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The Effects of Climatic Alteration on the Glacial Lake Flash Flood in the Himadri Range of Nepal and Adjacent Indian Region

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Abstract

The purpose of this study is to evaluate the impact that climatic alteration has on glacial lake flash floods in the Himadri range of Nepal and adjacent Indian region, which are places that are becoming increasingly susceptible to phenomenon of this kind. There has been an acceleration in the frequency and severity of glacial lake flash floods (GLFFs) as a result of rising global temperatures. These temperatures have accelerated the melting of glaciers and the development of glacial lakes that are unstable. This study makes use of historical flood data, climate models, and field observations in order to evaluate the changes that have occurred in glacial lake dynamics and the implications that these changes have for the threat of flooding they pose. The findings indicate that there is a correlation between rising temperatures and faster glacier retreat some time ago, which has led to a large rise in the constancy and intensity of (GLFFs). According to the findings of the study, there is an immediate requirement for improved monitoring, risk assessment, and adaptive measures in order to reduce the negative effects on the infrastructure and residents in the surrounding area. As a means of addressing the mounting issues that are being brought about by climate-induced glacial lake flash floods in the area, the recommendations include the implementation of integrated water management methods and the enhancement of pre-emptive alert systems.

Keywords:- Climatic alteration, Glacial Lake Flash Flood, Alleviate Hazards, Pre-emptive Alert Systems.

Introduction

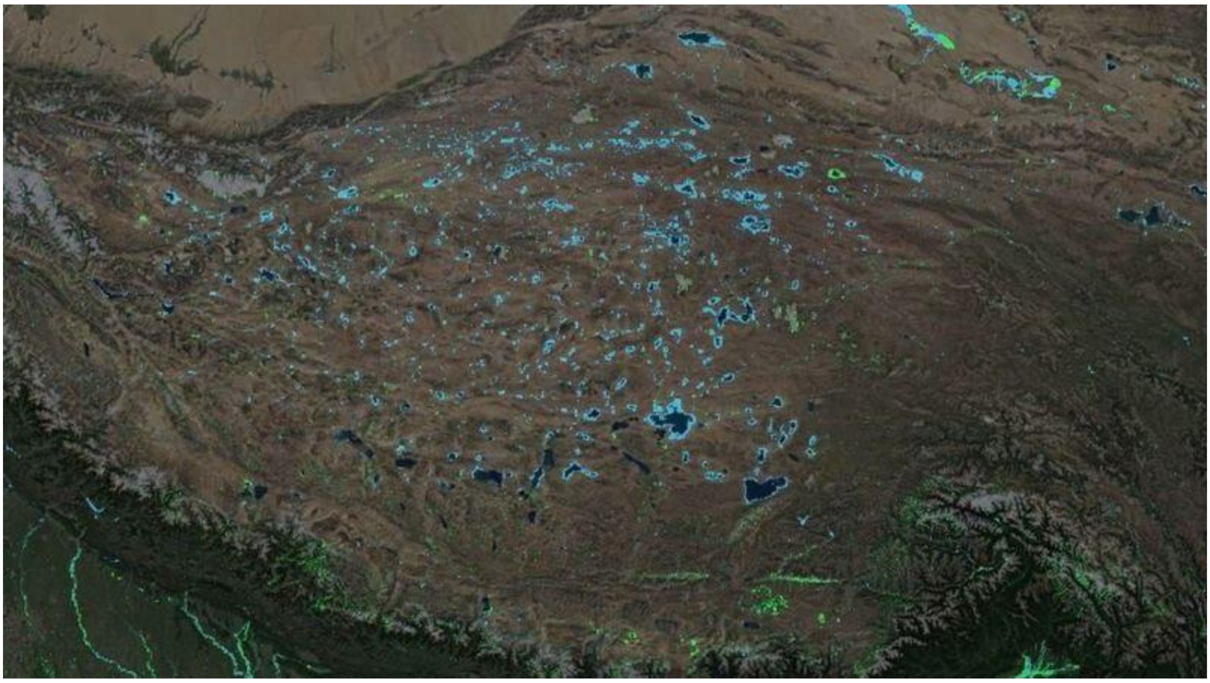
The outcome of glacial lake flash floods in Nepal and North India represents a significant environmental and humanitarian concern that has attracted heightened scrutiny in contemporary years. The floods, prompted by the abrupt discharge of water from glacier lakes, present considerable hazards to communities and infrastructure in the Himalayan area. Climatic alteration is hastening the fluxing of glaciers and the creation of potentially unstable glacial lakes, resulting in an enhancement in the frequency and intensity of these catastrophic catastrophes. This introduction will analyse the causes and repercussions of glacial lake flash floods, focusing on their impact on local ecosystems, communities, and developmental initiatives in Nepal and North India. Comprehending these effects is integral for formulating effective measures to alleviate hazards and bolster resilience in these susceptible areas.

Methodology:- The investigation in this paper is qualitative by nature and essentially derives content from secondary sources. The accessible primary as well as secondary sources are explored. Governmental records, yearly reports, policy discussions held by the ministries of both the countries of India and Nepal, as well as declarations and speeches made by different officials from both nations, are a few instances of primary materials that have been examined. We'll review every secondary source that is accessible, including books, journal papers, and research publications.

Major River Systems in Nepal: - Nepal encompasses significant rivers, including the Sapta Kosi River, the Karnali River, the Narayani River, and the Mahakali River. These streams deposit silt and residue on fields, nourishing them and restoring alluvial soil. They also offer prospects for the expansion of hydroelectric and water systems. India has utilized this asset by erecting dams on the Kosi and Narayani rivers adjacent to the Nepalese border, referred to as the Gandak and Kosi projects. Kosi River, a tributary of the Ganga River flows through the eastern Nepal and Bihar, is formed by the confluence of Arun Kosi, and Tamur Kosi Rivers. The Karnali River, a primordial watercourse, supplies water, nutrients, and sediments to productive agricultural lowlands. The Narayani River, alternatively referred to as the Gandak River in India, traverses the central region of Nepal and is fed by seven principal tributaries. Nepal hosts around 2,323 glacial lakes, predominantly formed through glacial processes. The lakes are located in four primary basins: Koshi Waterway Basin, Gandaki River Basin, Karnali Waterway Basin, and Mahakali River Basin.

Glacial Lake Flash Flood:- It appears difficult for the world's nations to reduce their greenhouse gas emissions so that the global temperature rise is confined to 1.5°C by 2050. Even if the temperature is 1.5°C, the average temperature in the Himalaya will rise by 1.8°C due to a phenomenon known as the "altitude effect." In the best-case scenario, one-third of the Himalayan glaciers would disappear this century. However, if greenhouse gas emissions continue at their current rate, by 2100, two-thirds of Himalayan ice will be gone.

This will severely affect water supplies for 1 billion individuals downstream of rivers emanating in the Himalayas and disrupt weather patterns. It will also increase the risk of GLFF in Nepal. Until the 1960s, only a limited number of melt lakes existed on the Imja Glacier adjacent to Mt. Everest. Since that time, the ice has been replaced by a lake measuring around 2 km in length, 600 m in width, and up to 150 m in depth. The ice is diminishing at a rate of 70 meters annually. The expansion of glacial lakes poses a risk of rupture due to water pressure, seismic activity, or avalanches entering the lakes. The risk of GLFF will increase as the average temperature in the Himalayas rises by 0.056°C per year. A remote sensing study conducted by the Centre on Climate Change of the Himachal Pradesh Council for Science Technology-Environment (HIMCOSTE) indicates that the number of glacier lakes potentially causing flash flooding in the state nearly doubled from 562 in 2019 to 1,048 in 2023.



Satellite Image of Glacial Lakes on the Sources of the Rivers on the Tibetan Plateau (Fig i)

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Rising Temperatures and GLFFs:- The temperature records of the past 44 years in Nepal, as per worlddata.info, provide a clear account of the temperature rise. The highest temperature recorded from 1978 to October 2022 was noted by the Dhankuta weather station. In August 2016, a record high of 34.1 °C was documented here. The most extreme meteorological summer from June to August, as recorded by all three weather stations in Nepal situated below 1,340 m in altitude, occurred in 2014, with an average temperature of 25.1 °C. The average temperature will typically be recorded every four to six hours, including during the night. The typical value is 23.5 °C. The mean highest daily temperature throughout that period was 28.9 °C. The Dhankuta weather station reported the coldest day in the past 44 years. The temperature decreased to 0.0 °C in April 2020. Dhankuta is situated at an elevation of 1,210 m above sea level. The coldest winter, spanning December to February, occurred in 1979, with an average temperature of 11.8 °C. In Nepal, the average temperature over this three-month period is typically 15.0 °C, with an increase of approximately 3.2 °C.

A recent report warned that global heating is causing the ice on the world's highest mountains to melt, endangering several lakes formed by glaciers in the Himadri Ranges. Nonetheless, just two of them have implemented mitigation steps to reduce water levels. These efforts have demonstrated excessive costs, raising concerns regarding their long-term viability and feasibility. Twenty years ago, the water table of Tso Rolpa glacier lake in the Rolwaling Valley was reduced following geologists' warnings that it was at risk of overflowing. The sluice gate reduced the water table by only 3 m, and scientists now assert that it must be lowered by an additional 20 m to mitigate risk.

The downstream grid of advanced warning stations has similarly failed to perform as anticipated. In 2016, the Nepal troops constructed a drainage canal and gate on Imja Lake in the Mt. Everest area, with assistance from the UN Development Programme (UNDP) and the Global Environment Facility (GEF), at a cost of $7.2 million. The project, situated at a height of 5,000 meters, faced criticism for being a costly spectacle in a renowned tourist destination near Mt. Everest, as well as for squandering funds on a lake that remains reasonably stable thanks to the two lateral mountains of the Nuptse and Lhotse Nup Glaciers. Glacial lakes in the Hongu basin, including Thulagi in Lamjung, have been identified as significantly more susceptible to bursting and necessitate urgent mitigating measures. Four years post-project completion, following a 3.4 m reduction in Imja Lake's water level, the Nepali troops and its primary contractor have not yet removed their bulldozers and tools from the site, contravening the instructions of Sagarmatha National Park's World Heritage Site.

The lakes formed by the glaciers are enlarging because of the accelerated melting of the glaciers that supply them, attributed to rising temperatures and heightened deposition of smudge particles on the snow. Research by ICIMOD published last year indicates that, even under optimal conditions, the Himalayas would suffer the loss of one-third of their ice by the end of this century. Recent research, however, has indicated that the defrost is occurring more rapidly than previously expected and is expediting. This has augmented the number and dimensions of lakes formed by glaciers in the Himalaya area in Nepal. The reports from the satellite-based tracking data indicates that there were 3,600 glacial lakes in 2015 Nepal's river basins. As of 2023, the number reached about 5000, in an area of 147.5 sq. km.

Researchers have consistently observed that the thawing rate is greater in the eastern Himalayan area compared to the western region, and the detail substantiates this finding. Notably, although the quantity of lakes formed by the glaciers in the Kosi basin has diminished, their aggregate area has expanded by 14 square km, primarily due to the amalgamation of supraglacial ponds or the drainage of lakes without breaching. The report documented 25 GLFF occurrences in the Nepal Himalayan area since 1977, with only 15 of these incidents associated with lakes situated in Nepal. This underscores the significance of the transboundary advanced warning system, particularly for the lakes in Tibet that are upstream of the Tama Kosi, the Arun, and others.

Earthquake and GLFFs:- Alongside the persistent threat of earthquakes, newly constructed hydroelectric facilities, river-adjacent roadways, bridges, and settlements must account for the possibility of GLFFs. In March, a flash flood at Nanda Devi in Uttarakhand, India, obliterated two under-construction hydropower plants. Nepal is urged to exercise caution through the development of cascade projects on the two Bhote Kosi rivers originating from China, as well as the Tama Kosi, Marsyangdi, and Arun rivers. The hazardous Thulagi glacier lake beneath Himalchuli in the Gandaki Basin presents an impending threat to three significant hydroelectric facilities located along the Marsyangdi River. Nepal is urged to exercise caution over the development of cascade projects on the Bhote Kosi rivers originating from China, as well as the Tama Kosi, and Arun rivers. The hazardous Thulagi glacier lake beneath Himalchuli in the Gandaki Basin presents an impending threat to three significant hydroelectric facilities located along the Marsyangdi River. According to geologists monitoring the glacier, the Thulagi glacier has retreated by 2 km since 1984, resulting in the formation of a lake in its place.

A survey conducted last year revealed that the possibility of GLFF is greatest in the eastern part of Nepal. Imja, Tso Rolpa, and Hongu are part of the 46 hazardous lakes located in the Kosi drainage. Any of such failures would result in the release of a deluge of sediment and water immediately downstream to the Kosi. Transboundary GLFFs pose an additional concern. The excess of seemingly minor glacier lakes in Tibet has already caused significant harm in Nepal. The first recorded incidence occurred in 1934, when a glacial lake flash flood inundated Tibet, causing destruction along the Bhote Kosi. In 1981, a calving glacier lake in China ruptured and caused a flood on the rivers in Nepal that damaged the Sun Kosi power facility and degraded a 25 km stretch of the Arniko Highway for a period of three years. Twenty-seven of the forty-nine hazardous lakes endangering Nepal's valleys originate from Tibetan glaciers. Since 1977, at least 20 glacial lake flash floods (GLFFs) have occurred, 14 of which were triggered by the rupture of glacial lakes in Nepal, while the remainder transpired in China.

In 2012, the flood occurred in Seti River caused the fatalities of more than 80 civilians north of Pokhara, representing a GLFF. While not caused by a glacial lake breach, it illustrated the catastrophic might of such a flood. Although Nepalis are not directly responsible for rising temperatures, this does not suggest that we should remain passive. While scientists strive to determine the rate of glacial melting, authorities in Nepal must initiate preparations for the forthcoming floods. The susceptibility to GLFFs is exacerbated by Nepal's location in a seismically vulnerable zone. In the occurrence of a substantial earthquake, multiple vulnerable Himalayan glacier- formed lakes may breach concurrently.

The imperative for hazard visualization, early alert systems such as Texting or television, and mitigation strategies aimed at lowering water levels in Tso Rolpa stream. The micro hydro project on the Langtang Lirung Glacier, which lowers the water level in a newly formed glacial lake while concurrently generating electricity, may act as a model for other isolated valleys in Nepal. Reducing the water levels of glacier lakes can be costly due to their high-altitude locations in remote areas lacking roadways. The majority of the equipment must be airlifted, and the operation is frequently impeded by elevation and meteorological factors.

Landslides and GLFFs:- The catastrophic collapse of the Nanda Devi glacier in Uttarakhand, India, on 7 February 2016, resulting in numerous fatalities, should prompt Nepal to prepare for analogous disasters in the future. According to a Planet Labs photograph, a rock-ice slope detached entirely from the summit of the

7,816-meter peak in the Garhwal Himalaya, adjacent to Nepal's western border, clashed with the glacier below, displacing ice and debris into the Dhauliganga and Alkananda Rivers. Satellite imagery reveals distinct indications of new brown dust. The ice liquefied upon encountering a warmer, lower elevation, culminating in a torrent flowing downstream. Two hydroelectric facilities on the rivers were completely destroyed, roadways were eroded, and settlements were submerged under meters of liquid and detritus. The Nanda Devi region tragedy closely resembles the 2012 Seti River flash flood north of Pokhara, which culminated in the deaths of over 80 individuals.

A substantial fragment of rock at the apex of Annapurna IV detached and descended onto the glacier, triggering a catastrophic flow down the Seti. In 2017, a rapid inundation in eastern Nepal was triggered by a slope failure on a mountain adjacent to the Nepal-China border, which collapsed over a glacial lake, resulting in a rapid inundation that inundated the primary river with debris. Incidents previously believed to be GLFFs were, in fact, rock-ice avalanches that caused glacier collapse in all three instances. The flood and debris subsequently flowed down the valleys, annihilating all in their trajectory. The increased probability of GLFFs in the Himadri range is evidently connected to the climate crisis, which is causing glacier melt and the expansion of moraine-impounded lakes; however, this does not appear to be the direct cause of catastrophe in the region of Nanda Devi, as it did not occur in the Seti and Arun regions. Rockfalls cause glacier collapse, displacing water from ponds and accelerating ice melt as they descend to warmer altitudes.

We should evaluate the potential hazards of GLFFs during the advancement of infrastructure and human settlements downstream. While GLFFs and glacial collapse garner significant attention, landslide-induced dam blockages also pose a problem in the Himadri range during the rainy season. The mountains are quite young, seismically active, and their slopes are highly unstable. Studies have demonstrated that monsoon precipitation can trigger landslides that block major rivers, a phenomenon that happened in June 2014. Fortunately, the river circumvented the barrier. Nonetheless, when the landslide dams collapse, the resultant lake can expand sufficiently to generate catastrophic Bishyari floods downstream. Geologists assert that the flat terraces supporting Pokhara were formed 7 centuries ago due to a landslip that blocked the Seti River upstream.

It collapsed, creating a tsunami 150 meters high. Pokhara is situated on the alluvial fan of this flood, which obstructed waterways and led to the creation of Phewa, Begnas, and additional lakes. It functions as a caution to prepare. We pray that the catastrophic possibility of a megaquake causing several GLFFs does not transpire in the near future. According to the Himalayan Glacier Lake Inventory, 47 of the enlarging glacial lakes in the Himadri range are at risk of overflowing, potentially causing devastating floods to the downstream. The Kosi River drainage in East-Nepal contains 44 lakes, the Gandaki basin has three, and the Karnali basin has two. Last year, the International Centre for Integrated Mountain Development and UNDP released research that mapped 3,628 glacial lakes in the Sapta Kosi, Narayani, Mahakali and Karnali drainage, identifying almost 50 lakes at risk of exploding. These 25 rivers flow into tributaries that supply water to Nepal. Currently, towns situated beside rivers must implement a pre-emptive alert mechanism. The risk of glacial flooding must be factored into infrastructure planning. Given that numerous high-risk glacier-fed rivers cross state borders, international cooperation is essential.

Results and Suggestions:- Analysing historical flood data, climate models, and field observations has highlighted many major findings:

1. Augmentation of Glacier Lake Volume and Quantity: Data indicates a substantial increase in both the number and size of glacial lakes within the area. Climate models demonstrate that rising temperatures have accelerated glacier melting, resulting in the establishment and expansion of these lakes. From 1980 to 2020, the quantity of glacial lakes in the area increased by over 30%, with many lakes demonstrating considerable volume growth.

2. Augmented Frequency of GLFFs: A significant rise has occurred in the prevalence of GLFFs. Historical data reveal a rise in reported flash floods associated with glacial lake outbursts, alongside the accelerated liquefaction of glaciers. The frequency of significant GLFF occurrences has increased from roughly one every five years in the early 2000s to nearly one every two years in recent times.

3. Elevated Temperatures of Glacier Lake Water: A significant rise has occurred in the prevalence of GLFFs. Historical data reveal a rise in reported flash floods associated with glacial lake outbursts, alongside the accelerated melting of glaciers. The frequency of significant GLFF occurrences has increased from roughly one every five years in the early 2000s to nearly one every two years in recent times.

The results underscore a substantial correlation between the changing climate and its fluctuations in the glacial lakes in the Himadri range of Nepal and India. The observed augmentations in the volume and number of melting glacier lakes are directly attributable to accelerated glacier melting caused by rising temperatures. The recession of glaciers creates new lakes and expands existing ones, altering the hydrological environment and increasing the risk of glacial lake eruption floods. The rise in the frequency and severity of GLFF is particularly concerning. Historical study demonstrates that when glacial lakes enlarge and their ice-dammed structures become progressively unstable, the likelihood of catastrophic eruptions increases. The ascend in lake temperatures exacerbates this risk by heightening the probability of rapid ice melt and structural failure. The consequences for downstream towns are substantial. Augmented GLFF activity poses a direct threat to life, real estate and infrastructure. The devastation from prior floods highlights the imperative for enhanced pre-emptive alert mechanisms, improved flood risk assessment models, and increased community preparedness strategies.

The mountainous areas of Nepal and North India are especially susceptible to glacial lake flash floods (GLFFs). The rupture of a glacial lake's moraine or ice dam can turn into catastrophic floods downstream. Global climate alteration is progressively exacerbating glacier melt, hence increasing the vulnerability of communities. To mitigate hazards and enhance preparedness, pre-emptive alert systems must function effectively. This research focuses on employing pre-emptive alert systems to monitor and control GLFFs in these regions. Dam failure causes glacial lakes to rapidly discharge their water, a phenomenon designated as a GLFF. Nepal and northern India require pre-emptive alert mechanisms to mitigate the effects of flash floods induced by glacial lakes. These systems can significantly enhance flood response and preparedness by integrating ground-based monitoring, data modelling, and satellite monitoring. We can improve these processes and alleviate the consequences of GLFFs on at-risk populations by resolving current challenges and augmenting community engagement.

1. Expanding Monitoring Networks by adding more sensors both on the ground and in orbit.
2. For Better Data Integration, Work on Improving Model Capabilities and Data Sharing Infrastructure.
3. Enhance community outreach, focused educational initiatives and emergency preparedness courses.
4. Invest in Technology, fund research into new technologies and improvements to infrastructure in places where danger is a concern. A more robust and well-prepared strategy for managing the risks of GLFFs in the region can be achieved by implementing these strategies.

Conclusions:- The results indicate that existing mitigation strategies may be inadequate in confronting escalating hazards, requiring a reassessment of flood control approaches considering climatic alteration forecasts. The influence of climatic alteration on glacier lake dynamics in Nepal and North India is significant and complex. The research underscores the pressing necessity for cohesive strategies to address glacial lake risks and adapt to the changing climate conditions. Improved monitoring, predictive modelling, and risk management measures are essential to alleviate the detrimental impacts of heightened melting glacier lake flash floods and protection at-risk communities in the area. Climatic alteration has markedly increased the likelihood of glacial lake flash floods, presenting an escalating threat to humans and ecosystems in elevated locations. The rapid melting of glaciers and the consequent rise in glacial lake volumes enhance instability and elevate the risk of catastrophic flooding. With the ongoing increase in global temperatures, the incidence and intensity of floods are anticipated to escalate, requiring immediate efforts to strengthen monitoring systems, refine risk management techniques, and execute effective mitigation actions. Resolving this issue is essential for safeguarding vulnerable communities and maintaining the fragile equilibrium of high-altitude ecosystems impacted by climatic alteration.

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