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Physical and Anthropogenic Factors of Flood Disaster: The case of Akurana Urban Area, Kandy District, Sri Lanka

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Abstract

Over the past few decades, several urban areas in Sri Lanka have been adversely affected by flooding disasters. Being one of the fast-growing urban areas in Sri Lanka, the Akurana town in Kandy District has experienced an increasing frequency and severity of flood disasters in recent years. The heightened concerns about the growing risk level make it imperative to examine the underlying causes of urban flooding. Thus, this study examines the physical and human factors contributing to the increased flood disaster risk in Akurana town. The study adopted a mixed-method approach for data collection and analysis. The primary data collection techniques employed in this study include questionnaire surveys, key informant interviews, and direct observation. Secondary sources were used to gain a comprehensive understanding and insights into the problem. Quantitative and qualitative approaches were used to analyse data gathered from various sources. Three Grama Niladari Divisions—Akurana, Waragashinna, and Kurundugahaela—that are regularly hit by flood disasters in the Akurana region were selected for this study. A questionnaire survey was administered to 66 households in these three divisions. The findings reveal that the frequency and magnitude of flood disasters have increased significantly in recent years, driven by various factors. While physical factors, such as rainfall and the physical landscape, play a significant role in causing flood hazards, human factors, including urbanisation coupled with population growth, changes in land use, improper building construction, a higher number of bridges, and poor drainage systems, have been recognised as key contributors. Although the study area was previously vulnerable to flooding due to natural causes, intensified human activities have increased its vulnerability to recurrent inundation in recent years. Therefore, it is essential to address these complex causative factors and issues, and to implement sustainable management practices to reduce the risk of flooding and promote a more resilient urban community in Akurana town.

Keywords: Flood, Human Interventions, Land use change, Risk, Urban Growth, River morphology

1. Introduction

Sri Lanka is frequently affected by natural disasters, including floods, droughts, and landslides (Karunarathne & Gress, 2022). There has been a discernible increase in the frequency of high-impact disasters

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since 2011, with an average annual impact of over a million people (Ministry of Disaster Management, 2017). Though many types of disasters hit Sri Lanka, flooding is among the most common hydro-meteorological disasters and has become a recurring event in recent years. Sri Lanka, highly susceptible to flooding, experiences recurrent flooding each year, causing substantial socio-economic and environmental consequences (Dasandara et al., 2022).

Floods and other water-related disasters pose a significant risk to Sri Lanka, and their frequency is increasing due to climate change (Walsh & Hallegatte, 2019). Due to their nature, severity, and frequency, floods cause devastating impacts on lives, property, and the environment. Flooding disaster strikes not only the economy but also the social status of affected areas and the entire nation (Manawadu & Wijeratne, 2021). While several regions across the country are vulnerable to flood hazards, urban areas stand out as having an exceptionally high level of vulnerability. Not only in Sri Lanka, but also in various regions worldwide, the problem of urban flooding presents a substantial challenge (Eldho et al., 2018).

Over the past few years, urban flooding has become a significant challenge to sustainable development in cities in Sri Lanka. Urban areas are particularly vulnerable to flooding, which has increased in frequency and severity alongside urban development (Dammalage & Jayasinghe, 2019). They further state that the most common types of flooding in urban and suburban areas are riverine and urban flooding, which occur more frequently than other types. In general, flooding can occur due to various environmental factors, including meteorological, hydrological, geographical, and geological conditions, and these occurrences may be exacerbated by human activities (Samarasinghe et al., 2022).

Urban flooding can occur from various sources, including riverine flooding, coastal flooding, pluvial inundation, groundwater, and the failure of artificial drainage systems (Manandhar et al. 2023). A combination of natural and human factors contributes significantly to the occurrence and severity of urban flooding. However, anthropogenic activities have significantly influenced the increase in flood disasters in recent times (Manawadu & Wijeratne, 2021). Among the anthropogenic factors contributing to flooding in urban areas, those associated with the urbanisation process pose a significant concern. Continuous urbanisation widens areas affected by flash floods and the floodplain (Feng et al., 2021). For instance, the emergence of newly flooded areas within the Lower Kelani is considered the consequence of urban development (Samarasinghe et al., 2022).

Rapid urbanisation leads to changes in land use, particularly through increased paving, which affects local hydrometeorological processes (Manandhar et al., 2023). Furthermore, paved impervious surfaces hinder natural infiltration, thereby decreasing surface infiltration rates (Feng et al., 2021). In particular, urban areas restrict the percolation of water in built-up areas and experience a sudden increase in floodwater (Agonafir et al., 2023). These factors lead to higher surface flow velocities and discharges. One of the significant problems in Sri Lanka and Asia is the ineffective management of stream corridors in areas that are becoming increasingly urbanised (Najimuddin et al., 2017).

Urban flooding poses a serious risk to human health and property due to the concentration of people and infrastructure. Thus, urban flooding has emerged as one of the most financially burdensome disasters in Sri Lanka due to its significant property damage and human casualties (Vidushan & Perera, 2017). Urban flooding also disrupts transportation networks by causing delays, road closures, and diversions, and by altering human mobility patterns (Abenayake et al., 2022). In recent years, due to intense rainfall, the number of people at risk from flooding has increased significantly. UNDRR (2019) also stated that the annual monsoons, coupled with flooding and landslides, result in intense socio-economic impacts and loss of human lives. Consequently, seasonal and local floods pose a severe risk, and it is anticipated that this risk will increase in tandem with the frequency of hydro-meteorological disasters (GFDRR, 2017). As a result, concern about urban flooding has increased nationwide.

Although flooding affects many areas of the country, the Eastern and Western provinces are particularly at risk and face greater challenges due to the rising flood risk. Despite having a lower risk of flooding than other provinces, certain areas in the Kandy district in Central Province have been at risk of flooding in recent years. Akurana is one of the areas that frequently experiences flooding, and it has become the most alarming issue in the town. Flood hazards occur more frequently or with greater intensity due to natural and anthropogenic factors. Certain human actions increase the likelihood of flood events and their subsequent negative impacts (Vojtek & Vojtekova, 2016). Thus, it is imperative to recognise and comprehend anthropogenic processes and their spatiotemporal relevance (Gill & Malamud, 2017); and, they must be systematically reduced.

Since urban areas are becoming increasingly vulnerable to extreme weather events due to population growth and development activities (Piyumi et al., 2021), it is crucial to address flooding in Akurana town and implement strategies to reduce the risk. Although some studies have been conducted in the past to explore the causes, comprehensive research remains necessary to identify the contributing factors and to develop strategies to reduce long-term flood risk. In this context, this study aims to make a significant contribution to the field by investigating the physical and anthropogenic factors of flooding in Akurana town.

Even though the social and economic effects of floods cannot be reversed immediately, identifying their underlying causes is crucial to society's well-being. Further, it can contribute to effective decision-making in flood risk management. This scenario emphasises the need for the study to achieve a comprehensive understanding of the underlying causes of flooding and to identify appropriate strategies for developing this commercial city into a sustainable one in the long run.

2. Materials and methods

2.1 Study area

The study area belongs to the Akurana Divisional Secretariat Division, one of the 20 Divisional Secretariat Divisions in Kandy District, located in the Central province (Map 1). Akurana is a vibrant town that always seems bustling, located just north of Kandy. The town is about 10 kilometres from Kandy town and is situated next to Katugastota town. It is an urban area located along the A9 road near Ampathenne town, undergoing rapid development. Its expansion is geographically constrained by hilly terrain and the Pinga Oya.

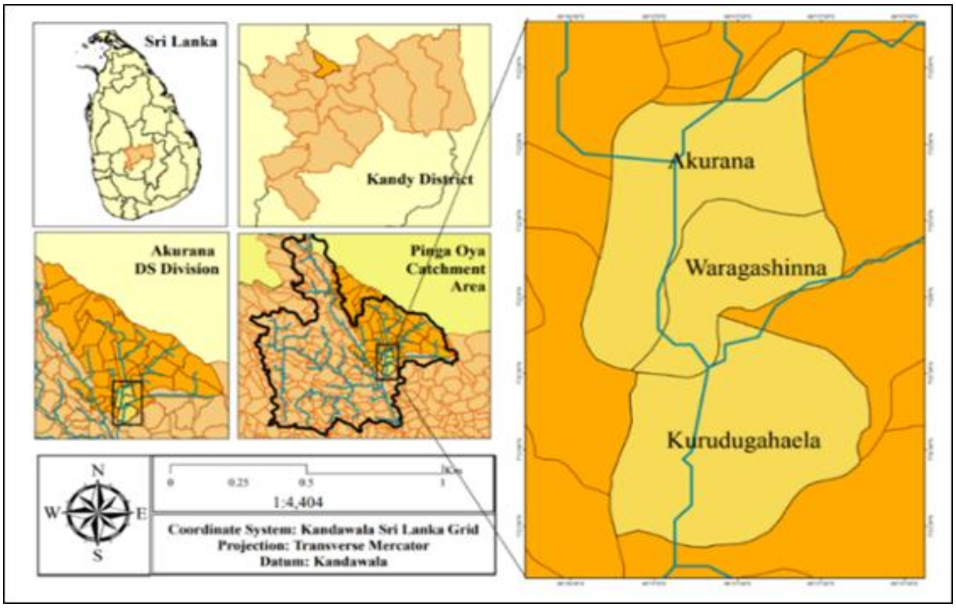


Figure 1: Location map of the study area, 20

The study area is situated in a lowland region surrounded by hilly terrain. Due to its temperate climate, this area has an average annual temperature of 24°C and receives between 2,500 and 3,000 mm of rainfall. The temperature varies spatially, ranging from 15°C to 30°C. Covering an area of 32.39 square kilometres, the Akurana DS Division comprises 35 Grama Sevaka divisions, 90 villages and 148,865 families (Akurana DS Division, 2021).

As of 2021, the Akurana region had a population of 79,021, with the majority of residents being Muslims (approximately 67%). Business is their main economic activity, making this area well-known for trade and industry in the Central Province. This economically significant city is part of a vibrant urban area due to its proximity to the central city of Kandy, as well as Katukastota and Ampatenna town. To study the causes of floods, three of the 35 Grama Sevaka Divisions under the Akurana Pradeshiya Sabha Division, namely Akurana (564), Waragashinna (566), and Kurundugahaela (592), which frequently experience flood disasters, were chosen. In the past 20 years, floods have often affected these three Grama Sevaka divisions (Akurana DS, 2021). In total, these three divisions contain six villages. However, the effects of floods vary among these three divisions.

2.2. Data, data collection and analysis method

This study sought to identify the physical and anthropogenic factors contributing to flood disasters in Akurana town. Thus, the study employed a methodological triangulation approach to achieve its goals, utilising both primary and secondary data sources to collect information on flood events, the nature of floods, and the physical and anthropogenic factors contributing to flood disasters. The survey method was the primary method applied in this study. A questionnaire survey, direct observation, and key informant interviews (KII) were used as the primary data collection methods.

Direct field observation was conducted to develop an understanding of flood-prone areas, the Pinga Oya watershed, land-use patterns, urban structure, settlement patterns, drainage patterns, and the prevailing management efforts in the study area. Additionally, data relevant to the nature of the flood hazard, risk level, causes, and effects were collected through key informant interviews with the Disaster Management Officer, the Development Officer, and the Grama Niladari Officers (from all three divisions). Five key informant interviews were conducted, lasting 20–30 minutes.

The primary method of data collection was a questionnaire survey, which yielded a significant amount of data. The structured questionnaire included both closed-ended and open-ended questions. These questions covered demographic information, flood event-related details, and data relevant to causal factors of flooding. According to the number of households in each of the three divisions, these questionnaires were distributed using a stratified random sampling method. Sixty-six households were selected for the questionnaire survey from the total of 1,901 households in the study area based on their flood risk level. Thirty-eight families (5%) were chosen from the 766 families in the high-risk Akurana Grama Sevaka division. In comparison, 18 (3%) families from the 612 families in the moderate-risk Waragashinna Grama Sevaka division were chosen. Of 523 families, 10 were selected from the lower-risk area of the Kurundugahaela Grama Sevaka division.

Secondary data were obtained from the Kandy District Disaster Management Centre, the District Secretariat in Kandy, the Divisional Secretariat Division in Kandy, the Meteorological Department, as well as maps, photographs, previous studies, and website sources. Rainfall data for Katugastota station (nearest station),were obtained from the Department of Meteorology, Sri Lanka, for 53 years from 1970 to 2023. Digital elevation maps were obtained from the United States Geological Survey through the Earth Explorer platform. A land use classification map was produced based on the satellite imagery for the two years (2003 and 2023) and processed in Arc GIS 10.4 to identify two primary land use categories, such as green cover and settlement. Google Earth images for the years 2003 and 2023 were obtained to examine bridges over the Pinga Oya using the timeline tool.

A combination of quantitative and qualitative analysis techniques was used to examine the data collected from primary and secondary sources. Questionnaire data were analysed using both quantitative and qualitative methods. Using frequency, percentages, and mean values, an overview of the respondents was identified, and the findings were illustrated using graphical representations, such as charts. For open-ended questions, qualitative techniques such as coding, ranking, and description were utilised.

Simple statistical analysis techniques were employed to reveal specific features of the quantitative data. The trend in annual total rainfall in the study area is depicted in a time-series plot, and descriptive statistics for seasonal rainfall were obtained using Minitab statistical software. ArcGIS 10.4 was used to generate the land-use map, digital elevation model, slope map, contour map, drainage map, population density map, and flood-hazard level map of the study area. Google Earth has also been used to identify land-use and bridge structures in the study area.

To analyse the findings from the key informant interviews and observations, thematic analysis was employed. The interview content was read multiple times to capture the pattern and key ideas, and codes were assigned to indicate causes of flooding, such as “expansion of buildings”, “concrete pavements”, “reduction of vegetation”, “rainfall”, etc. Then related codes were grouped into themes like inappropriate construction”, “land use change”, "urban growth", etc. Then, common causes were identified and validated through field observations and literature.

3. Results and Discussion

Over the past 20 years, flooding disasters have become more frequent in the study area. Three Grama Sevakar divisions, such as Akurana, Waragashinna, and Kurundugahaela, differ spatially in their vulnerability to flood disasters. Kurundugahaela GN Division is at low risk of flooding, Waragashinna GN Division is identified as having moderate flooding conditions, and Akurana GN Division is categorised as a high flood zone (Table 1). Overall, approximately 97 per cent of respondents have experienced flooding in the past, and only about 3 per cent of those living in flood-prone areas remain unaffected by the adverse effects of flooding in the study area

Table 1: Flood-affected GN divisions and their impact level

Division No	GN Divisions	Flood Impact Level
564	Akurana	High
566	Waragashinna	Moderate
592	Kurundugahaela	Low

Source: Akurana Divisional Secretariat Division, 2023/24

Between 1990 and 2023, the region experienced over 26 flooding incidents, highlighting a prolonged vulnerability to such natural disasters over the past three decades. The first recorded flood disaster occurred in 1978; no further significant flood events were reported for a considerable period afterwards. Subsequently, the situation changed, leading to an increased frequency of flooding, with notable events reported in 2001, 2006, and 2009. After 2010, there was a noticeable rise in the flood events in the study area. It is noteworthy that the situation has worsened over the last decade, and flooding has become an annual occurrence in the study area. The consecutive flood events occurred in 2011, 2012, 2013, 2014, 2015, 2018, 2021, 2022, and 2023.

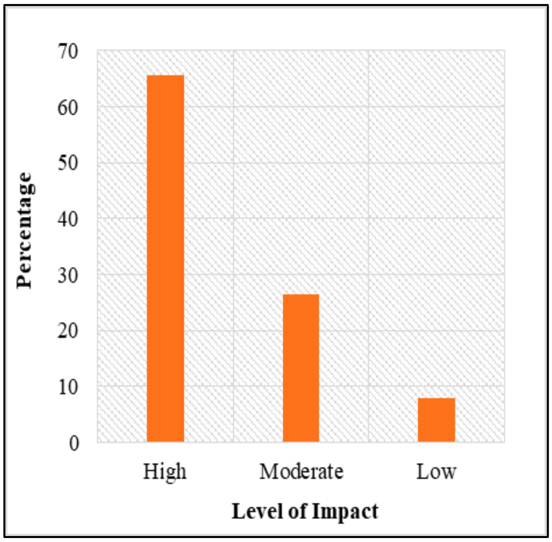
The town experienced a minor flash flood in early 2022, and at the end of the year, it was affected by severe flooding. The major flood that occurred in Akurana town on December 25th, 2022, is regarded as a massive flood disaster. Notably, the floodwater was found to be higher than 10 feet, and it took over 10 hours to recede. In 2023, the town was again inundated by floodwater, with water levels higher than those recorded in 2022. However, preparedness measures mitigated the impacts to a lesser extent than in 2022.

The trend suggests that the risk of flooding has not yet decreased, despite the implementation of specific management measures. Massive damage is caused by sudden flash floods and floods with rapidly rising water levels. It is noteworthy that flash flood is a significant environmental issue in Sri Lankan cities experiencing unplanned urbanisation. Although a normal rise in water levels does not cause substantial harm, daily life and traffic were affected.

The study revealed that three different types of flooding have occurred in the study area: flash flooding, river flooding, and urban flooding. Urban flooding is characterized by stagnant water due to factors such as the concentration of buildings, poor drainage, and the higher population density found in the town. River flooding occurs when the water level of the Pinga Oya rises due to heavy rainfall in the catchment area. Rainwater from the upper reaches of the watershed flows into the Pinga Oya. As a result, the Pinga Oya's water level of Pinga Oya rises rapidly and overflows, causing flooding.

The concentrated residential areas, commercial buildings, industrial activities, and agricultural lands are considered likely to be inundated in the study area. Regarding the population affected by the flood disaster, impacts are observed across all three Grama Sevaka divisions. In terms of spatial variation, the entire Kurundugahaela Grama Sevaka division is at risk, and the trend of flooding in this division is increasing.

Significantly, the majority of people in the study area have been affected by flooding multiple times. The majority of the population has been affected by severe floods more than five times. The situation highlights the vulnerability of the local population, as evidenced by the fact that 98 per cent of those in the study area have experienced flooding at least three times. Although the flood has severely impacted many people in the study area, some have experienced minimal impacts. Based on respondents' experience with flooding and the damage it causes, flooding is categorised into three categories: major, moderate, and minor. According to the findings, about 66 per cent of people are severely affected by floods, while only 26 per cent are moderately affected (Figure 1 & Map 2). A minor water level rise (defined here as a 0.5-foot increase) affects only 7.8% of the population.



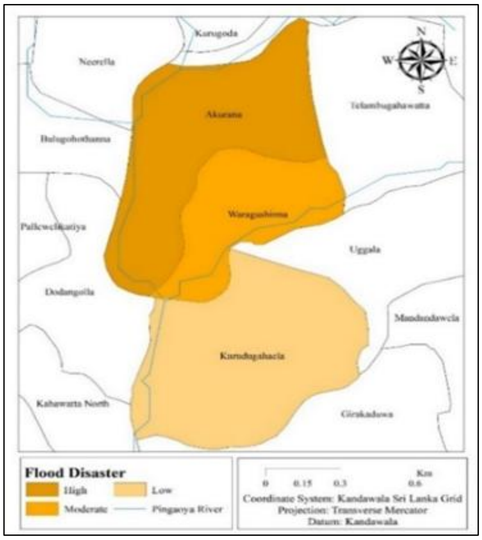


Figure 1: Level of impact, Figure 2: Level of impact (Source: Field Survey, 2023/24 and Data obtained from DS Division, Akurana)

The residents of the three chosen Grama Sevakar Divisions, particularly those in the Kurundugahaela area (near the Dunuvila road) and the Akurana urban area, are facing increased harm due to the high risk of flooding. Along with these spatial patterns, the study area is more vulnerable to flooding than it was previously. The study area's natural landscape and growing human activity are driving increased flooding.

3.1 Physical Determinants of Flood Hazards

The analysis indicated that several physical factors contribute to urban flooding, including topography, drainage patterns, soil, rainfall, and seasonal changes. The study area, located in low-lying areas with hilly terrain and receiving substantial rainfall, typically experiences increased water accumulation and rapid runoff. Thus, physical factors collectively interact and create conditions that can lead to frequent and severe flooding in the Akurana urban area.

3.1.1 Topography, Drainage Pattern, and Soil

Flooding is naturally more likely in the study area because it is located in a low-lying area surrounded by elevated terrain. Landforms in the area have varying elevations, with an average elevation of 543.7 meters above sea level (MSL). It is a region with diverse geomorphological landforms, including mountains, river valleys and lowlands.

Akurana, situated on the northern boundary of the Kandy Plateau, drops vertically from 2500 feet to 1500 feet from the west. It also shows rough gradients along the boundary of the Matale District. Elevation variations in the study area range from 455 to 575 meters. Low-lying valleys (455 – 468.3 meters) are mainly concentrated in the central part of the region (Map 3). The main river, the Pinga Oya, associated with flood events, passes through this low-lying valley (Figure 3 and 4).

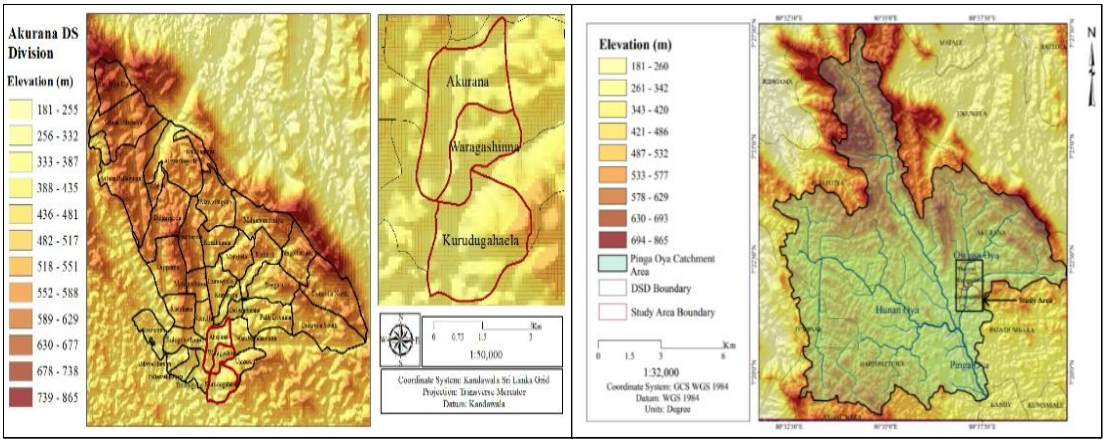


Figure 3: Topography of Akurana DS Division, Figure 4: Pinga Oya River basin and the study area (Source: USGS Earth Explorer, 2024)

The drainage pattern, in conjunction with the region's topography, significantly enhances the susceptibility to flooding. The area is rich in water resources, influenced by streams, small canals, and rivers (Figure 5). The Tangwadura River, Khandevela Canal, Aluth Bodwela Canal, Sathithodai Canal, Palakaduwa River, and Vanakala River are significant water sources in this region. Although multiple water sources exist in the area, the Pinga Oya, which flows through the town, is the primary driver of flooding.

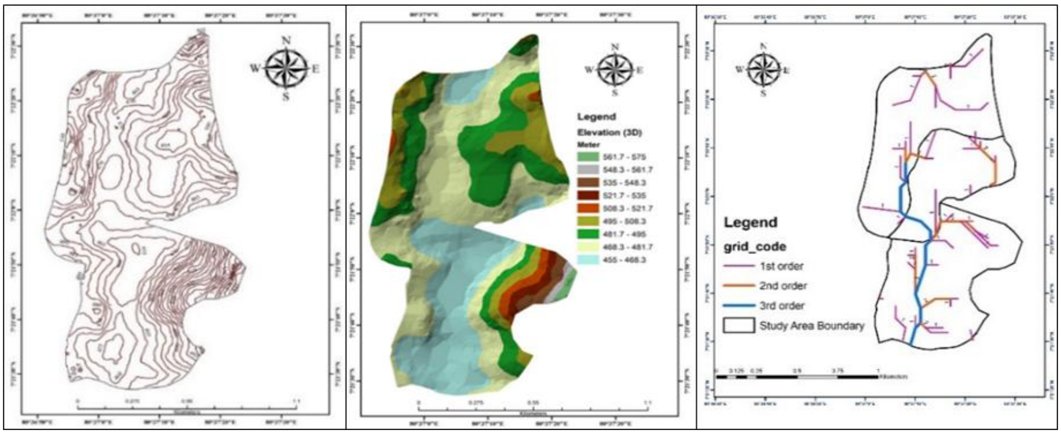


Figure 5: Contour Map, Digital Elevation Model and River Order Map of the study area (Source: USGS Earth Explorer, 2023)

The Pinga Oya, a tributary of the Mahaweli River, primarily flows through Akurana, Kurukala, and Ampathenna along the A9 highway. It converges with the Mahaweli River at Katuhastota Town. Consequently, from the point of confluence, the flood disaster spreads out through Pinga Oya for a distance of about 5 kilometres. The River Kasawatha and the Pinga Oya significantly influence flood events in the study area. The study revealed that flood events are becoming more frequent due to changes occurring in the Pinga Oya watershed. The changing morphology, width, depth, volume, flow, and characteristics of the Pinga Oya contribute to the increasing risk of flooding.

Increased sedimentation from the river networks of the Pinga Oya watershed has also led to more flooding in the study area. Since the area consists predominantly of soil types such as IBL - Immature Brown Loam Soil, RBL - Reddish Brown Latosol, and Lithosols, which are types are easily eroded they are washed out of upland areas along the slope lands during rainy spells. Eroded soil settles as silt in riverbeds, causing rivers to become clogged. Thus, increased sediments contribute to sediment accumulation on riverbeds, reducing river depth and causing sediment pollution, which has become a significant environmental problem in the region from an ecological perspective (Figure 6). Moreover, the sediment deposits alter the river's flow patterns, reducing its width and depth, and also restrict channel flow, resulting in frequent flooding.

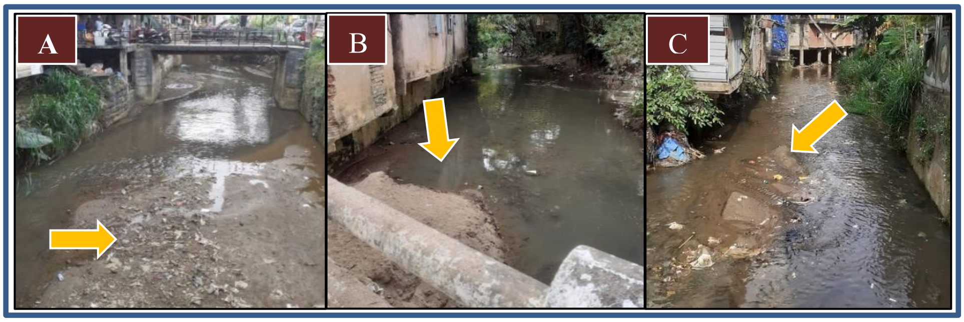


Figure 6: Deposits in the Riverbeds A-C, (Field Survey, 2023/24)

3.1.2 *Rainfall and Seasonal Changes*

Although several factors have increased the potential for flooding, it primarily occurs during periods of heavy rainfall. The study reveals that recorded flood events in the study area mostly happen during periods of heavy rain. During the monsoon season, heavy rainfall often triggers intense storms, leading to severe flooding in Sri Lanka (Samarasinghe et al., 2022). Najimuddin et al. (2017) state that although the patterns of rainfall have remained unchanged over the past 15 years (2001–2016), frequent flood occurrences have been observed in the study area.

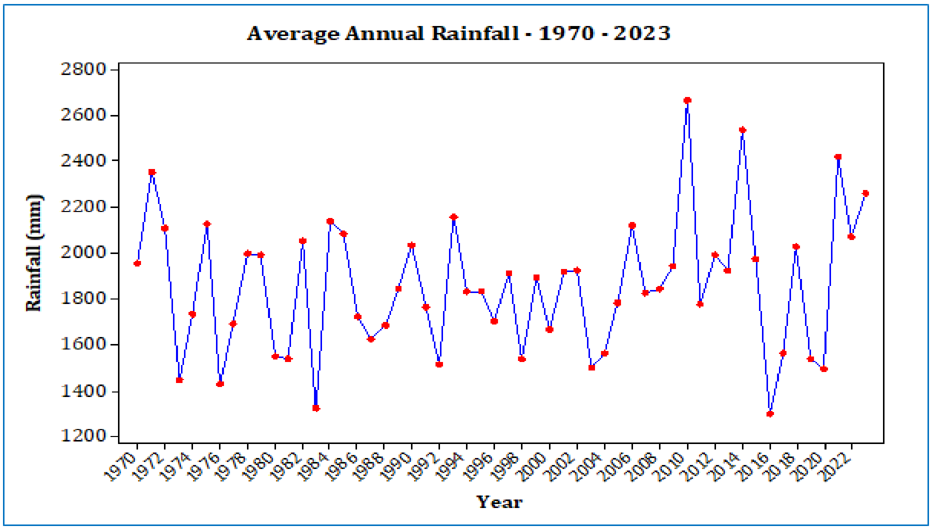


Figure 7: Annual Average Rainfall (1970 to 2023) Source: Meteorological Department, Sri Lanka, 2023

Although the study area receives rainfall throughout the year, the majority of rainfall occurs during the second inter-monsoon and the south-west monsoon. The pattern of rainfall and flood events in the study area is significantly influenced by these two seasons. The annual average rainfall in the region exhibits fluctuation, as indicated by data from 1970 to 2023 (Figure 7).

The flood events in the study area are primarily determined by variations in the annual rainfall and the changes in seasonal and daily rainfall patterns. The study reveals that the average annual rainfall is 1846 mm, with a standard deviation of 294.4 and a coefficient of variation of 15.95. The year 2010 is considered the highest rainfall year, with 2,665.6 mm, while the lowest annual rainfall of 1300mm was recorded in 2000. Over the past 53 years, nine years (1971, 1972, 1975, 1984, 1993, 2006, 2010, 2014, and 2021) have received rainfall exceeding 2,100 mm. Among them, the study area received more than 2,400 mm of rainfall in 2010 (2,665 mm), 2014 (2,539 mm), and 2021 (2,422 mm). Although annual rainfall shows this pattern, the seasonal rainfall trends reveal some significant insights.

The seasonal rainfall contribution in the study area comprises the Northeast Monsoon (19%), the Southwest Monsoon (35%), the First Inter-monsoon (15%), and the Second Inter-monsoon (31%). Rainfall is significantly greater during the second inter-monsoon and southwest monsoon seasons. In terms of trends, rainfall during the Northeast Monsoon, Second Intermonsoon, and First Intermonsoon periods shows a slight increase, while Southwest Monsoon precipitation shows a decrease (Figure 8).

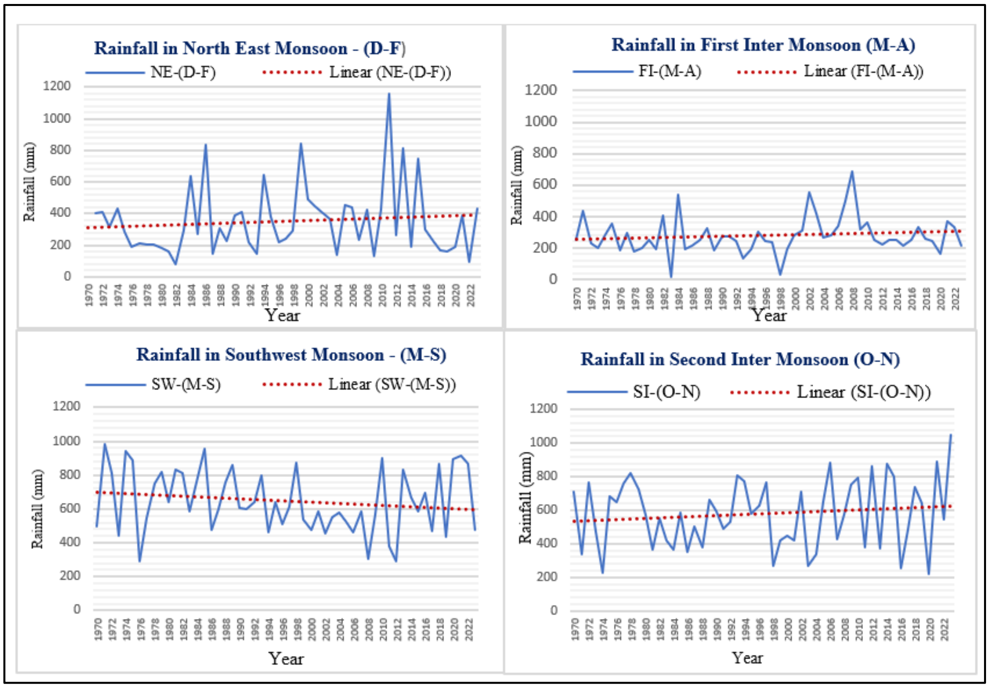


Figure 8: Seasonal Rainfall Trend (Source: Meteorological Department, 2023)

In recent years, flooding has also been observed in the study area during the northeast monsoon season. Increased catchment runoff converges into the Pinga Oya, overflows its banks, and causes flooding in the town.

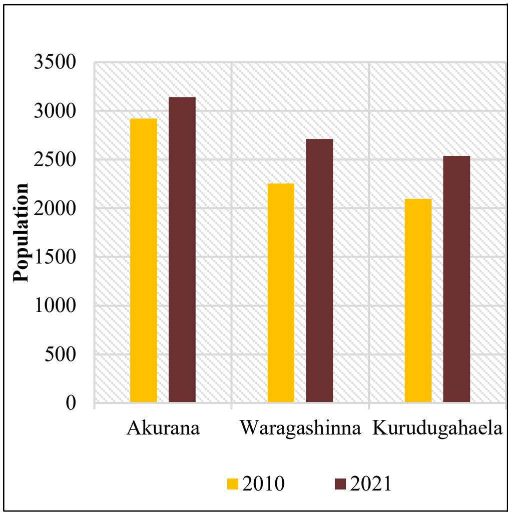
The natural environment in the study area, which is prone to flooding due to the aforementioned physical factors, further exacerbates the area's vulnerability. However, growing anthropogenic factors have increased both the severity and frequency of flooding in the study area. According to Manawadu and Wijeratne (2021), both natural and human factors contributed equally to urban flooding. Although various anthropogenic factors influence flood occurrence in the study area, the most influential are examined here.

3.2 Anthropogenic Factors

The results indicate that flooding is becoming increasingly likely in the Akurana region due to anthropogenic pressures. Increasing anthropogenic interventions are contributing to the recent rise in flood disasters, despite some of the study area's physical features making it vulnerable to flooding. The identified anthropogenic factors contributing to flooding include population growth and urbanisation, settlement expansion, increased bridge numbers, improper solid waste management, inadequate and improper construction.

3.2.1 Increasing population and rapid urban growth

Flooding is primarily caused by rapid urban and population growth in the study area. As a vibrant town, Akurana faces increased risk due to its higher population density and rapid urban development. According to data from the Akurana Pradeshiya Sabha, the area currently has 79,021 residents.



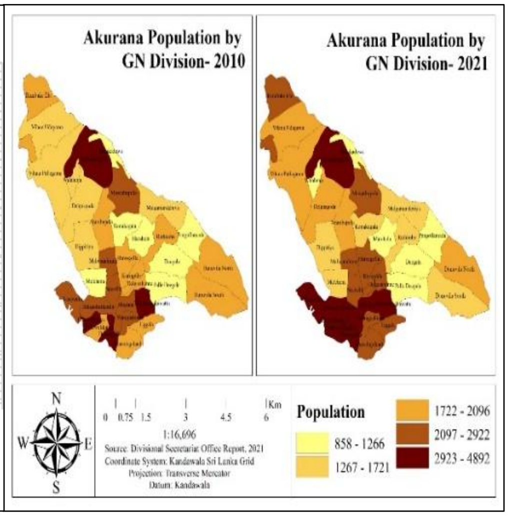


Figure 9: Population in selected three divisions, Figure 10: Population Distribution in the study area (Akurana DS, 2010 and 2021).

Since 2010, the population in this area has increased by 9,300 people. The combined population of these three divisions (Akurana, Waragashinna and Kurundugahaela) was 7271 in 2010, representing 10.43% of the total population of this DS division. This number increased to 8,387 in 2021, representing 10.61% of the entire population. Differences can also be seen in the spatial scope, which is similar to this temporal increase (Figure 9 and Figure 10).

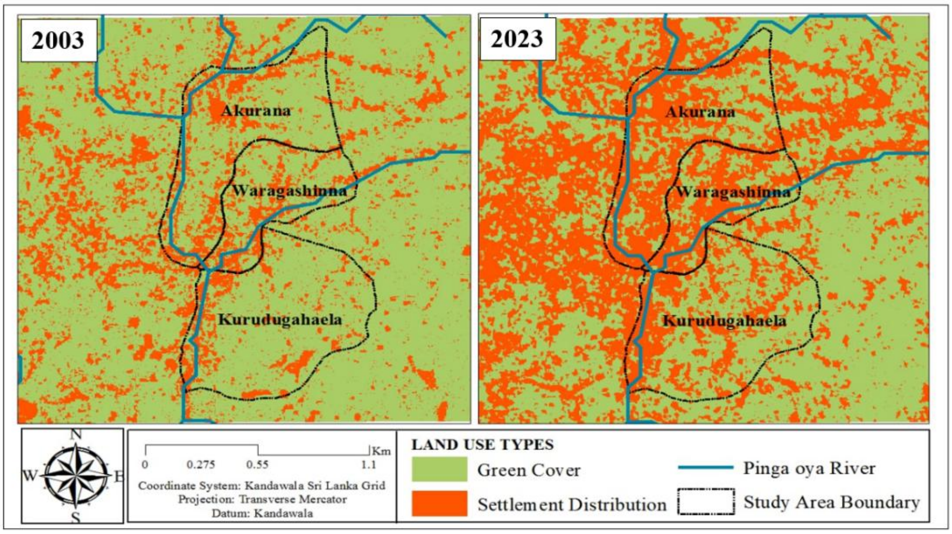
In all three divisions, the population has grown over the years, leading to increased pressure on the catchment area. This population growth also increases the number of individuals exposed to flood disasters. It is noteworthy that the primary cause of flooding in the study area, which is closely related to the Pinga Oya, is under increasing pressure due to the growing population. There has been a rapid population increase, changes in land use, and an expansion of land and resource use in the Pinga Oya catchment (Najimuddin et al., 2017).

The population trend over the past 20 years provides the background for the human factors contributing to flood disasters in this area. As Kandy city rapidly grows, the surrounding areas are also becoming increasingly urbanised. Urbanisation causes floodplains and/or stream reservations to be encroached upon (Perera & Jayasena, 2017). Thus, pressure on the river is growing as human activity expands, leading to the construction of numerous buildings, bridge foundations, and walls to conceal the Pinga Oya.

3.2.2 Settlement expansion

Population growth and changes in land-use patterns significantly increase the risk of flooding by increasing the settlements. The land use characteristics primarily comprise residential and commercial structures, home gardens, small-scale vegetable plantations, paddy and maize production, roads, and other infrastructure. Figure (11) depicts the changes in settlement distribution and green cover over the past twenty years (2003–2023) in the study area and its environs. Although urban land use characteristics are subject to temporal changes, shifts in settlement patterns and the consequent changes in green cover represent significant land use changes.

Figure 11: Changes in Settlement Distribution and Green Cover 2003 – 2023



(Source: Google Earth, 2003, 2023)

The extent of green cover has significantly decreased over the past two decades. Moreover, land used for settlement has increased substantially, particularly in the Akurana and Waragashinna Grama Sevaka divisions. Consequently, the average annual growth rate of the settlement land use is 5.81 per cent, while the annual average decline rate of the green cover is 1.53 per cent (Figure 12). These statistics not only show how settlements have changed over time in the study area but also how this rate of growth will affect future built-up land use.

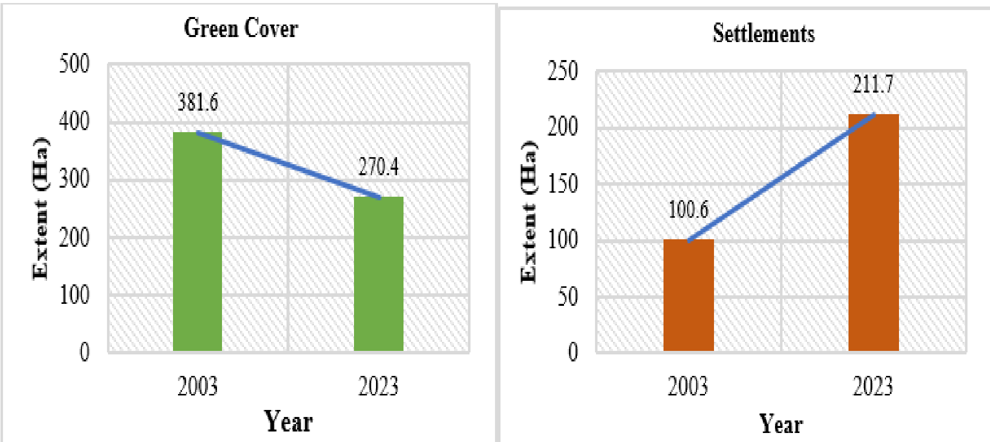


Figure 12: Changes in Settlement and Green Cover (Source: Google Earth, 2003, 2023)

An important man-made feature of the area is the expansion of buildings on both sides of the Pinga Oya. This pattern is primarily found in low-lying areas where flooding is frequent. The expansion of impermeable urban structures, such as paved roads, buildings, and concrete-paved surface structures, as well as construction activities, among other changes in land use, has decreased infiltration. Less water infiltration into the ground leads to more surface runoff, which drains to the river and contributes to flooding. Dammalage and Jayasinghe (2019) also emphasised in their study that, as watersheds are being transformed into urban or suburban land uses, flooding occurs more frequently than previously. Additionally, this change in land use over time exposes more people and buildings to increased flood risk because both settlement and population density are concentrated in the low-lying area, which is vulnerable to flooding.

3.2.3 Bridges over the Pinga Oya Canal

An increase in small bridges across the Pinga Oya also exacerbates flooding in the study area. The small causeway bridges built across the river for access to the buildings being constructed on the right bank of Pinga Oya are a significant factor in altering the river's flow. Concrete walls surround the banks on both sides of the river to facilitate their construction. This affects the morphology of the river, water capacity and river flow. Particularly during the monsoon season, the water level rises rapidly due to the lower capacity, leading to flooding. The cross-bridges built along the river between 2003 and 2023 are shown in figure 13.

Notably, the total number of cross-bridges tripled between 2003 and 2023. The construction of 27 new cross-bridges over 20 years demonstrates the rate of increase in human activity. In particular, construction activity along the riverbanks has increased. Both Akurana and Waragashinna divisions have a high concentration of these structures. Najimuddin et al. (2017) also emphasise that the increase in river bridges and flood events are closely associated. The study also found that the flood events in the area are consistent with the rise in bridges spanning the river.

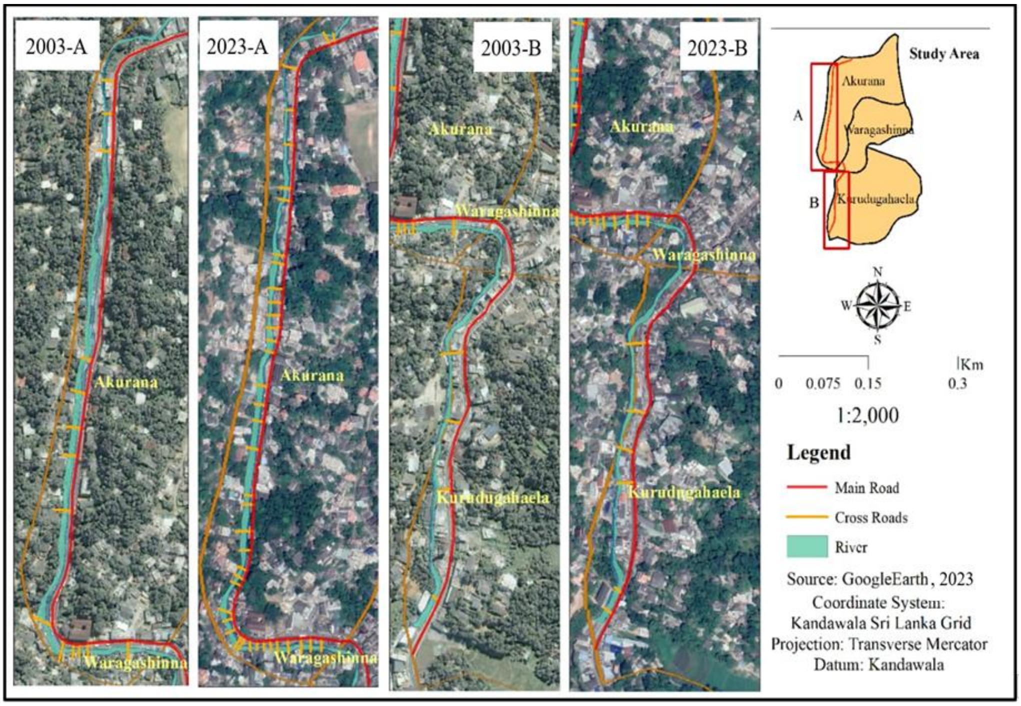


Figure 13: Cross Roads along the River 2003 and 2023 (Source: Google Earth, 2003, 2023)

3.2.4 Improper Construction of Buildings

The study reveals that the most significant contributing factor to the rise in flood frequency in the study area is the improper construction of buildings (KII, 2023). It is commonly recognised that haphazard urban development plays a substantial role in causing flooding in many developing countries (Glago, 2020). As per the department circular no. 08/2014 of the Irrigation Department, a buffer zone of 12 meters along the main road and 8 meters on the other side has been designated as a reservation area. The study revealed that many buildings within the area partially or fully occupy the designated reservation areas (Figure 14 and Figure 15).The expansion of unauthorised and illegal settlements, especially along the banks and flow path of the Pinga Oya, has also intensified the severity of the problem. Encroachment into the reservation zone by an increased number of buildings has intensified the flood risk across the region in recent years.

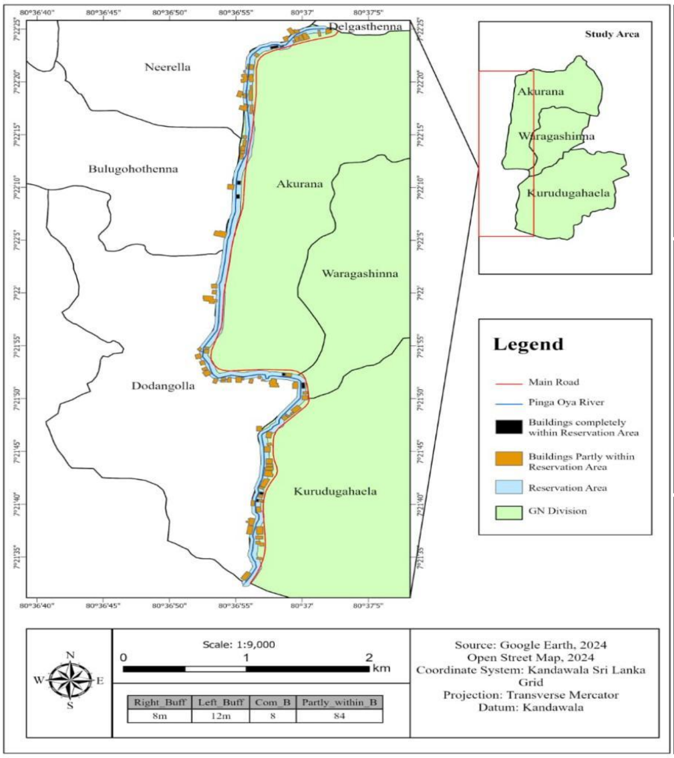


Figure 14: Building Construction – Reservation Area, Figure 15: Construction of Buildings A-C (Source: Field Survey, 2023/24

These factors alter the river morphology and flow characteristics of Pinga Oya, including its speed, flow pattern, and capacity. Perera and Jayasena (2017) also emphasised that the construction of the bridge footing, foundations of buildings, and pillars inside the reservation has prevented free water discharge through the stream in the Akurana area. Thus, the river can no longer carry a large volume of water, especially during the rainy season, because the constricted channel has reduced its capacity. This obstructed the natural flow in many places, as evident during the field survey. It is crucial to highlight that this issue remains a concern, despite numerous studies indicating that improper building construction is a contributing factor to the area's rising rates of flash and river flooding.

3.2.5 Improper waste management and poorly maintained drainage system

The results reveal that inadequate and improper solid waste management, sewage discharge into the Pinga Oya, and poor drainage systems also contribute to urban flooding. The growth of built-up area is accompanied by rapid urban population growth, resulting in increased waste generation, including domestic, commercial, and industrial waste. According to the records of each Divisional Secretariat, approximately 1,500–1,600 metric tons of garbage are collected annually. Of these, approximately only four metric tons are recycled.

Figure 16: Improper Waste Disposal - Water Pollution in the Study Area, A- C Field Survey, 2023/24, D-F Obtained from DS Office, Akurana)

The consumption culture, which consistently produces more solid waste, exacerbates the water pollution crisis in Pinga Oya, particularly in urban settings (Mahees et al., 2011). Thus, higher waste generation and improper solid waste management practices have emerged as a serious concern in environmental contexts. The unlawful dumping of solid waste into Pinga Oya and Kasawatha Oya by residents is a serious issue that is consistently reported in the study area (KII, 2023). As a result, the riverbed is deposited with waste dumped into the river and with sediments from the Pinga Oya watershed (Figure 16). It has a significant impact on water quality, contributing to drain blockage and exacerbating flooding in the area (KII, 2023). During the rainy season, urban surfaces, solid waste, and poor drainage cause water stagnation. This situation increases the risk of flooding in the shallow, narrow river channel.

The absence of a proper drainage plan to manage the sudden increase in water is a key contributing factor, in line with the increasing human pressure on the town. Modifications to Pinga Oya's flow channel have reduced water capacity, and rapidly growing built-up areas are obstructing water infiltration. As previously deliberated, various factors have prevented the free flow of water through streams, leading to higher flood peaks even during short spells of rainfall that inundate the main road along the Pinga Oya (Perera & Jayasena, 2017). While the study region's physical environment contributes to flood hazards through natural factors, the risk of flooding is mostly exacerbated by increased human activity in the area.

- ***Higher level of vulnerability***

The flood disaster in Akurana town has continuously posed various challenges for the last two decades. The frequent occurrence of flood disasters also leads to societal issues and severe economic losses. The devastation of property, businesses, and infrastructure caused by urban flooding disasters results in large-scale financial losses and expenses, as well as flood disaster management-related costs. Thus, increased flood risk has led many people in the study area to experience severe negative impacts. A flood-related death was reported in 2015. The A9 road frequently floods, disrupting transportation and causing heavy traffic.

Being a rapidly growing commercial town, the primary impact of the flood is economic loss (KII, 2023). As urban flooding incurs substantial financial costs (Agonafir et al., 2023), Akurana town also faces adverse economic effects of flooding due to its dynamic urban nature and higher level of urban functions. It is noteworthy that flood disasters associated with seasonal changes in Sri Lanka have a significant economic impact on the nation (UNDRR, 2019).

Given the high level of dynamic business activity and associated commercial land use, the expenses of recovering from each of these flood events, as well as the potential financial losses, are enormous. The floods, which have become annual occurrences in recent years, have raised concerns about the future of the study area. Since floods have become recurring events, people face flooding before they have fully recovered from the previous one. Thus, residents were significantly affected both economically and socially. In terms of economic impacts, the business community suffers greater losses than other sectors due to the financial effects of flooding, particularly because all commercial activity halts during this time (KII, 2023).

Damage to property and infrastructure, blocked roads, and obstructed goods transfers have also contributed to economic losses. Other issues include food shortages, contaminated water, power outages, disease, crop losses, and other physical and mental health issues (KII, 2023). Major environmental problems include topsoil erosion and nutrient removal, damage to the Pinga Oya riverbank, siltation, flood waste problems, and biodiversity loss (KII, 2023;

Direct observation, 2023/24). However, these problems have a long-term, detrimental impact on the study area's economic viability, suggesting that future flood risk scenarios should be planned for.

Despite the recurrent floods and significant effects, they still reside in the same place because they depend on their primary source of income. Their livelihood are deeply rooted in Akurana town, making it difficult to move elsewhere (KII, 2023). Higher economic functions, demand and value, the area's reputation as a good service centre, social connections, limited relocation options, adoption of some practices to avoid losses, are just a few of the many factors that have made the residents choose to remain in the same place (KII, 2023 and Survey Questionnaire, 2022). In recent years, some have been adopting various coping mechanisms, including temporary displacement, storing valuable and delicate items in elevated areas, clearing water stagnation, and following proper evacuation procedures.

4. Conclusion

This study aims to investigate the physical and human causes linked to an increased risk of flooding in Akurana town. Analysis of natural and artificial contributory factors reveals that flooding in Akurana town is a complex phenomenon driven by multiple interlinked factors. Natural landscape and related factors contribute to flood hazard at a relatively modest level, while growing anthropogenic factors have increased both the severity and frequency of flooding, thereby increasing risk. Physical factors, such as rainfall patterns and landscapes, are significant. Meanwhile, human factors, including urbanisation coupled with population growth, changes in land use, improper building construction, sedimentation, an increase in the number of bridges, and inadequate drainage systems, have been identified as major contributors. These human-induced factors have not only increased the frequency of floods but also intensified impacts on communities and infrastructure. Analysis of causative factors indicates that multiple interconnected subfactors contribute to flooding in Akurana town. The management of flood risk in this city area is indeed weak and inadequate, as evidenced by the repeated occurrence of flooding with increased severity. The flood disaster in Akurana town, a socio-economically highly dynamic area, is a significant barrier to achieving sustainable urban development in the long run. Therefore, managing flood disasters requires integrated initiatives targeting the various underlying causes identified. Therefore, reducing flood hazard here requires integrated initiatives aiming at each underlying cause. To reduce the risk level and make the town more resilient to flood hazards, both immediate and long-term strategies are necessary. Therefore, it is essential to address these complex issues and implement sustainable management practices in order to reduce the risk associated with flooding and promote more resilient urban communities in Akurana town.

Since interruption to the free flow of the river is the foremost factor of flood in the town, measures should be taken to reduce disruption to natural water flow to prevent the accumulation of flood water. Thus, in short term, interventions should aim to avoid blockages in drainage networks, restore natural waterways, and enforce strict regulations on waste disposal, improve stormwater management, ensure regular cleaning of drainage systems and restrict further construction and interruption into Pinga Oya. Public should strictly adhere to reserve land and land use regulations. Furthering raise awareness, introducing preparedness plans and evacuation routes, implementing proper early warning system and flood alert are essential to reduce the flood hazard. In the long term, special attention must be given to sustainable urban and land use planning. Nature-based solutions to maintain river banks with ecological value, green infrastructure development, and minimise flood vulnerability must be addressed. These integrated measures will significantly reduce flow interruptions in the Pinga Oya and enhance overall resilience to flood hazards.

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