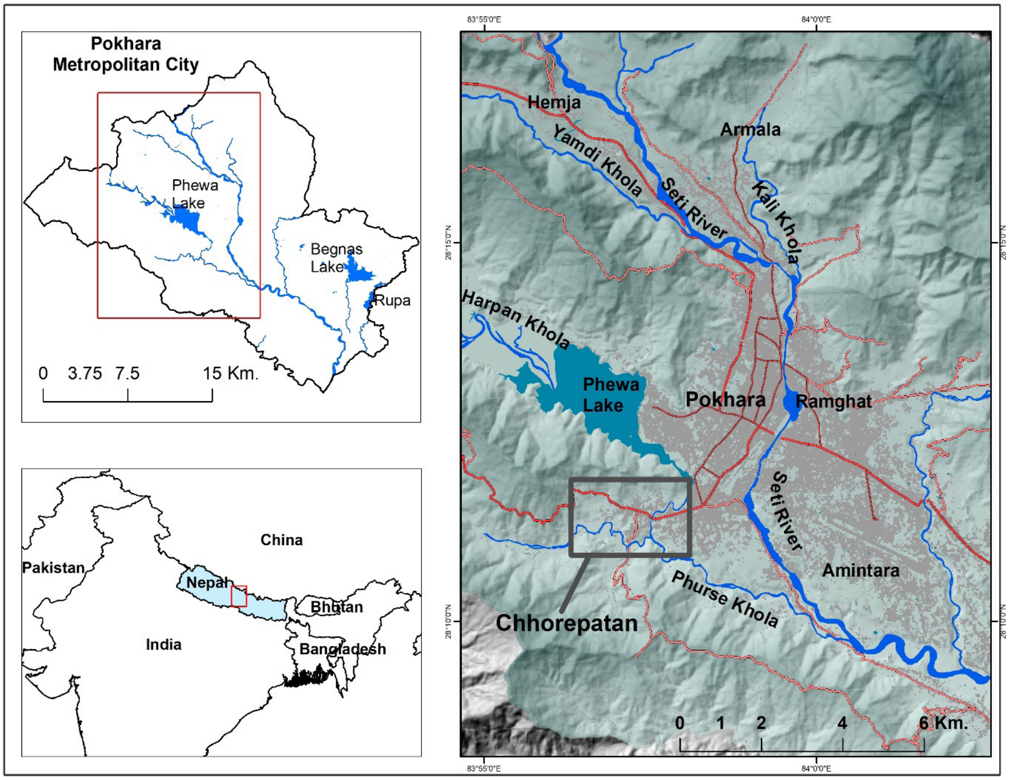

Figure 1: *Location map of the study area*

This paper adopts a quantitative, spatial-analytical approach for GIS/RS analysis of unplanned urban expansion and natural sensitivity. The positivist/empirical paradigm and Spatial Analysis Case Study Design are research approaches that emphasize objectivity, measurement, and observable data, making them ideal for GIS/RS studies analyzing spatial patterns and environmental impacts. This study utilizes remote sensing (RS) and geographic information systems (GIS) as tools for analyzing the spatial distribution of geological fragile characteristics (Abebe, 2013). Satellite images and aerial photos provide valuable information about the historical background of changing occurrences and urban growth (Poudel & Rawat, 2023; Xu & Gao, 2021) over various time periods.

For primary data, the multisource and multi-temporal satellite images from 1990, 2000, 2010 and Sentineal image 2020, field observations, interviews, and surveys with key informants have been conducted on August, 2023. During the field observation in 2023, expert consultations and informal interviews with various stakeholders were conducted.

Secondary data have been gathered from relevant reference materials. This research relied on secondary data to study the unplanned urban development of Chhorepatan. Geological maps from the Department of Mines and Geology-1998, population data from the Central Bureau of Statistics and the local boundary map from the Survey Department (2017) provided administrative limits for spatial analysis and aligned urban development with policies. Together, these sources allowed for an in-depth assessment of the environmental and geological impacts of urbanization.

The study involved verifying the geometric accuracy of Landsat TM and ETM, as well as Sentinel-2 images, using ENVI 5.3 software for image formation. The process included analyzing visual depiction, texture, and associations, and extracting information from satellite images, field visits, aerial photographs, and urban sector documents to identify built-up areas. Three categories of urban land use were identified: built-up area, non-built-up area, and water body. To maintain consistency in spatial resolution, the Landsat image (30-m) was resampled using the nearest neighbor resampling method to match the resolution of Sentinel (15-m). Maximum likelihood algorithm was used to calculate mean, variance, and covariance statistics.

The methodology involved extracting urban expansion maps from satellite images for the years 1990, 2000, 2010, and 2020. The growth rate indicates the proportion of existing land transformed into built-up land use. The percentage growth controls urban annual growth rates from the original built-up land-use zones.

Results and Discussion

Topography and geological sensitivity

The Chhorepatan area is situated in the southwestern corner of the Pokhara Valley's base in Ward No. 17 of Pokhara Metropolitan City. Its location at the bottom of the valley might explain its name, "Chhorepatan." The topography and geological structure of this area closely resemble that of the valley's base. While the overall structure of the approximately 124 square kilometers of the Pokhara Valley's base remains consistent, the strength of the geological structure varies across different regions. Some areas have limited but weak or sensitive geological structures, while other more extensive regions sit on comparatively stronger and more robust geological formations. This variation is due to the area's unique geological history, which is relevant to understanding the context of this study.

Around 65 million years ago, the Indo-Australian plate, one of Earth's seven massive plates, began to subduct beneath the Eurasian plate. This process led to the rising of the main Himalayan range from the ancient bed of the Tethys Sea. Approximately 35 million years ago, the Mahabharat range emerged to the south of the main Himalayas, creating numerous tectonic valleys (Gansser, 1964; Jhingran, 1981; Budathokey, 1968). One of these valleys is the Pokhara Valley, an intra-montane basin located in the mid-hill region of western Nepal. The rock formations visible on the slopes within the valley support this, while the sediments on the valley floor date back to the Quaternary age (Koirala, 1998).

The sediment at the base of the Pokhara Valley consists of Quaternary deposits. These deposits primarily consist of gravel transported by the Seti River from the Annapurna region in large volumes (3 to 7 cubic kilometers). The transportation of gravel took place mainly in three phases, approximately 700–1,100 years and 12–14 thousand years ago. These three phases of gravel flow buried the older valley base, forming the present-day valley floor (Yamanaka, Yoshida, and Arita, 1982). The gravel exists in both consolidated and unconsolidated forms. Dr. Harka Gurung referred to this gravel as the "Pokhara Gravel" (Gurung, 1968). The thickness of these deposits varies across locations but generally ranges from 80 to 100 meters. The last phase of gravel flow is known as the "Pokhara Formation," while the oldest is called the "Tallakot Formation." In areas influenced by the Tallakot Formation, gravel deposits can reach up to 200 meters in thickness. The "Ghachok Formation," which followed the Tallakot Formation, was formed 10–12 thousand years ago from subsequent gravel flows.

Hydrological impact on underground

The sensitivity of the geological structure, due to natural water flow, causes obstruction and diversion that creates underground stream channels (Bhandari et al., 2019; Fort et al., 2018). These have eroded cave passages, including the very famous Gupteshwor Mahadev Cave, along with several other caves in the vicinity. The presence of big caverns and underground voids beneath Chhorepatan shows that a considerable area of land in this location is hollow and prone to subsidence. According to Waltham, 1996, the caves, gorges, and barren fields around Pokhara have far greater importance, with particular mention of the Patale Chhango Gupha, where there are 2960 meters of large passage development carrying a small river (John, 2006).

In 1970, a British Karst Research Expedition (BKRE) led by A. D. Waltham, along with other research teams in 1974 and 1976, conducted studies on these caves, including the Gupteshwor Mahadev Cave. An initial survey came up with the cave being 1,479 meters with six entrances according to their records. This geological feature is important to the area because it shows that big karstic formations with huge underground channels of water exist. According to the Atlas book - "The Atlas of Great Caves of the World" p. 136 mention that:

Nepal

Long Caves:

Pathale Chhango… .... 2959m. (Chhorepatan, Pokhara, Gandaki)

Cave with 6 entrances formed in conglomerate (tourist site). Explored in 1970 by the BKRE Himalaya for 1479 m and extended in 1980 and 1982 by D. Gebayer (Gebauer, 1983)

The Gupteshwor Mahadev Cave is particularly notable, with a temple established at a depth of 40 meters from the entrance. The cave extends further east for about 100 meters, connecting to the base of the Davis Fall (Patale Chhango). From there, a long tunnel (approximately 1 km) extends northward, while two other tunnels branch off to the south, eventually merging with the Furse Khola (Gebauer, 1983).

Geological sensitivity and urbanization risks on Chhorepatan area

The increased density of sinkholes, caves, and underground voids in the Chhorepatan area makes it very sensitive to any geological

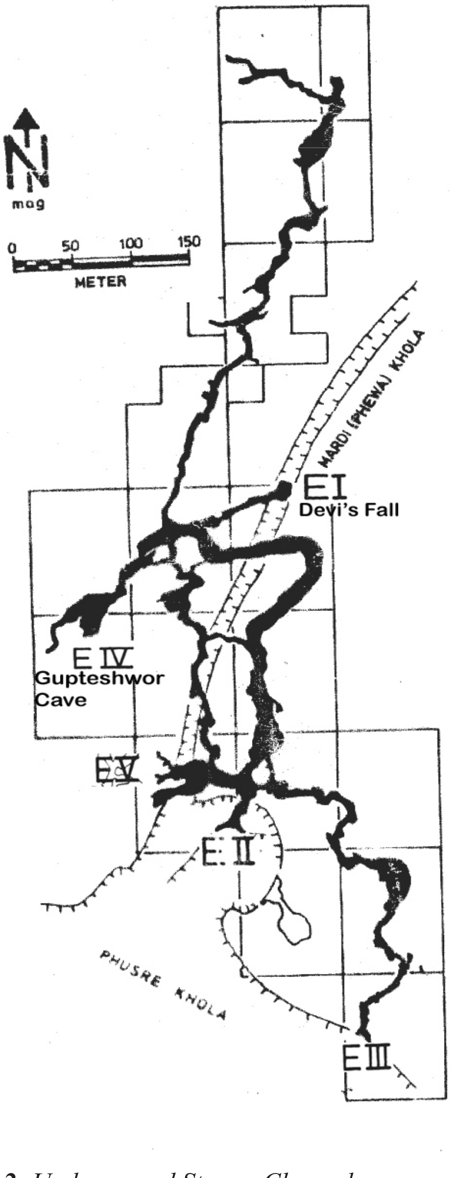

Figure 2: *Underground Stream Channel prepared by British Karst Research* Expedition-1976.

disturbances. The roofs of these caves are quite thin at places; this thickness is about 5 meters at some places. The geological sensitivity of the area is becoming increasingly difficult due to increased urbanization, roadways, and building construction. The other vulnerabilities discernable from the erosion and collapse of riverbanks are those falling along Pardi Khola and Furse Khola. The year-round discharge of subsurface water, as evidenced by mixing with Furse Khola, shows the continued geological processes that threaten the stability of the area. Gullies formed on the slopes of Chhorepatan are deepening and widening annually, which further illustrates the area's geological instability.

The construction of the Siddhartha Highway has had a notable impact on these processes. The highway has reduced surface water flow, slightly slowing the formation of gullies. However, the general geologic sensitivity of Chhorepatan remains a big concern, to say the least, given that the area had originally been filled up with gravel deposits by the Seti River. Gravel-filled land indeed does not provide very good ground for building any large structures, as was made clear in the 1998 engineering and environmental report on the Pokhara Valley. The report had even gone to the extent of clearly stating that when it comes to similar grounds, necessary research and deliberations ought to be extended prior to developing any structure on such land and large constructions should be avoided as much as possible.

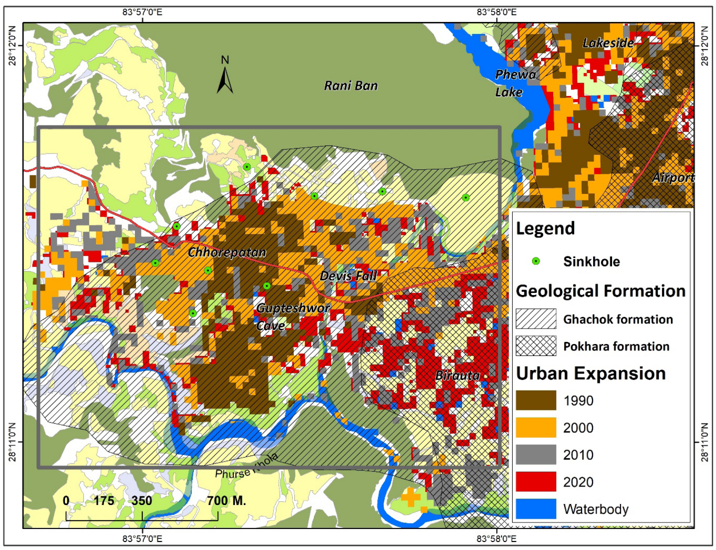

Figure 3: *Urban expansion with geological context of Chhorepatan area, pokhara*

This map shows the urban expansion from 1990 to 2020 in relation to geological formations, indicating the area prone to sinkholes. Brown, yellow, grey, and red depict the different phases of urban expansion in the years 1990, 2000, 2010, and 2020, respectively. Noticeably, it spreads out of the core around Chhorepatan and has been expanding east and south far more extensively.

The Ghachok geological formation covers large portions of the built-up area. These formations are known for their susceptibility to hazards like sinkholes, particularly in areas like Devi's Fall and Gupteshwor Cave, which are visible in the vicinity of the expanding urban area. The green-colored sinkholes show highly geological concern areas, indicating that this urban development is coming out in such a way that it may enter into highly geologically unstable areas, which is a question of safety and sustainability of further expansion of the city (Fig. 4).

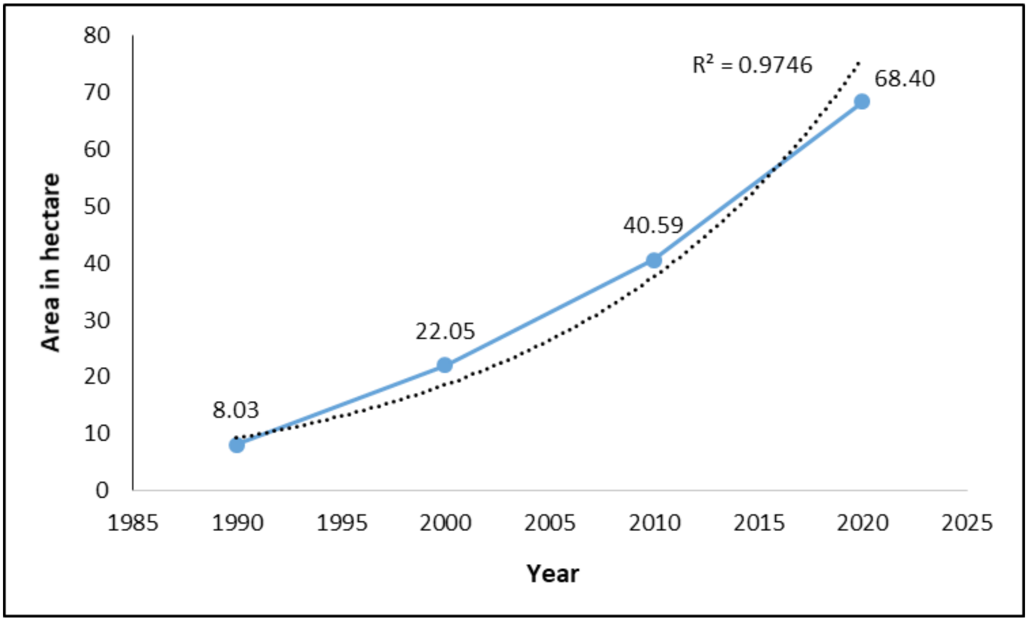

Figure 4: *Urban expansion over time of Chhorepatan area, pokhara*

This graph represents the increase in the urban built-up area in hectares from 1990 to 2020. The area has increased gradually from 8.03 hectares in 1990 to 68.40 hectares in 2020, showing very rapid growth in Chhorepatan. The exponential trend of expansion is represented by an R^2 value of 0.9746, which signifies that acceleration in urbanization is consistent due to growing population, infrastructure development, and tourism (Fig.4). Major jumps, regarding the expansion in land development, could be seen 2000 to 2010 and again from 2010 to 2020. The development activities are seen to increase during these periods. These periods also hold liability for improvement in road connectivity and infrastructure for tourism and residential construction. In such a way, Chhorepatan has undergone rapid urbanization. The expansion into the geologically sensitive area poses potential environmental and infrastructural instability. Hence, it requires cautious urban planning with hazard mitigation strategies for natural hazards-sinkholes.

Causes of sinkhole hazard

The Chhorepatan area essentially represents the gravels of Ghachok Formation, one of the younger sedimentary units developed in the last phase of gravel deposition in the Pokhara Valley (Thapa et al., 2023). This gravel typically consists of richly conglomeratic lime and silt-sized sediments with characteristic brown, yellow, and green boulders. The region also has cemented conglomerates, cavities, and caves, indicating the widespread presence of the Ghachok Formation. Due to the prevalence of Ghachok gravel and the thin layer of Pokhara Formation gravel, there is a high risk of ground subsidence and the formation of sinkholes in the area (Rimal et al., 2015). This is particularly high along steep slopes and on riverbanks, which are areas commonly afflicted by landslides and erosion. In fact, the porous nature of the ground allows water to seep through to a depth in the earth where the water flows underground at 80–90 meters from the surface.

During the rainy season, these streams originating from the Rani Ban area- Bhugane Khola, Damodar Khola, Pateko Phedro Kholsa, and Saune Pani Khola Khet cover in the flatlands. This is because of the relatively high rises of surface flow paths on which water percolates into the ground rather than flowing on the surface. Therefore, occurrences of subsidence and sinkholes have become really common, especially in corners of flatlands. Particularly, the Chhorepatan area is sensitive to geological disturbance with considerable expansion of vulnerable structures along edges at the base of the valley.

That is clear enough from the way sinkholes are popping along the north side of Chhorepatan, as at the foot of Rani Ban. As recently as September 18, 2014, within a metre or two near Barakobot about 80 metres south of the Durga Bhawani Temple, a sizeable new sinkhole had formed very close to the Siddhartha Highway. Other examples are the sinkholes developed by water flow through the Damodar Khola and

Photo 1: Sinkhole formation on Davis Fall Area (Photo by Author taken on Aug.18, 2014)

Pateko Phedro Khola, and the large sinkhole near Hanuman Basti developed by Saune Pani Khola. Besides this, the Siddhartha Highway, which was constructed in 1967, plays a significant role in blocking the natural flow of rainwater and runoff from those streams.

At the time, the relative unpopulation may have lowered the awareness or concern for the geological sensitivity of that area. Whereas the highway brought about settlements along its edges, and hence rapid urbanization ensued without regard for geological hazards which might underpin it. This further disregard of geological sensitivity of the area enhances the risk of ground subsidence and sinkholes with enhancing urbanization.

Conclusion

Chhorepatan, one of the geologically sensitive tourist hubs in Pokhara Valley, has undergone rapid and unplanned urbanization in the last five decades, changing its topography significantly. Heavy construction activities and settlement expansion in the geological fragile area, which was characterized by caves and sinkholes, have disregarded environmental sustainability. The Chhorepatan barren land has decreased by 88.74% (60.34 hectares), while settlement has surged from 0.39 hectares to 30.36 hectares - a monumental increase. At the same time, sinkhole areas have shrunk by 71.39% (0.35 hectares) due to arbitrary infilling for construction by real estate groups, increasing geological hazards. The activities deny the principles of sustainable development and point to the lack of a strategic approach toward management of the peculiar issues of this region. This means there is a dire need for sustainable urban planning to control risks and salvage the environmental integrity of the area since the unplanned urban expansion has increased the risk due to unexpected hazards.

To mitigate risks in the geologically sensitive Chhorepatan area, recommendations include: the alternative route for Siddhartha Highway with a concrete bridge over Pardi Khola; appropriate drainage systems; as little large construction as possible; only light structures with good drainage; sealed and maintained septic tanks; water conservation through sustainable farming; proper waste management into the streams and gullies; speed limitation; management of natural sites to enhance sustainable tourism; and detailed scientific research to guide effective policies.

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