Identifying Flood Hazard Potentials Based on Geographical Characteristics in the Jaffna District, Sri Lanka

Identifikasi Potensi Bencana Banjir Berdasarkan Ciri-ciri Geografi di Daerah Jaffna, Sri Lanka

PIRATHEEPARAJAH NAGAMUTHU, NGAI WENG CHAN & MOU LEONG TAN*
Geoinformatic Unit, Geography Section,
School of Humanities, Universiti Sains Malaysia,
11800 USM, Pulau Pinang, Malaysia.

Corresponding author: mouleong@usm.my

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ABSTRACT *Floods is a major hazard causing property damage, business and tourism loss, crop damage and negative effects on people in the Jaffna District of Sri Lanka. This study was conducted to identify the geographical characteristics that contribute to flood hazard potentials in the study area. Primary data was collected using focus group discussion and field visits, with data from government departments. Data were analyzed using the descriptive statistical method, and the results were mapped using ARC GIS 11.2 software. Rainfall variability, especially intensity, directly affects flood impacts. The geographical terrain of a place, whether low-lying, flat or in the form of depression has high flood potentials. The study revealed that 26% of the low elevation places of the district have experienced severe flooding during the last sixty years. Other geographical characteristics such as soil types, collapsed natural and human-made drainage systems, unplanned road development, railway track construction, and siltation of ponds are also found to contribute to the flood hazards. After identifying the geographical characteristics and flood potentials, the flood-prone areas can be mapped and appropriate flood-alleviation measures put into place.*

Keywords: Geographical characteristics, flood hazard, jaffna district, seasonal rainfall,vulnerable region

ABSTRAK *Banjir adalah bahaya besar yang menyebabkan kerosakan harta benda, kerugian perniagaan dan pelancongan, kerosakan tanaman dan kesan negatif terhadap penduduk di Daerah Jaffna, Sri Lanka. Kajian ini dilakukan untuk mengenal pasti ciri-ciri geografi yang menyumbang kepada potensi bahaya banjir di kawasan kajian. Data primer dikumpulkan menggunakan perbincangan kumpulan fokus dan kunjungan lapangan, dengan data daripada jabatan kerajaan yang berkaitan. Data dianalisis menggunakan kaedah statistik deskriptif dan hasilnya dipetakan menggunakan perisian ARC GIS 11.2. Variabiliti hujan, terutamanya intensiti, secara langsung mempengaruhi impak banjir. Rupabentuk geografi suatu tempat, sama ada di kawasan rendah, rata atau dalam bentuk tidak terjaga mempunyai potensi banjir yang tinggi. Dapatan daripada kajian ini menunjukkan bahawa 26% tempat dengan ketinggian rendah di daerah ini mengalami banjir besar selama enam puluh tahun terakhir. Ciri geografi lain seperti jenis tanah, sistem perparitan semula jadi dan buatan manusia yang runtuh, pembangunan*

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jalan yang tidak dirancang, pembinaan landasan kereta api dan siltasi kolam juga didapati menyumbang kepada bahaya banjir. Setelah mengenal pasti ciri-ciri geografi dan potensi banjir, kawasan yang cenderung kepada kejadian banjir dapat dipetakan dan langkah-langkah pengurangan banjir yang sesuai boleh dilaksanakan.

Kata kunci: Ciri-ciri geografi, bencana banjir, daerah Jaffna, hujan musiman, wilayah terdedah

1. Introduction

Globally and nationally, flooding is considered the most common and severe environmental hazards affecting human society (Schumann et. al., 2018). Among the many challenges of humanity, flood hazards are probably the most severe as they cause the highest number of human deaths, the greatest damage to infrastructure, property, and crops, and are the most common throughout the world (Centre for Research on the Epidemiology of Disasters, 2016). However, "*flood hazards and disasters are, therefore, neither solely the work of nature, nor are they solely caused by humans, but result from the interaction of both the human and natural systems"* (Chan, 2011). Almost all countries are affected by flood hazards, but developed countries cope better than developing countries because of better resources, technology, and other reasons. In order to reduce flood losses, governments have given top priority to coping and adaptation activities that mitigate the effects of flooding. Globally, flood hazards cause significant damages. Nearly 50,000 people die every year in the world due to floods (Lumader, 2010).

During the Southwest monsoon season from May to September, the western, southern and Sabaragamuwa provinces are affected by floods. Furthermore, during the months between December to February of the Northeast monsoon season, the eastern, northern and north-central provinces are affected by severe flooding. During both monsoon seasons, the rivers in Sri Lanka usually overtop their banks and floods the adjacent areas and the floodplains. Flooding is the most serious environmental hazard affecting Sri Lanka (Ministry of Disaster Management, 2014) have caused much destruction during the last twenty years compared to other types of natural hazards in Sri Lanka. More than 50 million Sri Lankan rupees worthy of agricultural productions are destroyed by floods in Sri Lanka every year (Weerakkon, 2003). The cities of Sri Lanka are also very susceptible to flooding (Wagenaar, 2019).

Historically and now, the geography of a place has shown to either bring resources (development) or hazards/disasters (under-development). Geography is the study of location and the natural features and phenomena of places on the Earth's surface and human interactions with them. The natural features include location, climate, soil, vegetation, natural resources, landforms, and others. The location of a place is highly variable in terms of its geography, and this determines whether humans can live well in a certain place or not. If the geography of a place is poor and hazardous, it requires humans to adapt their lifestyles to it (Diamond, 2005). Different countries are influenced by different factors of geography. Some countries are fortunate as they are geographically blessed with abundant resources and few hazards. Others, however, are

not so lucky as they have few natural resources but are exposed to many hazards. For example, Singapore lies in a geographically stable Sunda Platform free from natural disasters and is strategically located along the east-west trading sea routes. These geographical factors have contributed, amongst other factors, Singapore's rise to become one of the world's most advanced economies (Publicity Division, Ministry of Information and the Arts, 1994). In contrast, Bangladesh which lies in a geographical location that is exposed to annual severe monsoon floods, cyclones, and low-lying topography is impoverished by annual disasters (Brammer, 2012). It cannot be denied that there are many other factors influencing a country's development, but it is undeniable that geography with its traditional themes plays an important role in the development of a country (Murphy, 2014).

According to the geographical setting of the Jaffna district, it has many geographical factors that bring negative effects on its development. One of them is the high frequency of being hit by environmental hazards. For example, twenty-one floods, six droughts (partial droughts), five cyclones (in different scales), a tsunami, and forty-nine thunderstorms events were recorded in Jaffna district during the last thirty-four years from 1985 to 2018 (Jeyawardena, 2012). There is an increasing frequency of flood severity in the Jaffna District of Sri Lanka in recent years. According to the report of the District Disaster Management unit, every year more than 3 billion Sri Lankan rupees' worth of properties are damaged by floods in the Jaffna District of Sri Lanka(Piratheeparajah &Rajendram, 2015). Several geographical factors are suspected to be influencing the increase in flood frequency in the study area, especially after the implementation of the many development activities. Accompanying the increase in flood occurrences is the steady increase in the flood impact. All these flood-related problems stifled development in the study area and need to be urgently addressed.

These have caused human casualties and substantial economic damages to the district (Reports of the Jaffna District Secretariat and District Disaster Management Unit, 2019). When compared with the other types of environmental hazards, floods are most severe. At this juncture studies about the impacts of flood hazards in the Jaffna district is an essential matter to plan the process of the post-war development activities in Jaffna District. This paper aims to identify the reasons for the high flood hazard potential in the Jaffna district. Once reasons are identified, mitigation measures can be put in place to reduce the hazard, adapt to it and empower people to be more resilient to it. The results of this study can be used to assist all sectors that are involved in the reconstruction and rehabilitation activities towards the sustainable development of the Jaffna District. Generally, several geographical aspects are suspected to be responsible for creating flood hazards in the Jaffna District of Sri Lanka. These include geomorphological features, soil, surface water bodies, land use pattern, natural and developed drainage system, and development initiatives that induce flood vulnerabilities in the study area. All of these aspects will be examined.

In this background studies about the flood potential will help to the future planning and the development activities of the war affected Jaffna district of Sri Lanka and the development activities addressed with the flood potential will be the most sustainable development in the study area. In this context this study is discussing about

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the spatial and temporal geographical potentials for the flood hazard in the Jaffna District of Sri Lanka. Also this study will be the basic document for the further studies about the flood hazard in the study area and this study will be the first and primary literature sources for the disaster study in the Jaffna District of Sri Lanka.

The study area is the Jaffna District of Sri Lanka which is located in the northern part of Sri Lanka. It is a peninsula consisting of 15 sub administrative divisions, each called a divisional secretariat division (Figure. 1). The total area of the study area including water bodies is 1100sqKm with a total population of 630000. The main economic stay of the study area is agriculture. There are three lagoons situated in the study area, viz. Thondaimanaru Lagoon, Upparu Lagoon, and Jaffna Lagoon.

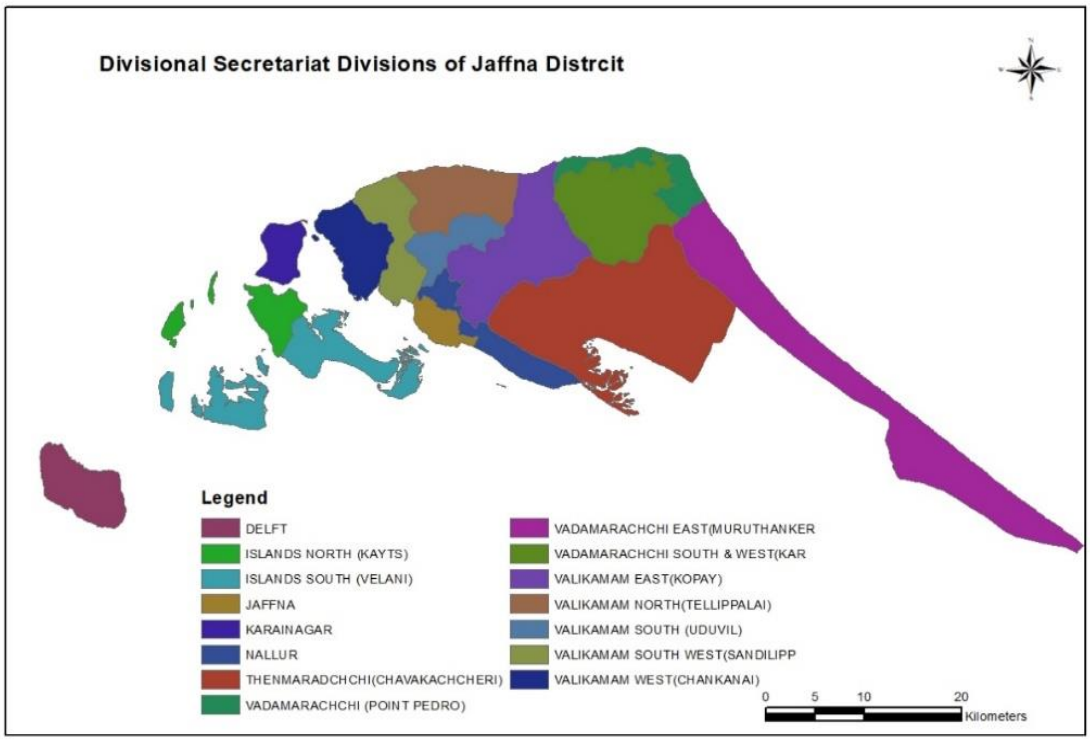

Figure 1: Study Area Jaffna District of Sri Lanka

2. Literature Review

Various researches in various places by various individuals and organizations contributed to the development of this literature review. Mostly recent and relevant researches on flood hazard have been studied. Various methodologies and approaches have been observed in local and international researches related to the current research topic. These researches have been of guidance to this research in several ways. According to Howard (2011) every year at least 0.8 trillion people are affected by natural hazards directly or indirectly. Economic losses amounting to at least 1000 Millions of US dollars are suffered every year due to the impacts of natural hazards.

Natural hazards define as 'A physical event which is destructive to life and/or property' (WMO, 2008) Historically, when compared to other types of natural hazards, climatic hazards have had more severe impacts several times on many parts of the

world. At least one of the following climatic hazards, such as cyclones, anticyclones, floods, drought, hail, storms, tornadoes, heat waves, cold waves, and thunderstorm is recorded periodically in all parts of the world. Compared to other types of natural hazards climatic hazards have occurred recurrently, in several parts of the world during the past 100 years.

Spatially they occur in all the parts of the world and no part of the world is spared from their impacts. Irrespective of anything, these may occur in any location be it hot or cold, at any latitude, or longitude, not only in the Tropical region or Sub Tropical region, but also in the Polar region. According to the past history of the world, when compared to other types of natural hazards, climatic hazards have caused much destruction throughout the world. More number of deaths has been recorded during these climatic hazards than during any others of the top ten destructive natural hazards (Wolksoun, 2011). Floood hazard have caused much damage, during the last 100 years and it has been noted that eight out of the top ten hazards have been of climatic origin. This would mean that climatic hazards pose a massive challenge to the world (Banuri, 2005).

According to 'Komatsu', compared to other types of natural hazards, climatic hazards have been the cause for much destruction in the world and they may occur every year, comparatively in greater magnitudes. Every year at least, 29 cyclones, 10 droughts, 118 floods, 35 cyclones or storms, 07 heat or cold waves, 20 tornadoes, and 340 thunder events are recorded in the world (Komatsu, 2011). Komatsu has also found that 'within the five years' period from 2005 to 2010, about 21,000 people have lost their lives due to climatic hazards. Out of this number, 15,000 people died in developing countries. A major portion of South Asia is extremely vulnerable to both seismic and hydro-meteorological hazards such as floods, typhoons, droughts, and derivative disasters such as wild fires and landslides. This vulnerability is compounded by socio-economic conditions, which exacerbate the impact of disasters. These conditions include:

1) Population stain- increase in the number of people affected, resulting in more people inhabiting marginal lands.
2) Environmental degradation- affecting the natural resiliency to disasters; and
3) Investments- in infrastructure across hazard prone areas with increasing vulnerability and potential loss of assets (Rahamn, 2010).

Every year more than 1,700 trillion Mt. worth agricultural activities are damaged by climatic hazards such as cyclones, floods and drought. In South Asian countries, agricultural products worth nearly 475 million US $ are lost due to the climatic hazards that occur annually. Agricultural activities of some countries are totally damaged during certain years by climatic hazards (WMO, 2009). Occurrences of flood hazards is more frequent in recent decade due to the climate change. There are number of flood occurrences have been recorded in Malaysia and the impact of the flood hazards also increasing because of the unexpected rainfall extremes. Heavy monsoon process and the

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convectional influences and the topography are the main reason for the increasing flood risk in Malaysia. Characteristics of the flood also changing due to the rapid urbanization deforestation and inappropriate land use planning and process in Malaysia (Chan, 1997).

Sri Lanka is a developing country, which is located in the tropical zone. It is also one of the South Asian countries located in the Indian Ocean. Due to the thirty years of internal war, the country has suffered much. Due to its geographical location it is prone to all types of natural hazards. Historically Sri Lanka has experienced many types of natural hazards such as Tsunami, floods, droughts, landslides, cyclones, wild fires and thunders (Chaguta, 2009). Weerasooriya (2009) conceded that, in disaster history of Sri Lanka more than 72% of the disasters are related to climatic hazards during the past 100 years. In Sri Lanka during the last 110 years from 1901-2010, out of the top twenty-five deaths caused by hazards, twenty are related to climatic hazards. Leaving alone the tsunami; many deaths have been recorded during other cyclones and floods too. During the last 100 years more than 3,225 people have died due to climatic hazards in Sri Lanka. The number of people affected by natural hazards is also recorded under climate related hazards. Within the top twenty-five natural hazards recorded, twenty-four are related to climatic hazards such as flood, drought, and cyclone. This indicates that climatic hazards rank high, out of the top twenty-five natural hazards in Sri Lanka, according to the extent of damage.

According to the statistics of the Disaster Management Centre (2012) compared to 1900-1950 and 1951-2010, climatic hazards within the last fifty years (1951-2010) have had their impacts 48 times which is 69% during the 100 years. This information indicates that in recent times, the impacts of climatic hazards in Sri Lanka are more frequent probably due to change of climate. Recent climatic changes form one of the major causes to the climatic hazards all over the world (Locswiltton, 2011) In addition, Sri Lanka National Report on Disaster Risk Poverty and Human Development Relationship listed the disaster profile of Sri Lanka. This list records 7023 attacks of animals, 2704 events of urban or wild fire,1397 floods (including river floods, urban floods, flash floods, and rain floods) 1,263 extreme wind events (cyclone, strong surge, storm, gale etc.), 285 droughts, and 1,156 landslides during the period 1974-2008 (DMC, Sri Lanka,2012).

Economic impacts consequent to climatic hazards are also indicated in this report (Sri Lanka National Report on Disaster Risk Poverty and Human Development Relationship, DMC, 2012) according to which, 71% has been recorded during climatic hazards. For example, 52.2%, of damages to agricultural crops are caused mainly by droughts, 38.9% by floods, and 4.2% by extremes of wind. Sri Lankan government is facing many challenges posed by natural hazards. To manage and reduce the impacts of natural disasters, Sri Lankan government has established a separate ministry under the name of Ministry of Disaster Management. This ministry has set up several disaster management centers and District Disaster Management Units in every district. The Ministry of Disaster Management was formed in 2006 and under its purview the Disaster Management Center (DMC) acts as the co-coordinating body of Disaster Relief Managing (DRM) works in Sri Lanka. Since flooding is the most frequent natural disaster DMC has

been focusing its attention on Flood Hazard Mapping as one of its priority tasks to be accomplished (Samarasinghe, et.al, 2010).

In Sri Lanka, the geographical features of the Northern Region are different, compared to other districts. Due to its geographical location it is exposed to certain types of natural hazards. In the history of the Northern Province of Sri Lanka, climate related disasters have been recorded several times (Balachandran, 2001). Also countries around the Bay of Bengal have much exposure to the climatic hazards especially to storms, heavy storm surges and cyclones (Nagamuthu, 2015). Northern Region of Sri Lanka has Bay of Bengal as one of its boundaries. Especially the districts of Jaffna and Mullaitivu have Bay of Bengal as their eastern boundary. Due to its location Northern region is much exposed to climatic hazards especially for flood hazard. Every year any one of the districts of Northern Province has to face the threat of climatic hazards such as cyclones, floods, and droughts (Balasundarampillai, 2011).

Governing authorities of the Jaffna district is facing challenges to manage the flood hazards. Every year study area is recorded for more than 100 million worthy of economic losses due to the flood hazard (Nagamuthu, 2015). Historically these climatic hazards have caused many damages in the study area during the last 100 years. These flood hazards have had their impacts on all parts of the Jaffna district of Sri Lanka. Especially the economy of the Jaffna district is facing considerable challenges from these climatic hazards. Sri Lanka is prone to different kinds of natural disasters with increasing losses of life and property in the past few decades. Several initiatives were taken by the government in the past to mitigate these damages before and after the worst devastation by the recent tsunami. Natural disasters in Sri Lanka are commonly caused by floods, cyclones, landslides, droughts and coastal erosion (Jayewardene, 2012). After the thirty years of war, Sri Lankan economy is facing many challenges due to climatic hazards. Jaffna district has experienced frequent natural hazards commonly caused by floods, cyclones, landslides, droughts and coastal erosion for generations with increasing losses to life and property in the past few decades (Palliyguru, et. al, 2014).

This study is focusing on the geographical potential for the flood hazards in the Jaffna district with the temporal and spatial background. This study is varying from previous studies with the emphasize of geographical aspect. Because of the Geographical setup of the study area is entirely different from other part of the country and the causes for the flood hazard also vary from other area. In this situation, this study is focusing on the identification of flood hazard potentials based on geographical characteristics in the Jaffna district, Sri Lanka.

3. Materials and Methods

Several types of data are used in this study. Primary data was obtained using focus group discussion and field observation. "*The focus group discussion(FGD)is a rapid assessment, semi-structured data gathering method in which a purposively selected set of participants gather to discuss issues and concerns based on a list of key themes drawn up by the researcher /facilitator*" (Kumar, 1987). For the focus group discussion, five groups were set

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up including 14 members in each group. One group was set up for the Thennmaradchi region, one for Vadamaradchi, one for Jaffna municipal area, one for the Valikamam region and the last one for the Island region. One group contained two disaster management officers (from divisional secretariat divisions), two Grama Niladhari officers, two economic development officers, two agriculture officers, two police officers or military officers and four civilians. These people were selected using a simple random sampling method. The questions were divided into two parts: the first part is related to the geographical factors contributing to the flood hazards and the second part is related to recommendations for the prevention of flood in the future. There are 30 questions: the first twenty is related to the first objective, and the last ten are related to recommendations for flood mitigation. More than three hours were taken to complete the discussion with the group, and the discussion was recorded in the sound recorder device. There were no sensitive or emotional questions, and all group members extended their excellent cooperation to have fruitful discussions. Field observation was in November, which is the peak flood month of a year. During the field observation, field notes, and still images were taken related to the objectives of this study.

Secondary data is also used in this study. There are several secondary sources that helped with this study. Meteorological data especially rainfall data were collected from the Department of Meteorology of Sri Lanka, Weather Observation Center of Tirunelveli and the District Secretariat of Jaffna. Flood damages data were collected from the Provincial Council of Northern Province of Sri Lanka, District Disaster management unit of Jaffna, District secretariats of Jaffna, the national and local printed media, District Irrigation Department, District Agrarian and agriculture Department, Regional Health Department of Jaffna, District Road Development Department and Authority, Railway Department of Sri Lanka and Urban Development Authority of Jaffna. The collected primary and secondary data were analyzed using a descriptive statistical method based on the Microsoft Excel worksheet.

Meteorological data were used to identify the seasonal potential for the flood hazards in the District. Meteorological data were collected for forty years continuously from 1970 to 2018. Though rainfall data for some years in Jaffna district is not available due to the internal conflict, this data was analyzed using the standard average system and the monthly average rainfall for every year from 1970 to 2018. The highest rainfall month in every year was identified for thirty years continuously. Then the highest rainfall week, within the highest rainfall month every year was also identified. On this basis, the seasonal potential for the flood hazards in the Jaffna district was identified.

GIS techniques were also used as a supporting tool to identify the geographical factors contributing to flood potentials in the Jaffna District. GIS Arc Map software was used to identify the spatial potential for the flood hazards in the Jaffna district. Elevation information is essential for flood-related disaster management. Identification of flood-prone areas requires the analysis of elevation data, land use data, road map, drainage information, and railway track map. In this research, elevation data were obtained from the medium resolution topographical map of Jaffna where the contour interval is based on the metric system. The contour map of the Jaffna district in digital format was

processed using a 3D analysis extension of the ARC MAP 11.2 version. The digital elevation model was derived and overlaid on the elevation class map. A basin map as developed flood-prone areas isolated by overlaying the above three maps. Also, land use pattern map of Jaffna district, Railway map of Jaffna District, Road network map of Jaffna district, and administration map was prepared using GIS techniques.

4. Results and Discussions

Several factors are found to be contributing to the flood hazard in the Jaffna District of Sri Lanka. However, the following are the main factors contributing to a bigger extent of flood hazards in the study area.

4.1 Intensive Rainfall

There are many types of flood events occurring everywhere in the world. According to the geographical setting of Jaffna district, it has high flood hazard potentials due to heavy rainfall within a short period. In some years, the cyclone was the primary cause of the heavy rainfall in Jaffna district, and it created flood potentials. There were 24 major and minor flood events recorded in Jaffna from 1980 to 2011 due to heavy rainfall within a short period (Balachandran, 2000). Jaffna district gets most of its rainfall during the North-East Monsoon Season (NEMS) due to the formation of depressions in the Bay of Bengal. During the last thirty years' history of the Jaffna district, its monthly rainfall is highly variable. Some months were the driest months of every year. In these months the district received lower than 50mm. These months were May, June, and July. In contrast, some months are the wet months every year. During these months the district received above 200mm rainfall. These months are October, November and December.

Table 1: Flood Events in Jaffna from 1980-2012

No	Year	Months	Dates
1	1981	November*	17-20
2	1982	November	19-22
3	1985	November*	20-24
4	1987	November*	02-06
5	1987	November	17-20
6	1988	December	19-22
7	1989	November	13-18
8	1990	November*	21-24
9	1992	November*	09-13
10	1992	November*	20-24
11	1993	November	23-27
12	1994	November	18-21
13	1995	November	20-24

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14	1996	December*	04-09
15	1998	November	20-25
16	1999	November	20-24
17	2001	September*	11-16
18	2002	November	21-24
19	2004	November	22-26
20	2005	November	27-De-01
21	2006	October	21-25
22	2007	January	19-23
23	2008	November*	22-26
24	2010	November	20-22
25	2012	November	19-23
26	2014	November*	26-29
27	2017	December	09-15
28	2018	November	28- Dec. 03

*Thus flood events have made much destruction in the Jaffna district.
Source: Balachandran,2000, DMC,2019 and Thamphiyapillai, 1973

All the flood events are recorded in the wet months, especially in October, November, December, and January. For the last thirty years, 80% of the annual rainfall of the Jaffna district are received in November. Every year nearly 800 mm out of 1240mm of the annual rainfall is received during just one month in November. The period between November 20^{th,} to December 10th 650mm of rainfall, was received (Thampaiyapilai, 1974). Due to this heavy rainfall concentrated within three or four days, it caused severe flooding in the Jaffna district. According to the history of the district during the last thirty years, 19 out of 24 floods events were recorded in November and December especially between the dates of 20th November to 10th December (Table 1). November gets much more rainfall than the other months. Based on the rainfall pattern alone, this geographical factor is considered to have contributed to a high flood potential in the Jaffna district. The records proved that flooding occurred mainly in November and December, especially between November 20th and December 10th.

4.2 Land Elevation

Several other geographical factors are also identified as inducing the flood hazards in the Jaffa district. Another primary geographical factor contributing to flooding hazard potentials in the district is the low and flat land elevation or topography. More than 45% of the total land of the district is below 2m. Especially some areas along beside the Thondaimanaru lagoon, Upparu lagoon (Figure 2) and the Jaffna lagoon areas are located below one meter from Mean sea level (MSL). It is not surprising to find high flood potentials in areas within the Jaffna district which are very close to the lagoons and low lands of the district. Nearly 26% of the land area has flood potential.

Thondaimanaru lagoon areas such, *Valalai, Atchchuvely, Avarangal, Puttur, Vatharawattai, Mandan, Kappoothu, Karanavai, Anthananthidal, Karaveddy, Varani, Sarasaalai, Mulliyan, Eluthumadduval, Amban, Upparu Lagoon areas such as Siruppiddy, Neervely, Kopay, Irubalai, Kalvijankadu, Ariyalai, Thanankilappu, Maravanpulavu, Navatkuli, Kaithady, Valukkaiyaru areas such as Sandilippai, Sulipuram, Tholpuram, Vaddukkoddai, Arali, Sangaraththai, Navali, Pandaththarippu, Piranpattu, Periyavilan, Chankanai, Mirusuvil and Pandithar Kudiyiruppu* areas have high potentials to the flood hazards in Jaffna district (Figure 4).

These areas' elevations are lower than 15M above mean sea level (Figure 3). Due to its low elevation during the rainy period, rainwater is stagnated and this created flood hazards in these areas. These areas are the low lying areas in the district. Especially bank areas of the lagoons were the most vulnerable areas due to its geographical location. Seventy-two percent of the people in the study area expressed that, after the implementation of the freshwater schemes of the Thondaimanaru and Upparu lagoons, flooding has increased because of many walls built between the oceans and lagoons in order to store rainwater in the middle and lower parts of the lagoons. Historically these areas had many flood records in the district.

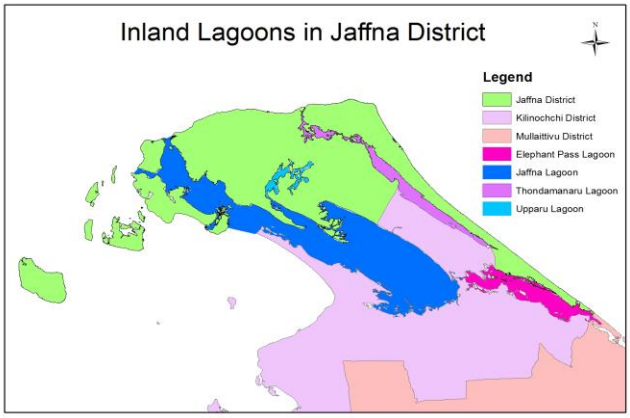

Figure 2: Inland Lagoons in Jaffna District

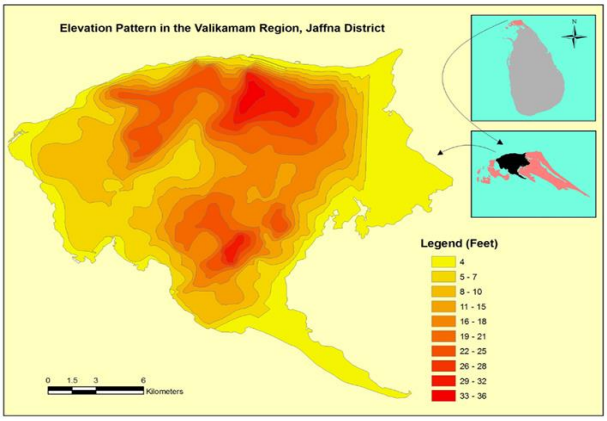

Figure 3: Elevation Pattern in the Valikamam

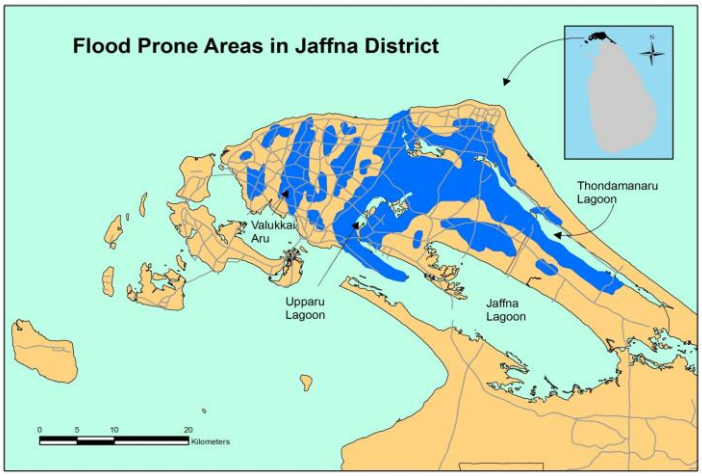

Figure 4: Low elevation and flood in the Jaffna District

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4.3 Soil Type and Distribution

Soil is another geographical factor that contributed to the flood potential of a place. Type of soil, soil texture, infiltration capacity of the soil, and soil properties determine whether the rainwater will flow into the ground or stay on the surface as floodwaters. There are six types of soils found in the study area. Thus are reddish Brown earth (RBE), Red Yellow Latasols(RYL), Alluvial, Regasol, Soils on recent marine calcareous sediments and Celtic Red Yellow latosol (CRYL). But within this group of soil, RBE, RYL, CRYL have much higher potential for the flood vulnerability in the study area because of their fine texture. For example, a precise extent of (100mm) rainfall occurring in the short period (one hour) can result in flooding the texture of the soil does not allow for rapid rainwater infiltration into the ground. Such soils are responsible for the storage of the rainwater on the surface, hence inducing flooding in the Valikamam East, Valikamam South West, Valikamam West, and North areas.

4.4 Land use pattern

Landuse is another geographical factor, though it is a human geography factor. According to the focus group discussion, 86% of the participants viewed that the land use pattern determines the flood impact in the Jaffna District to some extent (Figure 5). Some types of land use to induce the flood impact in the study area. Construction development land uses, and hoe garden land uses can cause floods in the study area. More than the 27% of the land use in the area is for the construction process and these constructions are functioning as barriers to the natural and artificial surface water flow as they become obstacles in the flow of the water leading to the occurrence of floods in the city area of the Jaffna district. Obstructive constructions were found to be the main factor causing floods in the Jaffna city, Chunnakam, Manippai, and Thirunelvely areas.

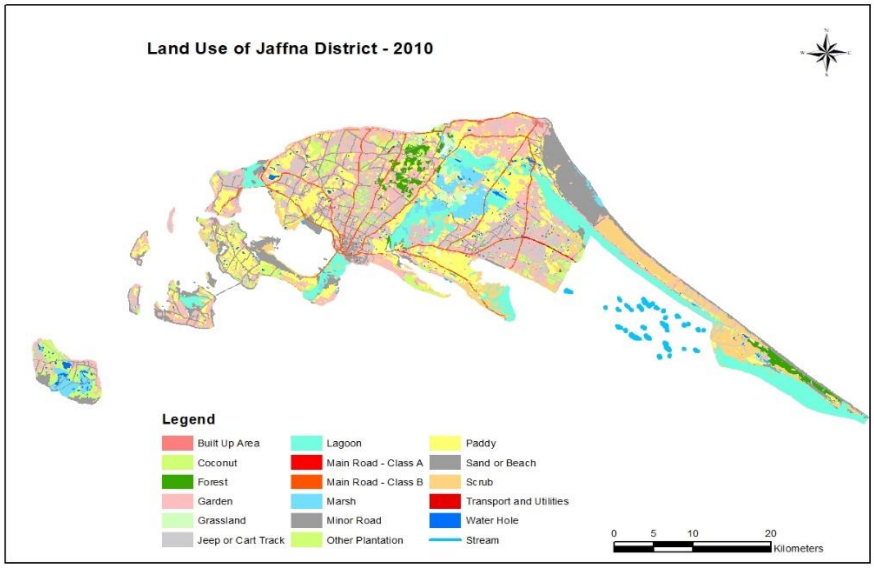

Figure 5: Land use pattern of Jaffna District

4.6 Road and railway track development

Besides geographical factors, there are other factors also contributing to high flood potentials in Jaffna district. After the thirty years of internal war, there are many development initiatives carried out by the government in the Jaffna District. After the civil war, more than 287 km length of carpet roads were constructed by the government with the aid of various international development agencies. Carpet road was constructed on the old road with the 0.75 m height without any proper consideration for water flow ways like Irish way or small bridges (Figure 7). In this context, some road appears and functioned as the bund of the reservoir. During the intensive rainfall period, rainwater is stored beside the carpet road, and it causes flooding. In this way, Point Pedro Road, KKS Road, Play Road, Manippai Road, and A-9 Road areas are exposed to high flood potentials because of the construction of this carpet road. Hence, These roads act as the catalyst factor for the flood in the Jaffna District. 78% of the people in the study area stated that they had experienced the floods after the construction of the carpet road near to them and the carpet roads are functioning as the barrier for the natural streamflow.

After 2009 May, with the end of the internal conflict in the Northern Province of Sri Lanka, many countries helped to reawaken the northern province of Sri Lanka. In this context, the Indian government helped to construct the 195 km length of railway track from Vavuniya to Kankesanthuurai (Figure 6). This railway track was constructed in 1.25 m height like a dam. There are 16 decks or small bridges within the Jaffna district to help the rainwater movement during the rainy season. However, it requires more than 29 small bridges to freely move without any stagnation along with the railway track in order to prevent flooding in the adjoining areas. During heavy rainfalls (100 mm/h) without adequate water transportation, it inevitably leads to floods. After 2012, there are 9 flood events recorded in the inside areas of the railway track. Also, railway track constructed as 'ᑎ' shape in the Jaffna district and areas inside the railway track were found to have been flooded in every year during the NEMS.

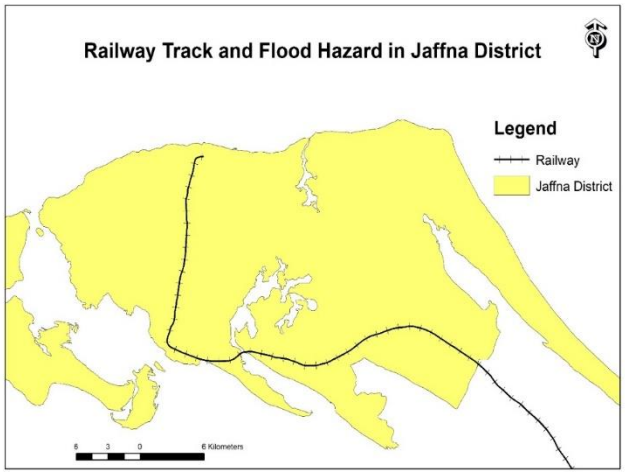

Figure 6: Railway track in the study area

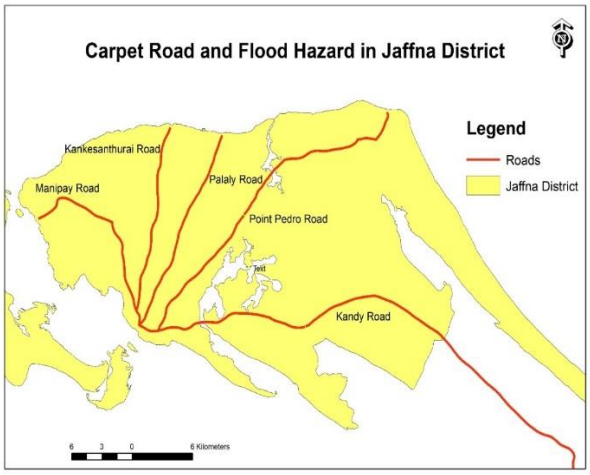

Figure 7: Major Carpet road of Jaffna district

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4.7 Damaged Natural Drainage systems

Natural drainage systems are an important geographical factor that controls flooding. However, it was found that there are several naturals and artificial drainage systems that collapsed due to unplanned, arbitrary, unsustainable development activities carried out by the individuals, departments, and institutions in the study area. These drainage patterns help to convey surface flow and runoff quickly in the area without any stagnation or blockage to the way of water. After the collapse of these systems, surface flow stagnated and gets trapped leading to the occurrence of floods.

4.8 Siltation of ponds and reclamation of lands

Another two non-geographical factors that contributed to floods in the area are the siltation of ponds and land reclamation. In 1980 there were 1,056 ponds of various sizes in the Jaffna District. These ponds served as the groundwater recharge sources (Figure 8). More importantly, they also control flooding during the rainy season by storing excess rainwater. The ponds can hold much of the rainwater and gradually recharge the groundwater aquifers of the Jaffna District. However, more than 54 ponds were closed by private and public developments. Also, another 31 ponds lost their actual extent due to encroachment. The following table indicates the actual and the current extent of the ponds. In the past, these ponds have contributed to the study area in three ways such as:

1. Groundwater recharging sources of Jaffna district
2. Flood preventing Sources
3. Creation of cooler micro-climate.

After the collapse of the natural and human-made ponds, the percentage of the groundwater recharge decreased significantly leading to an increase in flood occurrences (Figure 9).

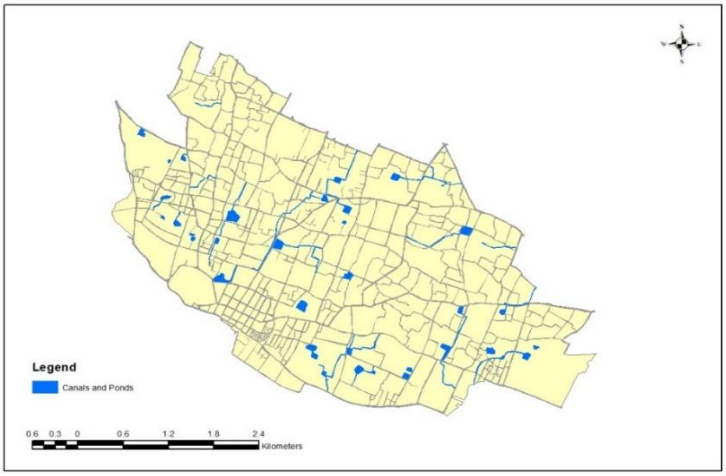

Figure 8: Major ponds and cannel areas of Jaffna Municipal area

5. Conclusion

The geography of a place plays a big role in its development or under-development. Geographical factors such as climate, soil type, vegetation type, topography, drainage and location, all affect the flood potential of a place. In Jaffna District, floods are found to be a major hazard causing property damage, business and tourism loss, crop damage and negative effects. Frequent occurrences of flood hazards have stifled development in Jaffna District, the study area. This study identified the geographical characteristics that contribute to flood hazard potentials in the study area. The results showed that there are substantial variations of rainfall, both in terms of the spatial and temporal patterns. Rainfall variability, especially intensity, directly affects flood impacts.

The geographical terrain of the study area is low-lying, and this caused high flood potentials. The study revealed that 26% of the low elevation places of the district have experienced severe flooding during the last sixty years. Generally, the areas near to the *Jaffna* and *Thondaimanaru* and *Upparu* lagoons, catchment regions of *Valukkaiyaru* and low lying areas of *Mirusuvil* are flood-prone. The recommendation for these low-lying areas is to be declared as flood-risk areas whereby only low-density and low-impact development such as recreation, water-catchment, agriculture, and aquaculture can be allowed. Other geographical characteristics such as soil types, collapsed natural and human-made drainage systems, unplanned road development, railway track construction, and siltation of ponds are also found to contribute to the flood hazards. The recommendation for impervious soils is to specially mark it for agriculture, especially paddy farming. If development is allowed on such soils, the sustainable drainage system should be implemented first.

Figure 9: Flood events in 2014 December in the Jaffna District.

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The identification of the periods and places with high flood potentials allows for prudent planning towards sustainable development of Jaffna district. The month of November is the potential month for the flood hazard in Jaffna district. From the 20th of November to the 10th December is identified as the potential period of flood hazards because during this period Jaffna district receives much amount of rainfall within a short period due to the intensity of the North-East Monsoon period. Spatially some areas have great potential for the flood hazard in Jaffna district. As such, flood disaster management activities should be focused on this period. Flood-preparedness activities should be conducted just before November every year, typically in October to get people prepared. Floods cannot be totally avoided. However, flood losses can be reduced by properly planned and executed early warning systems, preparedness training, raising awareness and empowerment of flood resilience. The authorities can also focus on flood forecasting and warning. An early warning via accurate prediction will reduce all types of flood damages in the Jaffna district. Creating greater flood awareness among the public will also help to reduce flood losses. Finally, in order to tackle the non-geographical factors, the authorities in Jaffna District need to conserve the ponds and drainage systems, and even to rehabilitate them. They also need to plan properly when building roads and railways to ensure they do not contribute to flooding. Finally, all human activities should be environmentally-friendly towards achieving the United Nations Sustainable Development Goals in Jaffna District and Sri Lanka. When the floods are addressed, the SDGs will have a good chance to be achieved.

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