Assessment of Cloudburst and Landslide in East Siang District, Arunachal Pradesh: Combining GIS and Remote Sensing

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ABSTRACT

The development of civilisations is part of human evolution, but it comes at the cost of nature's destruction. Unsustainable human development results in long-term human destruction itself. This paradox underscores the need to implement a sustainable approach that balances human progress with environmental preservation. Due to climate change, many activities in nature become extreme, which directly and indirectly impacts human lives. Cloudbursts and landslides are two calamities that attract researchers' attention. Cloudburst and landslide are interrelated with precipitation. Most of these incidents remain undocumented. The downstream ecosystems of the affected area witness loss of life and property. The Eastern Himalayas are prone to heavy rains, especially cloudbursts, which can cause rapid slope failures and landslides in steep hilly terrain. Recently, that region has faced many calamities that cost human lives and property. This study uses remote sensing and GIS tools to analyse the incidence, spatial distribution, and risk assessment of landslides triggered by cloudbursts in East Siang District, Arunachal Pradesh. Our study area comes in the lower Siwalik range of the Himalayas. The study uses satellite images, Digital Elevation Model (DEM) data and rainfall data. It was found that some parts of the study area are at risk of landslides and cloudbursts. The findings promote improved planning for catastrophe risk reduction in remote areas of the country.

Keywords: remote sensing, East Siang, Himalaya, cloudburst, landslide

INTRODUCTION

Cloudbursts and landslides are interrelated hydrometeorological dangers that significantly impact mountainous regions along with human settlements (David Raj & David Raj, 2025). A cloudburst is an intense precipitation event, usually above 100 mm per hour in a specific region. It is generally induced by vertical lifting and atmospheric thunderstorm instability (Samantray & Gouda, 2024). Landslides are characterised by a massive flow of earth, rocks, and debris down a slope. Major factors are geological structure, slope grade, and anthropogenic activity (Singh & Kansal, 2021). A world disaster report (International Federation of the Red Cross and Red Crescent Societies, 2001) shows that flooding and landslides account for 42% of the global incidence of natural disasters. In addition to the loss of lives, flooding and landslides result in significant economic losses totalling billions of US dollars in countries such as India, Nepal, Italy, and the USA (Union, 2011). Research indicates that the frequency and intensity of cloudbursts and landslides are increasing due to climate change, especially in the Himalayan region (Dimri et al., 2017; Singh & Kansal, 2021). Researchers studied cloudbursts and the associated landslides based on their geomorphic signatures (Hobley et al., 2012; Sangode et al., 2017). Some researchers worked on observation of such events (Gupta et al., 2013; Juyal, 2010) and studies based on modelling (Thayyen et al., 2012; Kumar et al., 2012).

It was found that these types of cloudbursts in mountainous regions are associated with thunderclouds. In these events, a heavy downpour ranging from 200 to 1000 mm/h occurs over a very short period in a localised area (Deoja, 2000; Dimri et al., 2017; Singh & Kansal, 2021). Researchers examined the cloudburst event that happened on August 3, 2012, over the Asi Ganga, a tributary of the Bhagirathi River, in the Garhwal Himalayas (Gupta et al., 2013). The study indicates that the factor that causes cloudbursts is the orographic structure of mountainous terrain, which makes these areas favourable for the formation of localised cyclonic storms (Gupta et al., 2013; Gupta et al., 2016). It was found and identify in research the two distinct methodologies for assessing the characteristics of landslides using remotely sensed data (V Singhroy & K Molch, 2004; Vern Singhroy & Katrin Molch, 2004; Singhroy et al., 2002). It was argued that the use of remote sensing in the study of landslides was not fully exploited and was used for only landslide studies and hazard zonation (Mantovani et al., 1996). In recent investigation it was predicted and dismissed the likelihood of a cloudburst according to the IMD's definition of the catastrophic floods in Uttarakhand in 2013 and Jammu & Kashmir in 2014. They proposed that the interaction between low-level westward-moving monsoonal systems and eastward-moving mid-tropospheric westerly troughs was a primary factor. These studies confirmed that in the Himalayan region the positioning and timing are critical factors for the occurrence of cloudbursts (Ray et al., 2019; Sikka et al., 2015).

Recently, Arunachal Pradesh has encountered recurrent landslides that have impacted communication, agriculture, and infrastructure as a result of major rainfall-induced landslides. Arunachal Pradesh, which comes under the Eastern Himalayan area of India, has significant susceptibility to cloudbursts and landslides (Rehman & Azhoni, 2023). The East Siang District Disaster Management Authority states that the district is susceptible to several natural hazards, including floods, cloudbursts, and landslides, particularly during the monsoon season. Three different locations from various parts where cloudbursts and landslides happen are being studied to assess the regions. The aim is to understand the underlying geographical and meteorological factors contributing to these natural events. The combination of Geographic Information Systems (GIS) with remote sensing technologies is crucial in mitigating disaster risk and evaluating prospective dangers. This also improves disaster readiness along with sustainable land-use management.

METHODOLOGY

Study Area

The East Siang District is in the Lower Himalayan foothills of Arunachal Pradesh (Sharma & Shukla, 1992). The district consists of mountains, flood plains, many bodies of water, dense forests and the mighty Siang River, which divides it. **Figure 1** shows the study area.

Data Acquisition

Satellite Images obtain high-resolution images from google earth and USGS. DEM from USGS. Rainfall Data from IMD/Global Precipitation Measurement as shown in **Figure 2**.

GIS-Based Susceptibility Mapping

ArcGIS was used to integrate and spatial distribution of multiple factors.

Topography

Slope gradients are directly associated with a frequency of landslides due to gravitational forces exerted on saturated soils. Steep valleys in the East Siang mountainous regions correspond with landslide areas, as seen in satellite images. The digital elevation map (DEM) of the study area shows the terrain features that contribute to the instability of the slopes as shown in **Figure 3**.

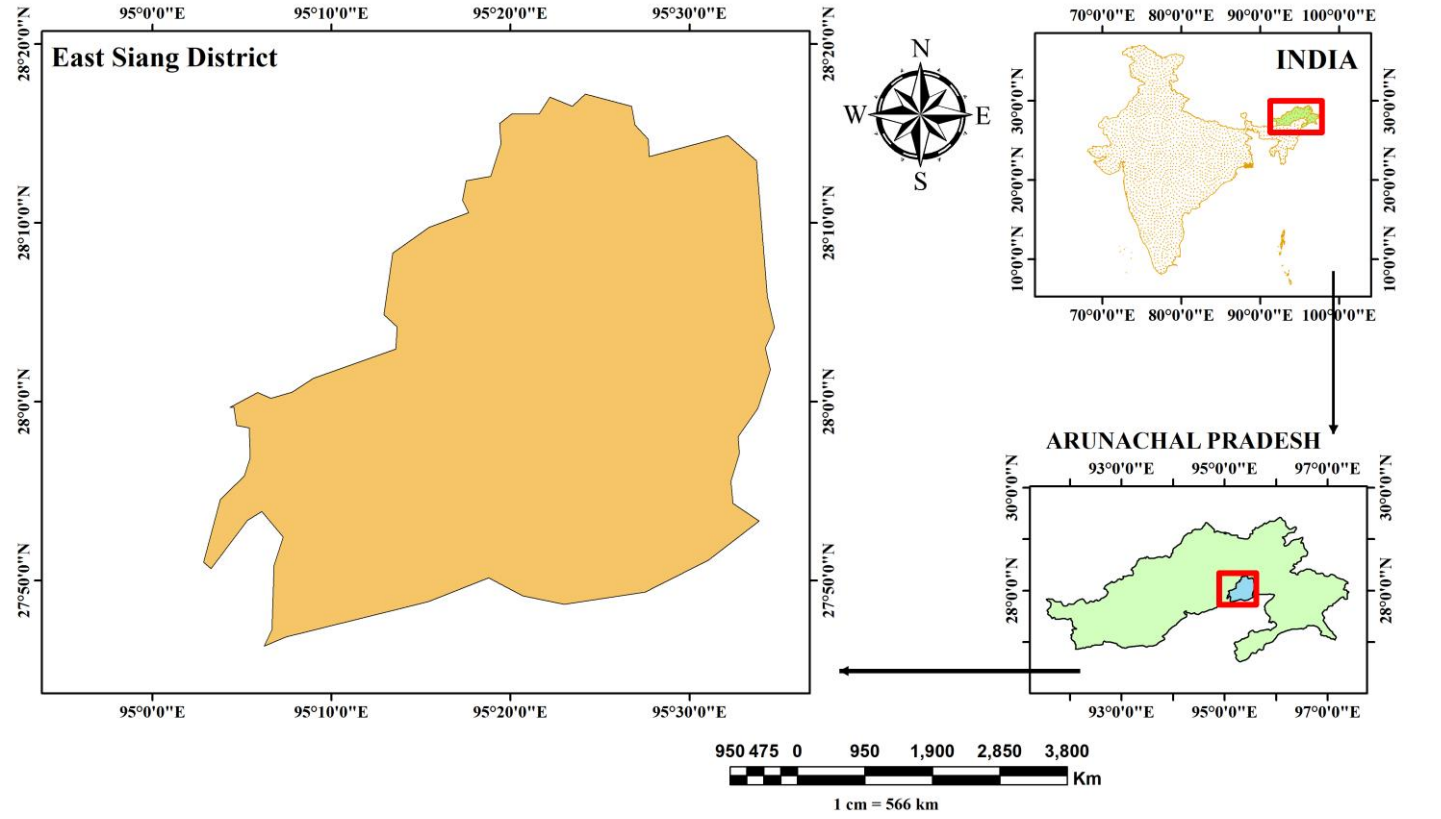

Figure 1. Map of the study area.

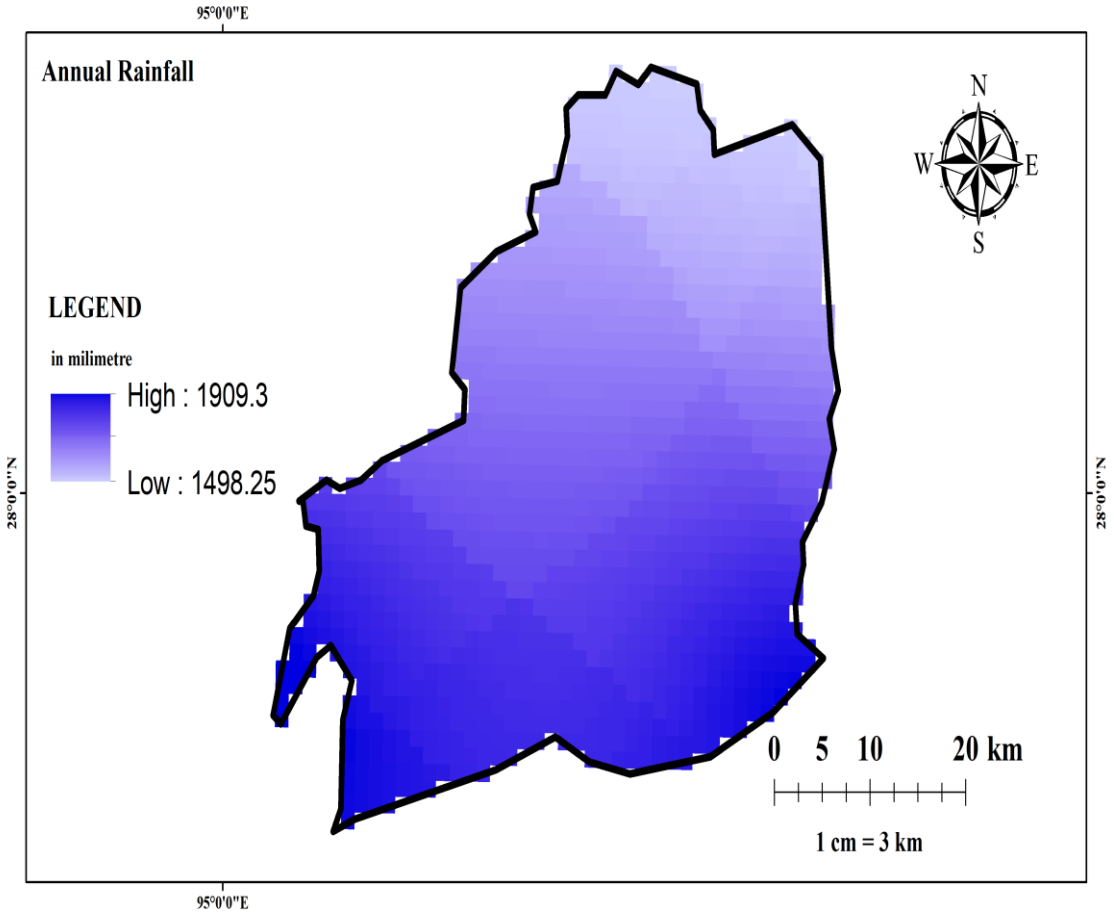

Figure 2. Annual rainfall of the study area.

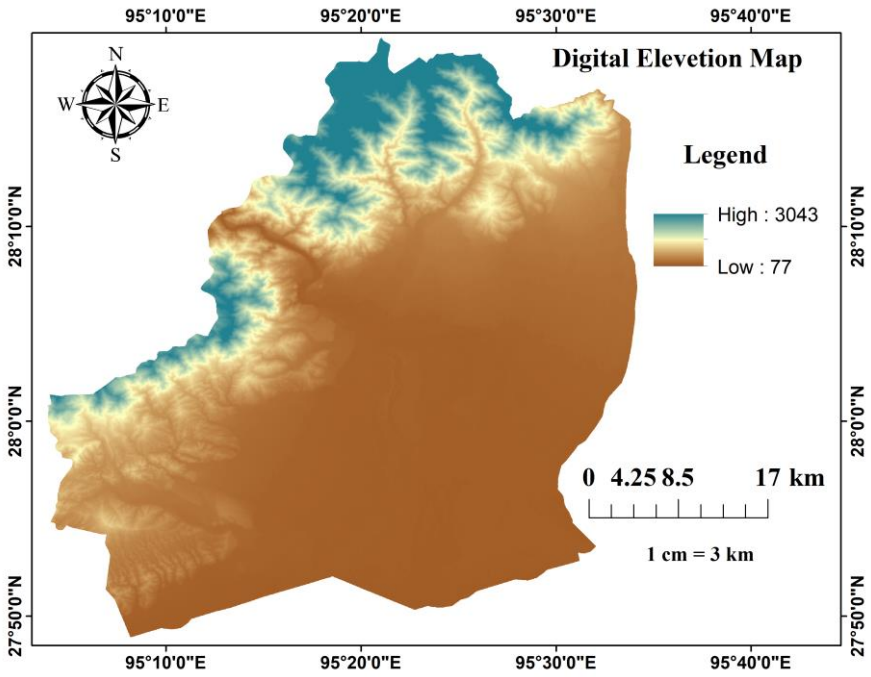

Figure 3. Digital elevation map of the study area.

RESULTS AND DISCUSSIONS

We have taken three places where cloudbursts and landslides took place, which covered the whole study area. **The Figure 4** shows the location these events. The events took place during monsoon seasons when rainfall was maximum. No lives were lost during the event, but property was damaged.

As shown in **Figure 5(b)**, the location is situated on a highway nearest to Bodak village. It is a small stream tributary of the Siang River. This event occurred in 2020, the year when Covid-19 was rampant and the weather was extreme all over the world (Ezeh et al., 2021; Walton & van Aalst, 2020). The isolated regions and sparse human settlement prevented any fatalities, but the highway sustained minor damage. Similarly, location 3 was located in an isolated area [**Figure 5(c)**], resulting in minimal damage to human lives. Location 2 is on the way to Yagrung Village, as shown in **Figure 5(a)**. The event is two decades old, but with time, the area of damage increases year by year and continues to damage the property. Compared to the other two locations, the affected region has a relatively high population density. This disaster continues to damage many roads and agricultural fields in low-lying parts. These places also consist of small water streams.

Rainfall can rapidly saturate soil layers and induce slope failures, which result in landslides and cloudbursts. Similar occurrences have been recorded in other regions of Arunachal Pradesh, where cloudbursts resulted in landslides. Remote sensing of rainfall helps in identifying patterns of strong rainfall and exact places that may precede slope failures. Areas characterised by steep inclines, heavy rainfall, intricate drainage systems, and sparse vegetation exhibit a high susceptibility to landslides and cloudbursts (Ramya et al., 2023). Although data on cloudburst occurrences in East Siang is limited, the integration of rainfall intensity and topographical data suggests that valleys with steep slopes along water bodies may experience conditions conducive to cloudbursts due to the increase of monsoon clouds.

Deforestation, development, and agricultural activities on hilly areas change land cover and uses, increasing vulnerability to landslides. Spatial hazard maps are essential for local authorities to strategies risk reduction, distribute resources, and establish early warning systems in high-risk areas. The limitations of satellite capture hinder real-time observation of cloudbursts and landslides. Ground verification and high-resolution precipitation data are crucial for improving risk prediction.

Figure 4. Location of cloudbursts and landslides of the study area.

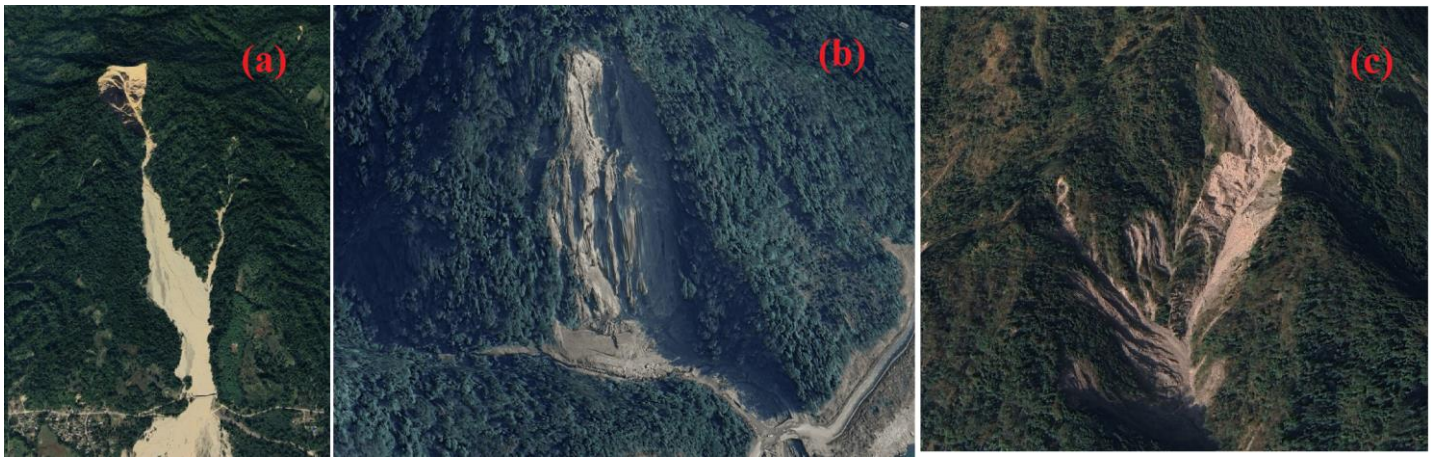

Figure 5. (a) Location 2; (b) Location 1; (c) Location 3 of the study area.

CONCLUSION

From the investigation we can conclude that most of the events that happened were associated with water streams. This study helps reduce landslide-induced cloudburst risks in the study area. By integrating these techniques, we can pinpoint high-risk zones for cloudbursts and landslides.

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