

# Spatial and Temporal Patterns of the Occurrence of Floods in Sri Lanka: With Special Reference to Kalutara and Rathnapura Districts

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## Abstract

Increasing the occurrence of extreme rainfalls due to climate change has become a common feature of the climate in Sri Lanka during the recent past decades. According to the study on national climate change adaptation strategy for Sri Lanka - 2011 to 2016 undertaken by the Environmental Ministry of Sri Lanka, increase in the intensity of rainfall in the wet-zone due to climate change is expected to increase the propensity for flooding of flood prone rivers. River Kalu is the 2nd largest river in Sri Lanka, causing floods along its route from the most upstream major city of Rathnapura to the most downstream city of Kalutara. According to the Disaster Management Center report in 2005, settlers in the river Kalu flood plains are affected by floods that occur almost annually. With this brief background, the present study was aimed to assess the occurrences and trends of flood events in Kalutara and Rathnapura districts and their spatial and temporal distributions considering the period of 1980-2019. Ordinary Least Square Linear regression method has been used to identify the trends of flood events. Both graphs and maps were used to display the results of the analyses and Arc GIS 10.1 software was used to portrait the maps. The results of the study revealed that both districts have shown a continuous increase in the occurrence of flood events both in spatial and temporal dimensions. The frequency of flood events has increased in the decade of 2000-2009 in both districts. In terms of the spatial distribution of the flood events too, the recent past decade has become more marked compared to the remaining three decades. In Kalutara district, all the DS divisions have experienced flood occurrences during the last two decades. The situation in Rathnapura showed that all the DS divisions have experienced of flood occurrences in the most recent decade of 2000-2009. Bulathsinhala DS division in Kalutara district and Rathnapura DS division in Rathnapura district have reported flood events in every decade and represented of having the highest number of flood events among the DS divisions in their respective districts.

Keywords: climate change; extreme rainfalls; frequency; occurrence of flood events; spatial and temporal dimensions

## 1. Introduction

The occurrence of extreme climate events such as floods, droughts, landslides and cyclones could be due to the anticipated climate changes caused by global warming. The Intergovernmental Panel on Climatic Change (IPCC) has suggested that it is likely that in the future such extreme events would occur with higher intensity and frequency than now.

Floods are more common occurrences in Sri Lanka than other extreme events. According to the study on national climate change adaptation strategy for Sri Lanka - 2011 to 2016 undertaken by the Environmental

Ministry of Sri Lanka increase in the intensity of rainfall in the wet-zone due to climate change is expected to increase the propensity for flooding of flood prone rivers and to increase the intensity and frequency of landslides associated with prolonged and heavy rains in this region. In the regions where precipitation is generally high, more intense rainfall expected from climate change scenarios would lead to more soil and land erosion and increase the frequency of floods and landslides. Therefore, it has become necessary for the identification of spatial and temporal distributions of flood events, possibility of predicting such events and possibility of controlling such events totally.

In terms of Sri Lanka, River Kalu is the second largest river in Sri Lanka, causing floods along its route from the most upstream city of Rathnapura to the most downstream city of Kalutara. According to the Disaster Management Center report in 2005, settlers in the river Kalu's flood plains are affected by floods that occur almost annually (Perera, Gunarathne and Ranasinghe, 2014). Severe floods in the study area were reported in the years 2003, 2006, 2008, 2010, 2011, 2012 and 2016. Especially, the Kalu river basin area is a highly populated area with urban centers and agricultural areas. River floods frequently occur in this area with destructive results. Local planners, decision makers and disaster relief organizations are in desperate need of accurate information on the spatial distribution, magnitude and depth of flooding. It is also important for the development of appropriate land use planning in flood prone areas. In this context, it is worthwhile to study the spatial and temporal patterns of flood events in Kalutara and Rathnapura districts where the present study is based on. Overall, the finding of the study will contribute to the efforts in enhancing disaster risk management and mitigation measures in flood prone areas in the Kalutara and Rathnapura districts.

With this brief background, the main purpose of the present study was to assess the occurrences and trends of flood events in Kalutara and Rathnapura districts both spatially and temporally during the period of 1981-2020.

## **2. Methodology**

### *2.1. Study Area*

The study areas for this research are Kalutara and Rathnapura districts. Figure 1 shows the relative location of the study areas.

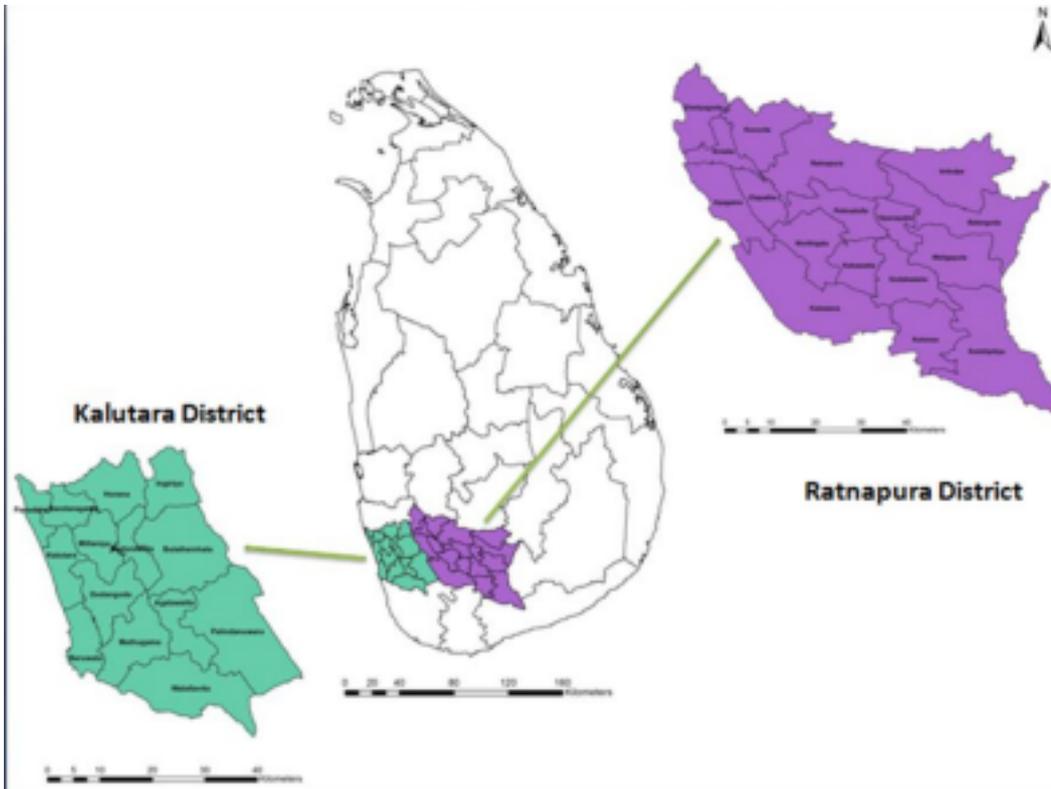


Fig. 1. Relative Location of the Study Areas (Source: Survey Department, 2001)

Kalutara district is located in the Western Province and on the Southern Coastal belt in Sri Lanka, between 60 25/ and 60 45/ of North Latitudes and 790 50/ and 800 20/ of East Longitudes. The elevation of the district is between the lowest of 61 m to the highest of 660.5 m above mean Sea Level (MSL) and it receives an average annual rainfall of 3233.6 mm. The average annual temperature of the district is around 30.6 0C and there are high humidity levels. Kalutara district has a total area of 1606.4 Sq. km. Administratively, Kalutara district has been divided into 14 Divisional Secretariat (DS) divisions and 762 Grama Niladhari (GN) divisions (Kalutara District Secretariat, 2017). Especially, the current study is based on fourteen Divisional Secretariat Divisions (DSDs) namely: Panadura, Bandaragama, Horana, Ingiriya, Millaniya, Kalutara, Dodangoda, Madurawala, Bulathsinghala, Beruwala, Mathugama, Agalawatta, Palindanuware and Walallawita. Kalutara district is a multi-ethnic, multi-cultural and one of the most populated districts in the Sri Lanka. According to the Population and Housing Census (2012) in Sri Lanka, the total population of Kalutara district is recorded as 1,221,948 persons and population density is 765 persons per square km.

Rathnapura district is located in the Sabaragamuwa Province, between 60 15/ and 60 55/ of North Latitudes and 800 10/ and 800 65/ of East Longitudes. The total area is approximately 3275.4 Sq.km. It receives an average annual rainfall of 4000-5000 mm. The average annual temperature of the district is from 24 to 35 0C and there are high humidity levels. The elevation of the district is 259 m from Sea Level. It has 17 Divisional Secretariat (DS) divisions and 575 Grama Niladhari (GN) divisions for administrative purposes (Rathnapura District Secretariat, 2017). Especially, the current study is based on seventeen Divisional Secretariat Divisions (DSDs) namely: Ayagama, Balangoda, Eheliyagoda, Elapatha, Embilipitiya, Godakawela, Imbulpe, Kahawaththa, Kalawana, Kiriella, Kolonna, Kuruwita,

Nivithigala, Opanayaka, Pelmadulla, Rathnapura and Weligepola. According to the Population and Housing Census of 2012, the total population of Rathnapura district is recorded as 1,088,007 persons and population density is 3275 persons per square km. Rathnapura is an important area of the wet zone of Sri Lanka where agricultural land use accounts for both field and plantation crops (Punyawardena & Cherry, 1999).

Kalutara and Rathnapura districts are also located in the low-lying, severely flood prone areas. Therefore, both districts are mostly vulnerable to the seasonal flooding. The main river in the study area is the River Kalu (Kalu Ganga). As already mentioned, both districts are located in the Kalu-Ganga River basin and along its route from the most upstream city of Rathnapura to the most downstream city of Kalutara. Figure 2 depicts the Kalu Ganga river basin.

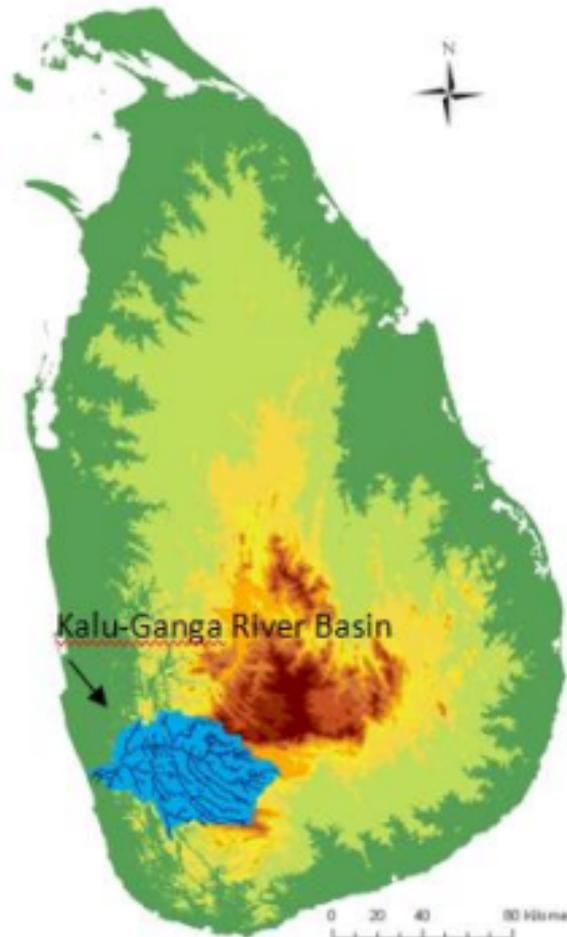


Fig. 2. Kalu-Ganga River Basin (Source: Samarasinghe, et al. (2021))

## 2.2. Data Collection

The study was based on divisional secretariats of the districts and the total number of divisions are 14 and 17 in Kalutara and Rathnapura respectively. Data used for the study was based on secondary sources, the flood frequencies for each divisional secretariat of the two districts obtained from the EM-DAT database of Global

Risk Information Platform (GRIP) and DesInventar database of Disaster Management Center (DMC) in Sri Lanka. Flood frequency data were collected for the 40-year period from 1980 to 2019. Further, the entire period considered i.e., 1980-2019 has been divided into decades; 1980-1989, 1990-1999, 2000-2009 and 2010-2019 for clear identification of the temporal patterns of flood occurrences and their trends.

### 2.3. Methods of Analysis

Arc GIS 10.1 software was used to demonstrate the spatial distributions of flood events. Ordinary Least Square Linear regression method has been used to identify the trends of flood events. Regression based trend analysis is conducted using linear trend model that is given in an equation below.

$$Y = mx + c$$

Here,  $m$  represents the rate of changes and  $c$  represents the  $y$  intercept of the line. The R-squared ( $R^2$ ) value ranging from '0' to '1' or the 'corrected R-squared' ( $R^2$ ) which is adjusted for degrees of freedom indicates the explanatory power (goodness of fit) of the model. Both graphs and maps were used to display the results of data analysis.

## 3. Results and Discussion

### 3.1. Spatial and Temporal Patterns of Flood Events in Kalutara District

In order to identify the spatial and temporal patterns of flood events in Kalutara district, the study has focused on the frequencies, trends and spatial distribution of flood events. According to the frequencies of the flood events, Kalutara district has showed a continuous increase in the occurrence of flood events up to the decade of 2000-2009 (Figure 3). It is also evident that the decade of 2000-2009 has become more marked in flood events. As shown in Figure 3, last decade (2010-2019) is shown a decline of number of flood events.

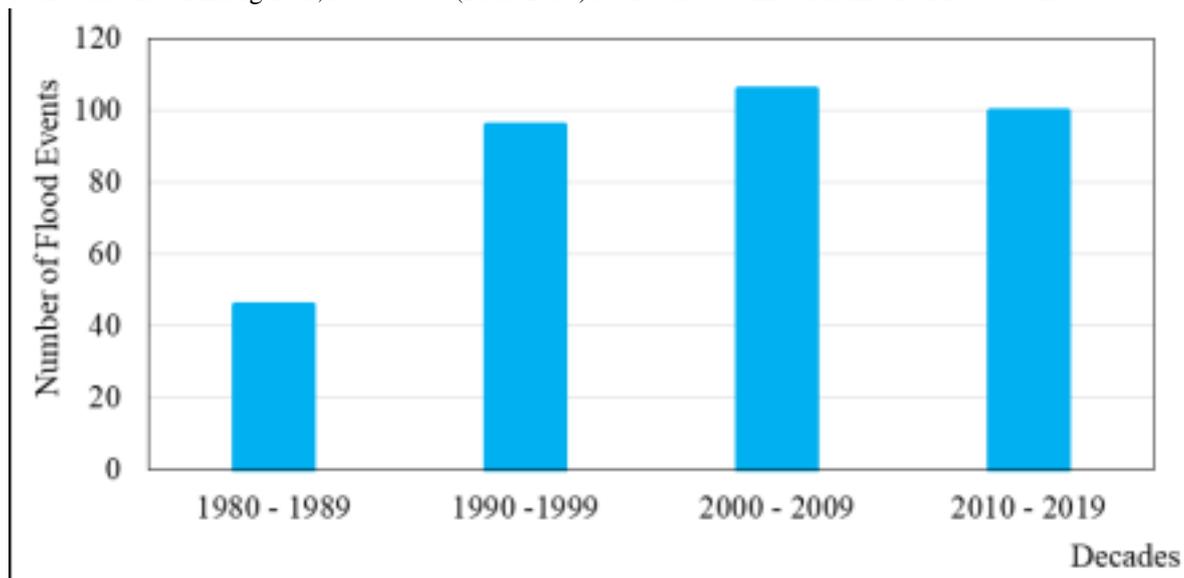


Fig. 3. Total Number of Flood Events in Kalutara District (Source: EM-DAT database, 2021)

Figure 4 displays the trend of the number of flood events during the whole period of 1980 to 2019. As seen

in Figure 4, in the Kalutara district, number of flood events showed a positive trend during the considered period of 1980-2019. The highest frequency of flood events was observed in 2008 (39 flood events). Years 1992, 2007, 2010 and 2018 are also marked with comparatively higher frequencies of having flood events.

When considering the DS divisions in the Kalutara district alone, as seen in Figure 5, flood events are more visible in all decades in most of the divisions. It also showed that around 50% of the DS divisions in the district have been affected by floods in every decade. Beruwala, Ingiriya and Walallavita DS divisions have shown a continuous increase in the occurrence of flood events up to the decade of 2010-2019. Among all the DS divisions, DS division of Panadura has experienced in flood events only for the last three decades. It also needs to mention that in the Kalutara DS division, the frequency of flood events has increased by 300% in the decade of 2000-2009 when compared with the decade of 1990-1999.

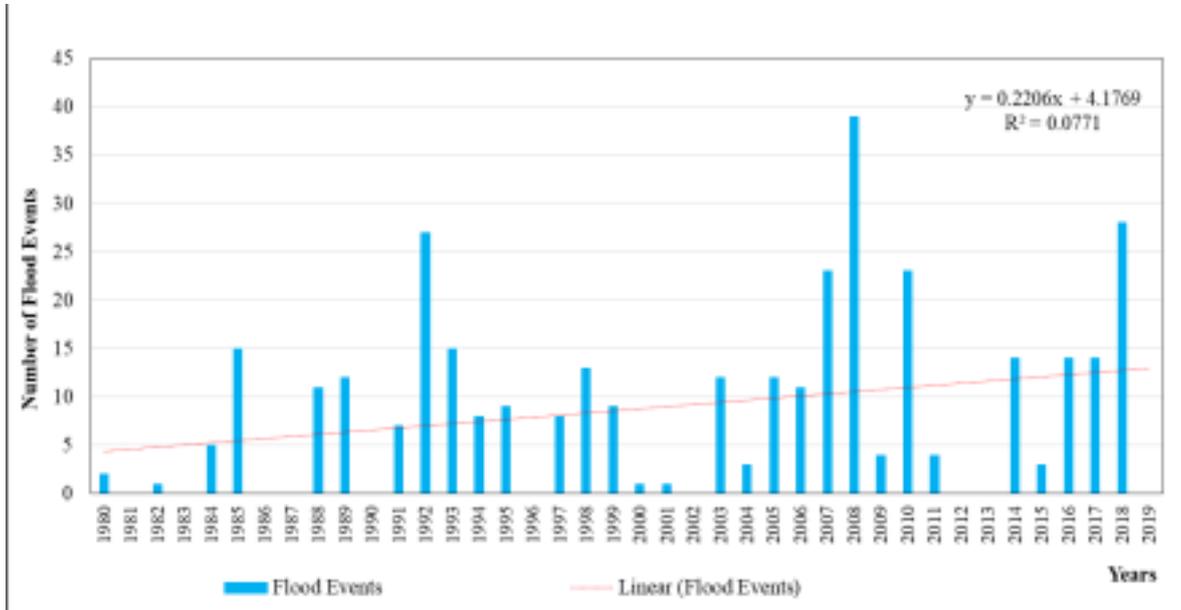


Fig. 4. Trend of Flood Events in Kalutara District (Source: EM-DAT database, 2021)

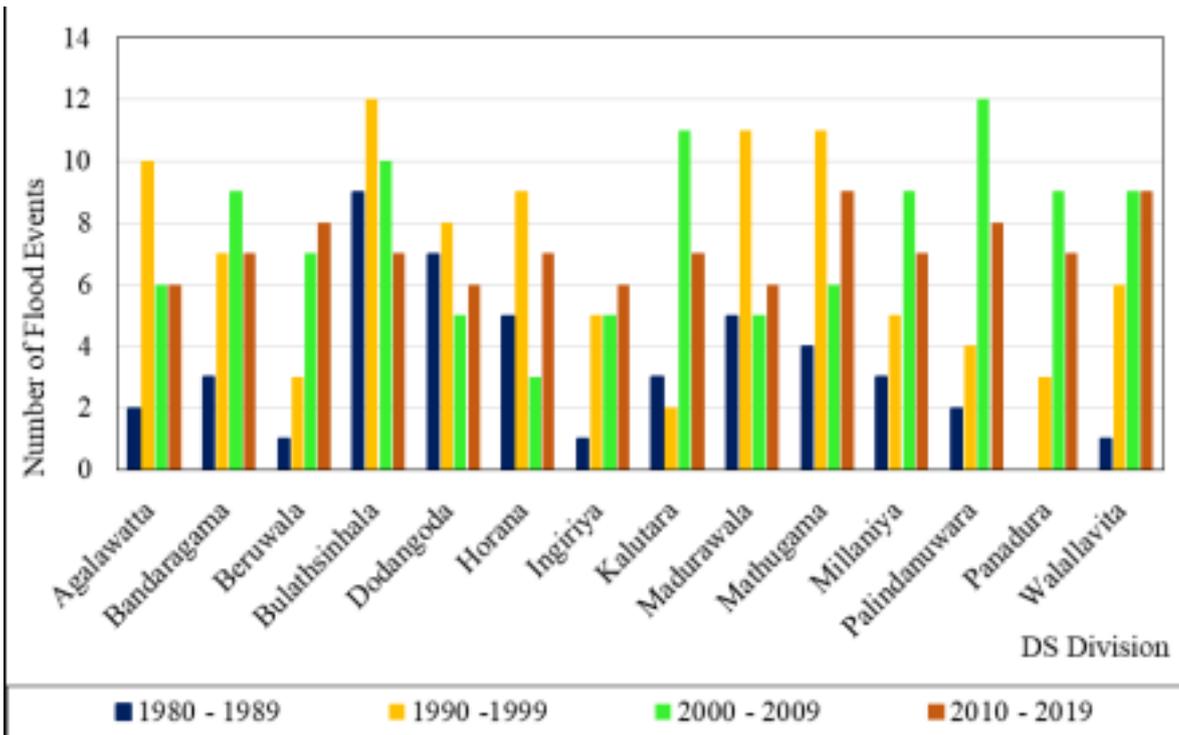


Fig. 5. Decadal Wise Flood Frequencies of Divisional Secretariat Divisions in the Kalutara District (Source: EM-DAT database, 2021)  
 When considering the spatial distribution of flood events in the Kalutara district, in the decade of 1980-1989, events were mostly confined to the northern part of the district. It is vital to mention that Bulathsinhala division has reported flood events for every decade and represented of having the highest number of flood events among all the divisions. Moreover, Bandaragama, Millaniya, Madurawala, Dodangoda and Mathugama divisions have also reported a higher number of flood events, while Beruwala division has the lowest number of flood events occurred during the last four decades (Figure 6).

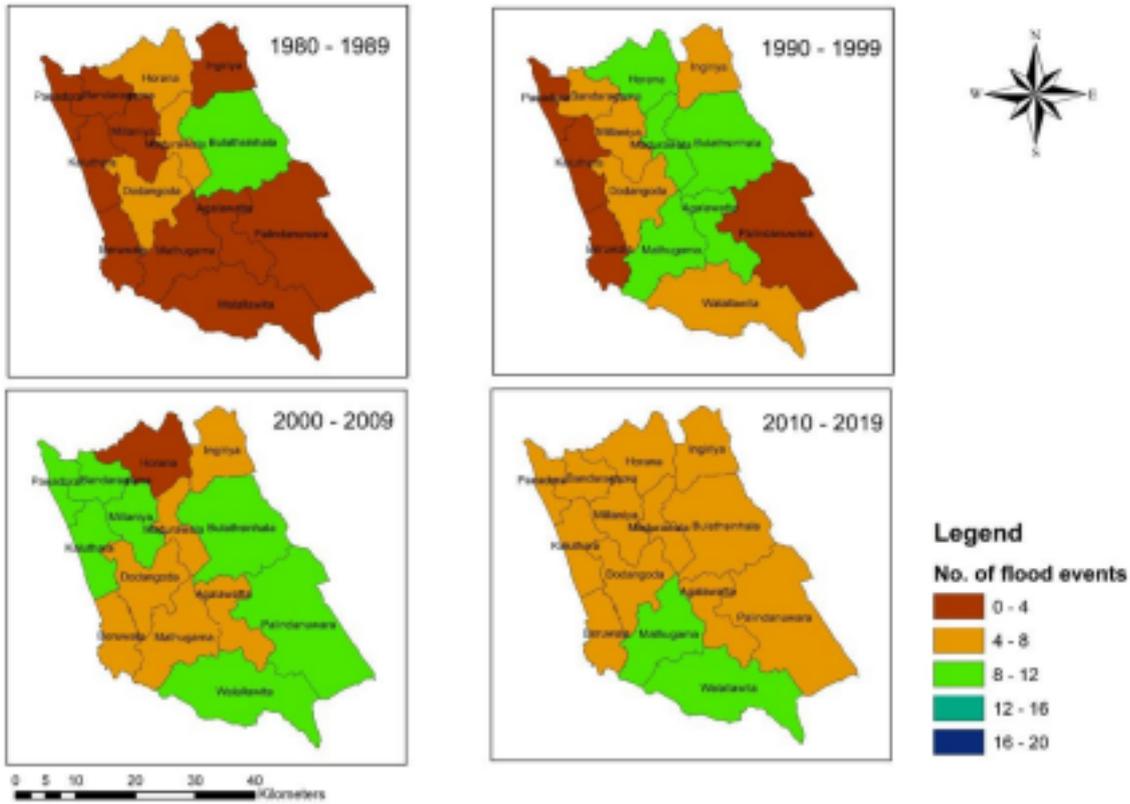


Fig. 6. Spatial Distribution of Flood Events in Kalutara District

### 3.2. Temporal and Spatial Patterns of Flood Events in Rathnapura District

As seen in Figure 7, the Rathnapura district showed that the frequency of flood events is higher in the decade of 2000-2009. It also showed that the frequency of flood events has increased by 118% in the decade of 2000-2009 when compared with the decade of 1990-1999. Therefore, in the Rathnapura district too, the most recent past decade has become more marked on flood events than the remaining three decades considered.

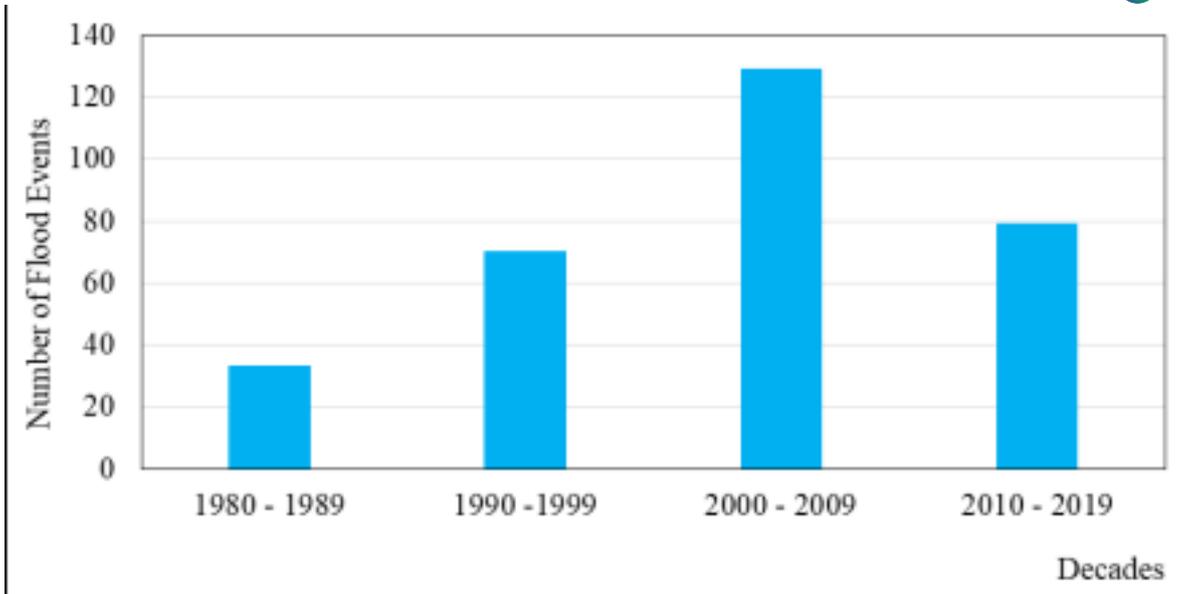


Fig. 7. Total Number of Flood Events in Rathnapura District (Source: EM-DAT database, 2021)

As appears in Figure 8, the overall trend of the number of flood events shows a significant increasing trend ( $R^2 = 0.163$ ). It is also clear that higher number of flood events have been recorded in the most recent past decade of 2000-2009. When comparing the flood years, the year 2008 has the highest number of flood occurrences, amounting of 32. Also, another marked flood events in the Rathnapura district could be identified in 1999, 2003, 2005 and 2009, amounting to 20, 18, 19 and 22 respectively.

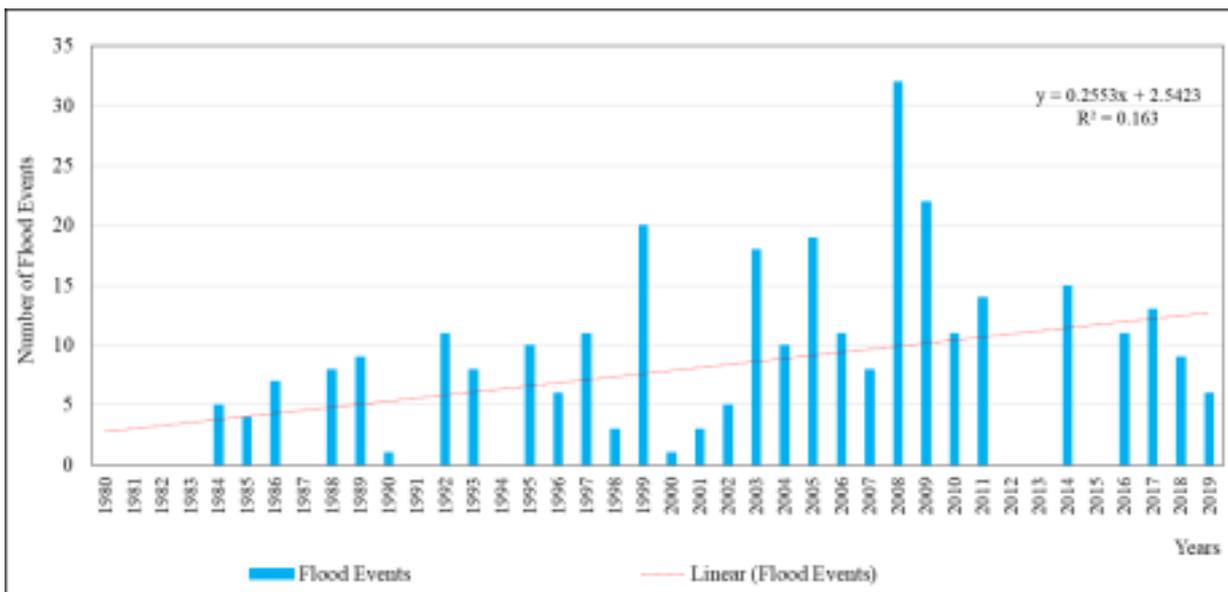


Fig. 8. Trend of Flood Events in Rathnapura District (Source: EM-DAT database, 2021)

In Rathnapura district, the frequency of flood events has increased in the decade of 2000-2009 in most of the

DS divisions (Figure 9). It is also showed that the decade of 2000-2009 has become more marked for the Balangoda, Godakawela, Kalawana, Kiriella , Kolonna, Nivithigala, Opanayaka and Pelmadulla DS divisions. Further, Ayagama, Elapatha, Kahawatta, Kalawana, Kiriella, Kuruvita, Nivithigala, Pelmadulla and Rathnapura divisions have been recorded for flood events in every decade and have shown a continuous increase in the occurrence of flood events. Among all the DS divisions, Embilipitiya and Weligepola have experienced flood events only for the most recent decades of 2000-2009 and 2010-2019.

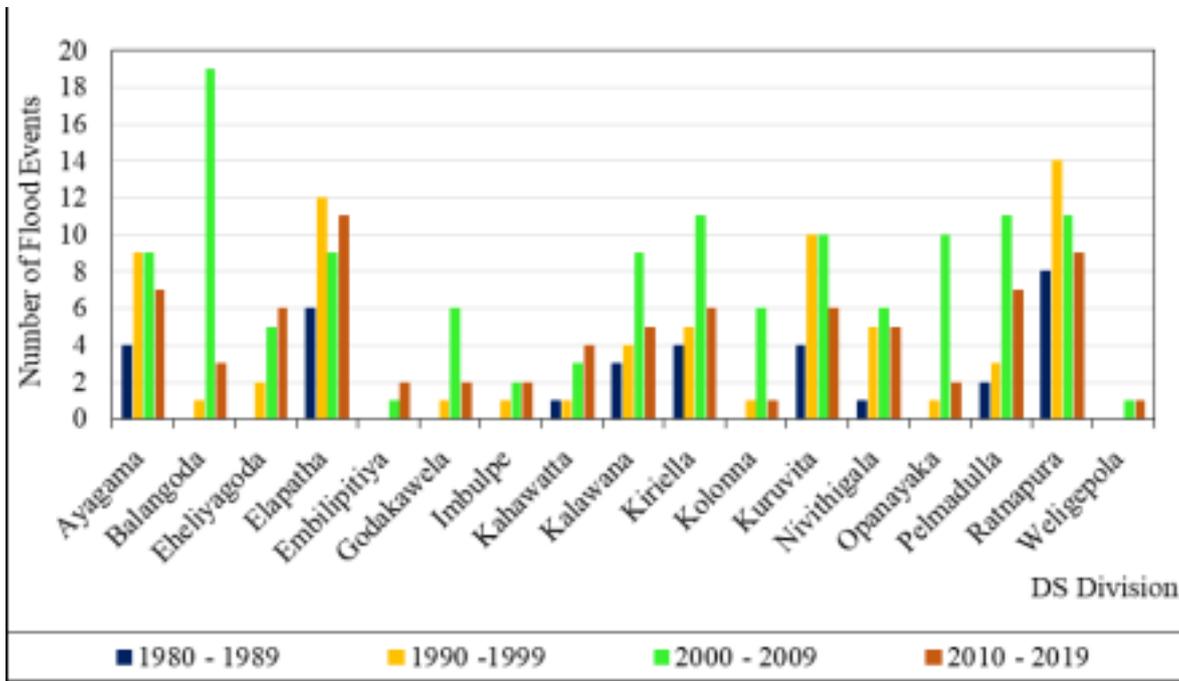


Fig. 9. Decadal Wise Flood Frequency of Divisional Secretariat (DS) Divisions in the Rathnapura District (Source: EM-DAT database, 2021)

In Rathnapura district, the frequency of flood events has increased in the decade of 2000-2009 in most of the DS divisions (Figure 9). It is also showed that the decade of 2000-2009 has become more marked for the Balangoda, Godakawela, Kalawana, Kiriella , Kolonna, Nivithigala, Opanayaka and Pelmadulla DS divisions. Further, Ayagama, Elapatha, Kahawatta, Kalawana, Kiriella, Kuruvita, Nivithigala, Pelmadulla and Rathnapura divisions have been recorded for flood events in every decade and have shown a continuous increase in the occurrence of flood events. Among all the DS divisions, Embilipitiya and Weligepola have experienced flood events only for the most recent decades of 2000-2009 and 2010-2019.

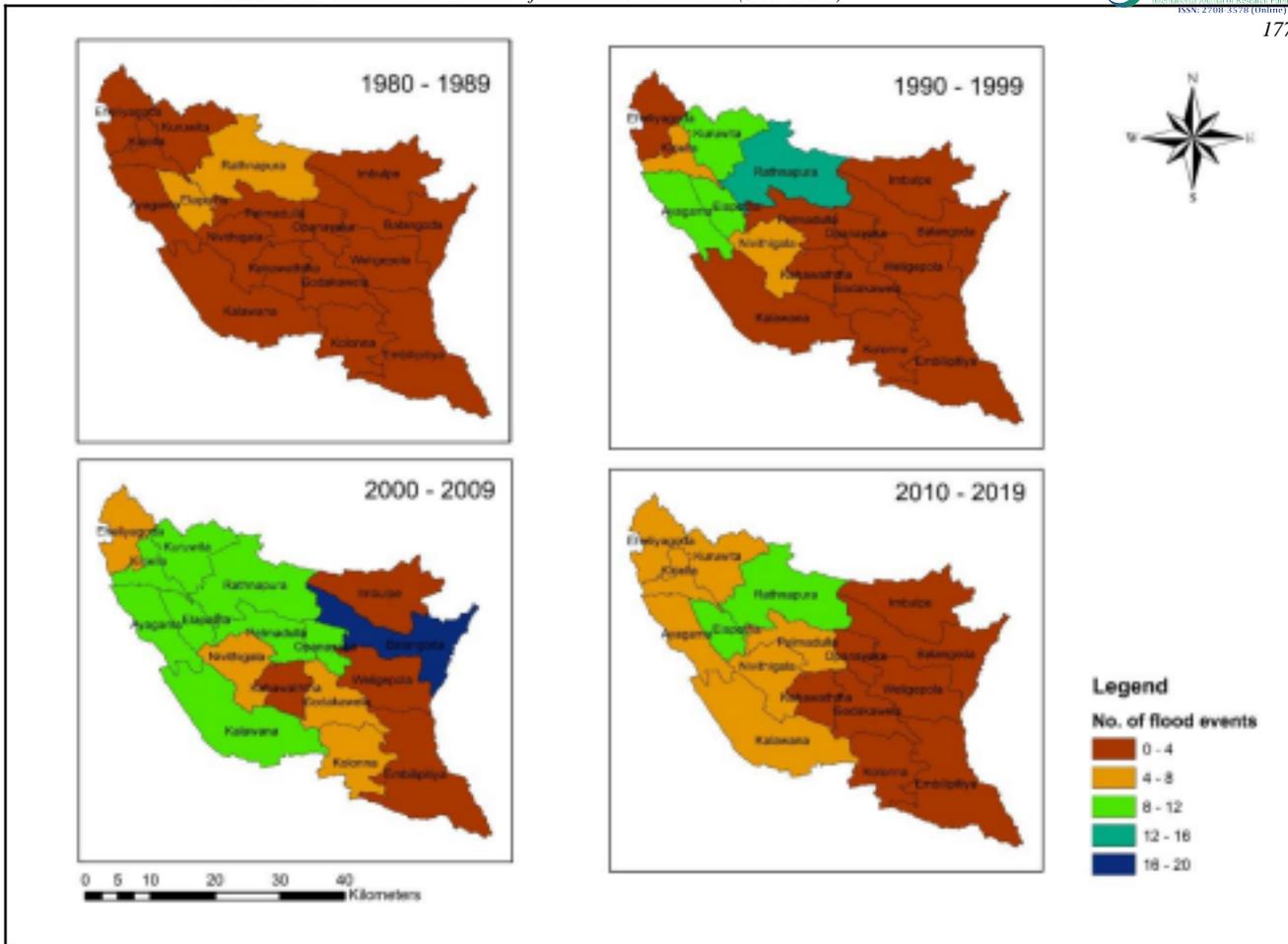


Fig. 10. Spatial Distribution of Flood Events in Rathnapura District

However, in this district, all the DS divisions have experienced flood events in the decades of 2000-2009 and 2010-2019 (Figure 10). In all decades, the highest flood frequency has been recorded in the Balangoda division.

When considering the spatial distribution of flood events in the Rathnapura district, comparatively, northern part of the district has more floods in the decade of 1980-1989. By the decade of 1989-1999, flood occurrences have been spread to the western parts of the study area.

It is vital to mention that Rathnapura DS division has been affected by flood events in every considered decade and represents of having the highest number of flood events among all the divisions. DS divisions of Ayagama, Elapatha, Kuruwita, Kiriella, and Rathnapura have reported higher number of flood events, while Weligepola and Embilipitiya divisions have reported the least number of flood events during the last four decades.

#### 4. Conclusion

The results of the study revealed that both districts have shown a continuous increase in the occurrence of

flood events both spatially and temporally. Both in Kalutara and in Rathnapura districts the frequency of flood events has increased in most of the divisions in the decade of 2000-2009 and the spatial distribution too has represented that this decade has become more marked compared to the remaining three decades considered. It is vital to mention that Bulathsinhala DS division in Kalutara district and Rathnapura DS division in Rathnapura district have reported flood events in every considered decade and represented of having the highest number of flood events among the all the DS divisions in their respective districts. Therefore, it is needed to have a special focus on Bulathsinhala and Rathnapura DS divisions. Overall, the study therefore confirmed that almost all the DS divisions in both districts were affected by flood events. This detailed research will benefit the flood management authorities in both the districts to identify the temporal and spatial dimensions of the vulnerabilities of flood events. Therefore, an integrated plan is suitable for flood management in the two districts.

## Acknowledgements

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