EFFECTS OF GLOBAL WARMING ON LANDSLIDE FREQUENCIES IN RATNAPURA DISTRICT, SRI LANKA

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ABSTRACT: Unpredictable variability of rainfall patterns could probably be due to global climate change with the increased frequency of extreme weather events. Infact, rainfall is the most relevant factor for the triggering of both shallow and deep-seated landslides in Sri Lanka. Landslides related to heavy rainfall cause widespread property damage and occasional loss of lives. Recent years, numbers of rain induced landslides have been increased in Ratnapura District due to heavy rainfalls. One of the most critical concerns in landslide study at the moment is the potential link between climate change and the frequencies of mass movement occurrences. In this research an overall study of the climate change on landslide frequencies in Ratnapura district is done by analyzing the trend of the rainfall and temperature variation patterns.

KEYWORDS: 1. Landslide, 2. Climate change

1. INTRODUCTION

Global climate change is possibly impacting the frequency of landslide in the world and will continue to do so in the future. Previous research has demonstrated the linkages between climate change and landslide activity in Europe (Buma and Dehn, 1998). Most of the investigations of the effect of climate change on landslide frequencies suggest an increase in both rainfall and temperature over the next century around the world. Climate change scenarios for SE England concluded this change is likely to have a number of potentially contradictory impacts on different types of mass movement process in the SE England (Andrew et al, 2000). Research findings indicate that the average temperature of the earth has risen by 0.7^0C over the past 100 years due to the emission of greenhouse gasses. The last few decades have been identified as the warmest period in the last thousand years (Varginiya et al, 2001).

This paper explores the effect of climate change on landslide frequencies in Ratnapura district. Landslides were previously considered as a minor type of disaster and not a common occurrence in Sri Lanka. Until the year 2002, the annual average number of landslide records did not exceed 50 (Sri Lanka National Report on Disaster Risk, Poverty and Human Development Relationship, 2009). However, the present records show a sudden increase in the occurrence of landslides during the period from 2003 to 2008. By considering that fact, the period of last decade is selected to analyze the climate change on landslide frequencies. This study looks at extreme rain conditions in the context of climate change. In the last ten years it has become clear that the most devastating landslide events tend to occur as a result of comparatively shorter duration, high intense rainfall compared to the previously had lower intense rainfalls for a lager period.

2. METHODOLOGY

The interrelationship between the rainfall data and the global warming effect was identified using three different methods, such as identification of Annual rainfall variation throughout the year, identification of average daily rainfall variation and the studying of the rainfall variation of the year in the wettest and driest months. The other factor studied was the temperature variation in selected landslide prone district considering annual average maximum temperature variation, annual average minimum temperature variation and the annual mean temperature variation. Overall objective has been identified using three different objectives such as identification of the effect of global warming on the rainfall, identification of the effect of global warming on the temperature and the identification of effect of global warming on landslide frequencies. The following information was collected from Department of Meteorology and National Building Research Organization Sri Lanka (NBRO).

1. Monthly rainfall data
2. Monthly Maximum temperature data
3. Monthly Minimum temperature data
4. Landslide data

Known landslide events considered in this paper were analyzed with respect to the associated rainfall and temperature data. The analysis was carried out in terms of the following parameters:

1. Variation of the monthly rainfall in the year of the landslide event.
2. Variation of the daily rainfall associated with the landslide event.
3. Variation of the Hourly rainfall associated with the landslide event.
4. Variation of the monthly maximum and minimum temperature associated with the landslide event.

3. RESULTS AND DISCUSSION

Mainly six trend patterns were developed to get the effect of global warming in Ratnapura district.

Annual rainfall variation in Ratnapura district is shown in figure 1. Annual rainfall data was calculated by using cumulative monthly rainfall data which was collected from the department of Meteorology.

Identification of the trend pattern of the annual rainfall variation was done considering last 10 years period (figure 1).

The trend pattern shows a significant increment of the annual rainfall variation in Ratnapura district. The rainfall has increased approximately by 33.02 mm per year during the last decade showing that there is a possible impact of the global warming on the rainfall pattern in Ratnapura district.

Table 1: Annual rainfall data in Ratnapura district in last decade.

Year	Annual rainfall in mm
2000	3628.2
2001	3398.1
2002	3202.3
2003	4021.2
2004	3741.6
2005	3404.8
2006	3735.6
2007	3104.5
2008	3883.5
2009	3394.1
2010	4163.1

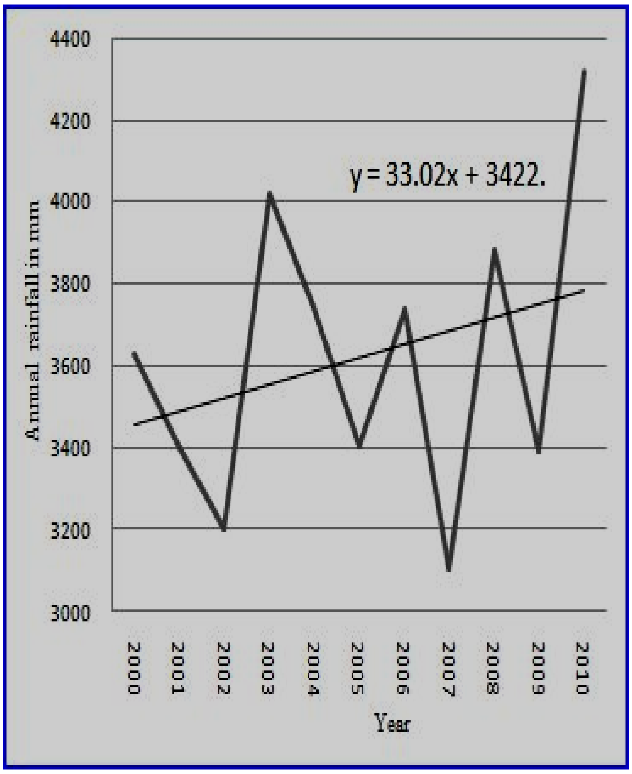

Figure 1: Annual rainfall variation in Ratnapura district from 2000 to 2010

Since the annual rainfall trend pattern clearly shows an increment, the effect of the wettest month rainfall pattern and the driest month rainfall pattern were also studied to find out further clarifications.

Table 2: January and October monthly rainfall data in Ratnapura district from 2000 to 2010

Year	January	October
2000	184.6	293.9
2001	359.4	365.6
2002	70.2	609.1
2003	91	309.9
2004	89.3	671.1
2005	52.2	609.8
2006	222.7	560.9
2007	91.6	509
2008	51.4	400.9
2009	22.2	330
2010	233.6	436.6

Figure 2 clearly shows the trend pattern of the wettest month monthly rainfall where the trend pattern has 2.131 mm increment of the monthly rainfall. The trend pattern also clarified that the wettest month has experienced more rain during the past 10 years and it will be continuing. Then the concentration was given to the driest month rainfall variation where the trend pattern has 9.323 mm decrement of the monthly rainfall variation.

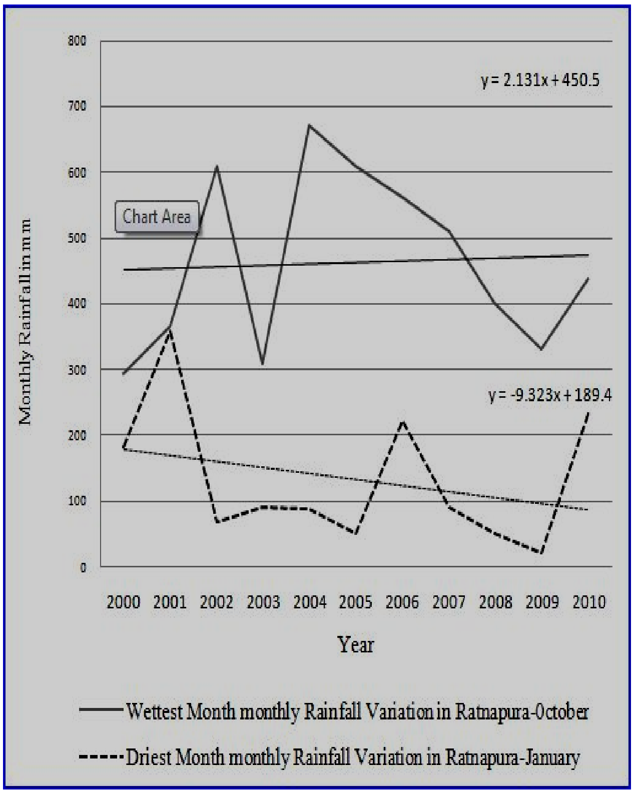

Figure 2: Wettest month and driest month monthly rainfall variation in Ratnapura district during last decade

The comparison between SE England GCMs modeling and the above Ratnapura variation was carried out to understand the possible relationship between the global trend and the local trend. Modeling climate change scenarios for SE England expect to rise winter rainfall by approximately 10%. Summer rainfall is expected to remain approximately as they are at present. Global warming is predicted that there will be greater warming impacts in the winter than in the summer (Andrew et al, 2000).

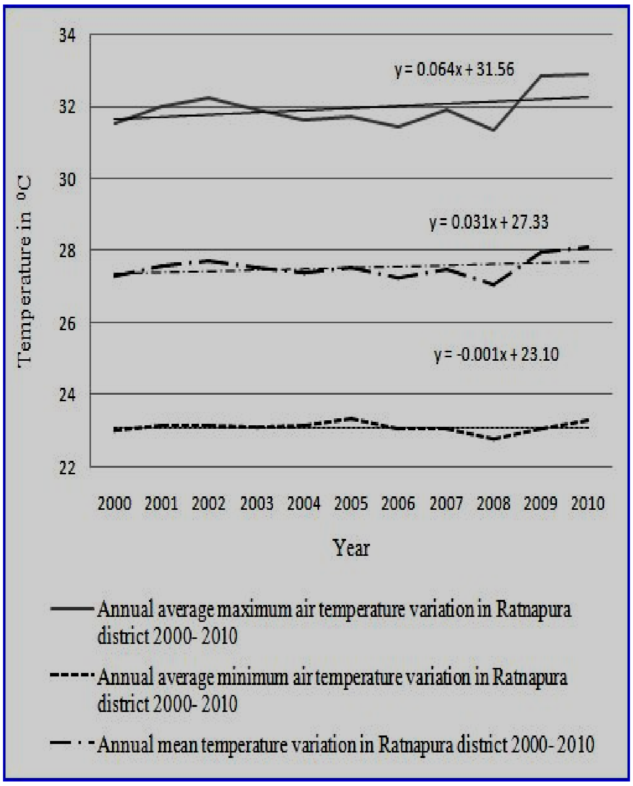

Figure 3: Annual average maximum, minimum and mean temperature variation in Ratnapura district 2000- 2010

Figure 3 clearly shows an increment of the annual average maximum air temperature in Ratnapura district during the last decade. The rate of increase of average annual maximum air temperature in Ratnapura district for the 2000-2010 periods is in the order of 0.064 ^{0}C per year. One distinct quality of the global warming effect is increasing the annual average maximum temperature in the world. Therefore the trend pattern clearly proves the effect of global warming for the annual average maximum air temperature in Ratnapura district.

Annual average minimum air temperature in Ratnapura district during the last decade is shown by the figure 3 and it clearly shows a decrement. The rate of decrease of average annual minimum air temperature in Ratnapura district for the 2000-2010 periods is in the order of 0.001 ^{0}C per year.

The minimum air temperature has reduced in Ratnapura district during the last decade and that will show some possible relationship with the global warming. Figure 3 shows the annual mean temperature variation in Ratnapura and clearly clarified that the increment of annual mean temperature of 0.031 ^{0}C per year. Annual mean temperature has been decreased since 2002 to 2008 with a minimum value of 27.33 ^{0}C and then a sudden increase similar to 2000-2002 periods.

Further data are needed to conclude any possible cycle of increasing and decreasing the annual temperature. Considering the climate modeling research in SE England, experiment suggest a rise in global temperature of between 3 and 4 ^{0}C by the year 2100, and the rise in winter temperature by approximately 10% (Andrew et al, 2000).

According to the present records (Case studies on mitigating disasters in Asia and the Pacific, 2005) and figure 1, the extreme weather condition was recorded in the year 2003 where there were large numbers of devastating landslides occurred in Ratnapura district. Since the global warming shows the trend of shorter duration high intense rainfall this study has analyzed the extreme weather events in Ratnapura district in year 2003 and year 2008.

Figure 6 clearly concluded that the trend pattern has a 0.666 annual increment in the landslide frequency in Ratnapura district during the period from 2000 to 2008. However, this was largely affected by the extreme rainfall on 17th May 2003 and 21st July 2008.

On 17th May 2003, Ratnapura had extremely heavy and unusual rainfall of 347.2 mm within 24 hours. Floods that hit the city inundated the commercial area by the end of the day's downpour. This was recorded as the most severe event during the last 47 years in Sri Lanka. Many landslide occurrences have also been observed within the Ratnapura district surrounding the municipality area. Around 2.00 p.m. on 17th May, a Landslide occurred in Palawela, Elapatha. The entire "Abhepura" village was destroyed with the loss of 75 lives. Another landslide occurred in Pallegedara in the same DSD killing 4 more persons. Two other landslides occurred in Panapola and Elukpotha in Kalawana DSD where 11 persons were killed. Another 4 persons were killed in the landslide in Devalakanda village in Nivithigala DSD (Case studies on mitigating disasters in Asia and the Pacific, 2005).

The landslide was occurred due to the short duration high intense rainfall fallen in May 2003. The extreme condition was occurred during the period between 1 p. m and 3 p.m. This information is shown in figure 7 and 8. Variation of the daily rainfall in May 2003 clearly notes that until about 12 days after the landslide the rainfall did not exceed the limit of 0.1 mm. The area was almost dry during that period. Period between 1.00 p. m to 6.00 p. m can be identified as a critical moment before the landslide happens. With in very short period there was nearly 300 mm rainfall fallen in Ratnapura district on 17th of May 2003. It is clearly shown in figure 7.

Below figure 4 shows the annual time series distribution of landslides in Ratnapura district. The records of landslides are high in the months of May and June and once again from November to January, showing a clear relationship with two monsoon seasons in Sri Lanka (Sri Lanka National Report on Disaster Risk, Poverty and Human Development Relationship, 2009, figure 5).

Other extreme landslide event was recorded on 21st of July in Ratnapura district. Around 10.00 p.m. on 21st July, a Landslide occurred in Othnapitiya, Elapatha with the loss of 35 lives. On 18th July 2008, Ratnapura had extremely heavy and unusual rainfall of 186.1 mm within 24 hours. And the rainfall was recorded nearly 2mm in the same date that the landslide occurred.

After the landslide the rainfall was recorded nearly about 120mm on 22nd of July. The extreme rainfall condition was recorded three days before the landslide occurrence. Variation of the daily rainfall in July 2008 clearly shows that until about two days before the landslide the rainfall did not exceed the limit of 5 mm.

The landslide was occurred due to the short duration lower intense rainfall fallen in July 2008. The extreme condition was occurred during the period between 8 p. m and 11 p.m. This information is shown in figure 11.

Figure 6 and Figure 9 respectively show the variations of May and July monthly rainfall variations during the last decade in Ratnapura district. Both months are associated with the landslide events. The monthly rainfall variation in May shows an increment of 6.04 mm per year during the last decade and July variation shows an increment of 13.08mm per year during the last decade.

Variation of the maximum and the minimum monthly temperature variation associated with the Landslide event in month May during the last decade are shown in above figure 12. Figure shows a decrement in both maximum and minimum daily temperature. Variation of the maximum and the minimum daily temperature associated with the landslide event in July 2008 is shown in figure 13. Figure shows a decrement in both maximum and minimum daily temperature.

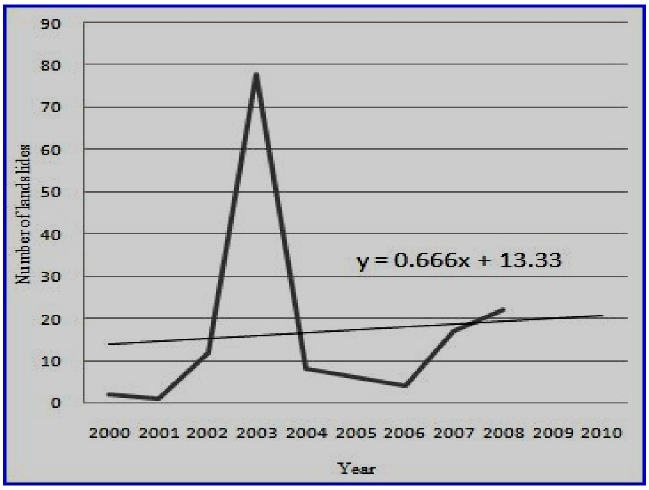

Figure 4: Landslide frequency in Ratnapura district during the last decade.

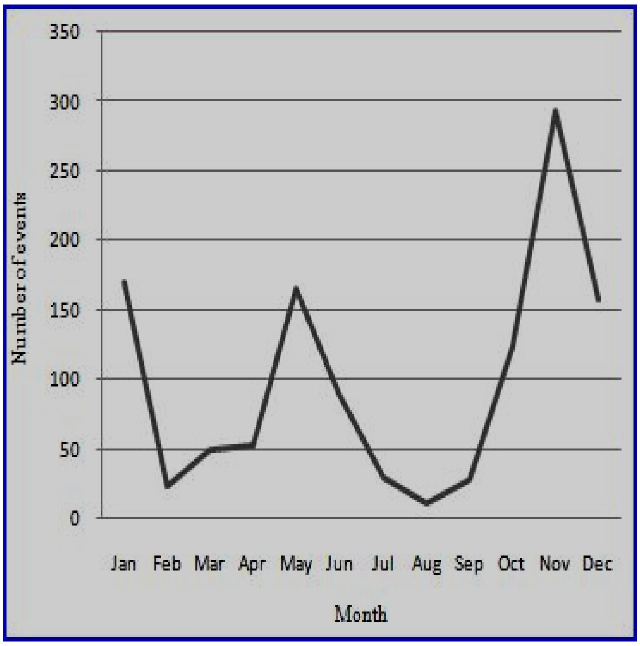

Figure 5: Seasonal Distributions of Landslides in Sri Lanka: 1974 – 2008(Sri Lanka National Report on Disaster Risk, Poverty and Human Development Relationship, 2009).

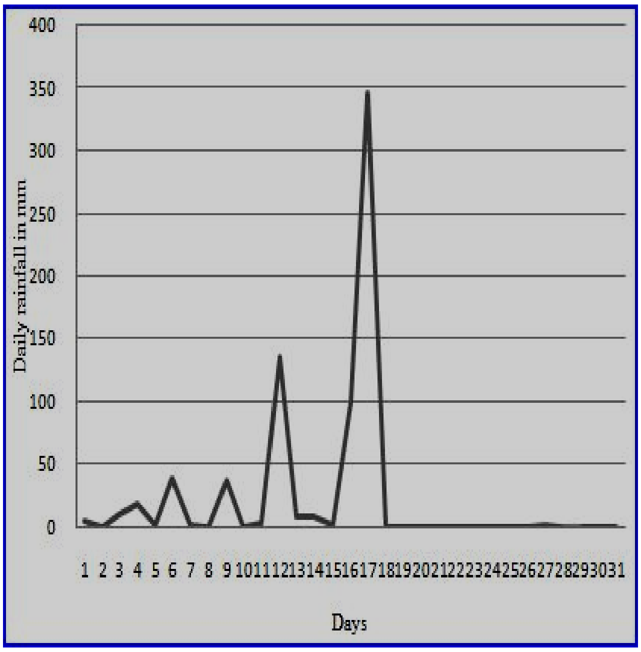

Figure 7: Ratnapura district daily rainfall variation in May 2003

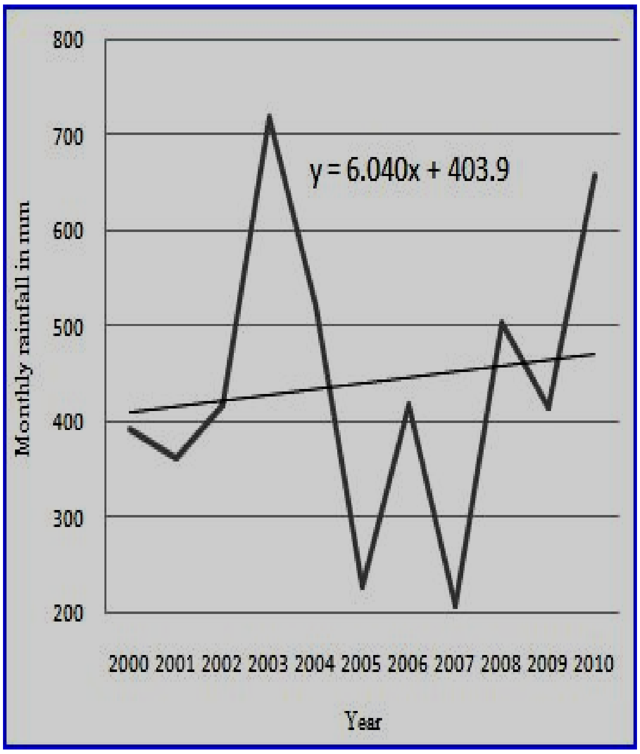

Figure 6: Monthly rainfall variation in month May during last decade in Ratnapura district

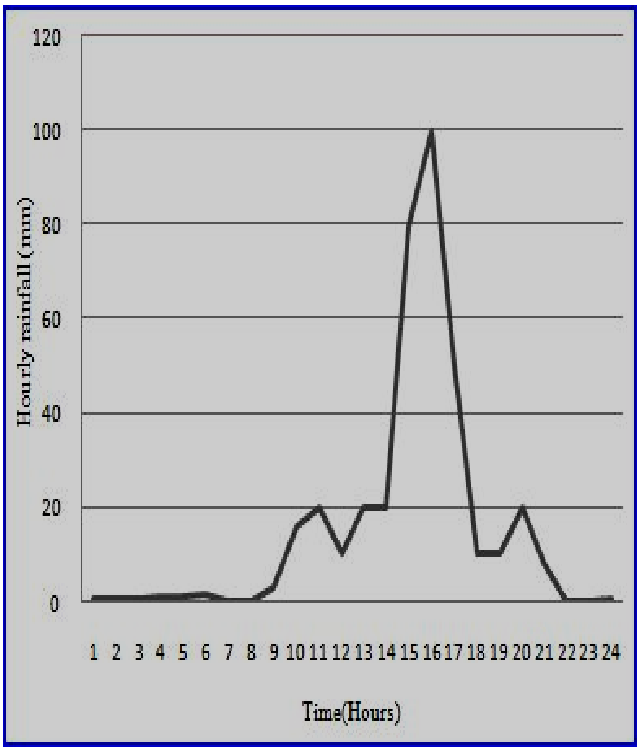

Figure 8: Hourly rainfall variation on 17th May 2003 in Ratnapura district

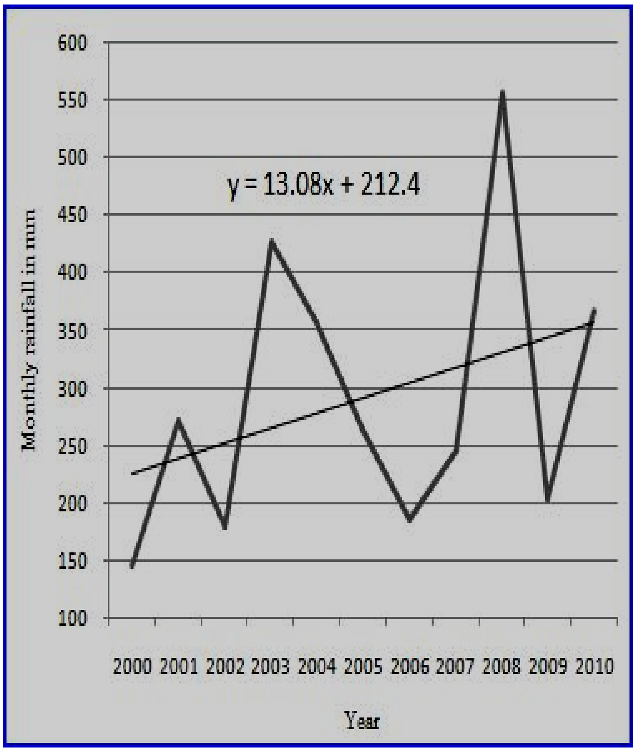

Figure 9: Monthly rainfall variation in month July during last decade in Ratnapura district.

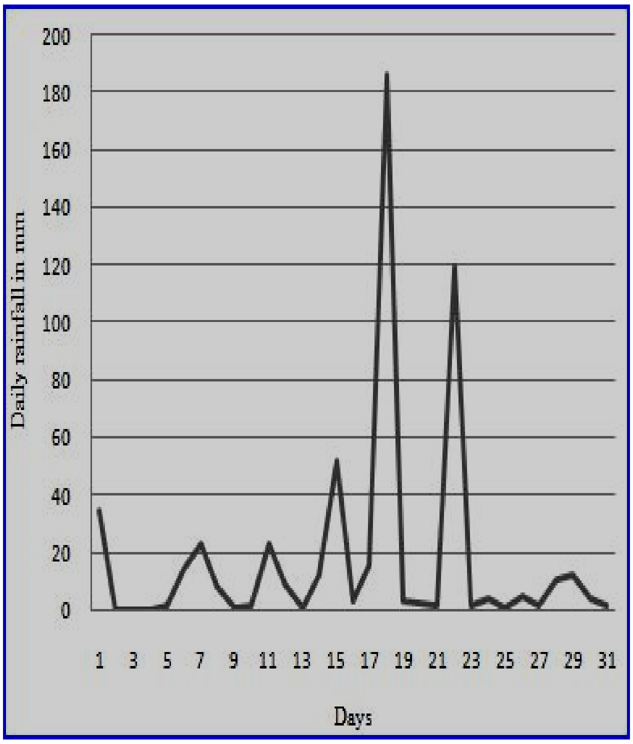

Figure 10: Daily rainfall variation in July 2008 in Ratnapura district.

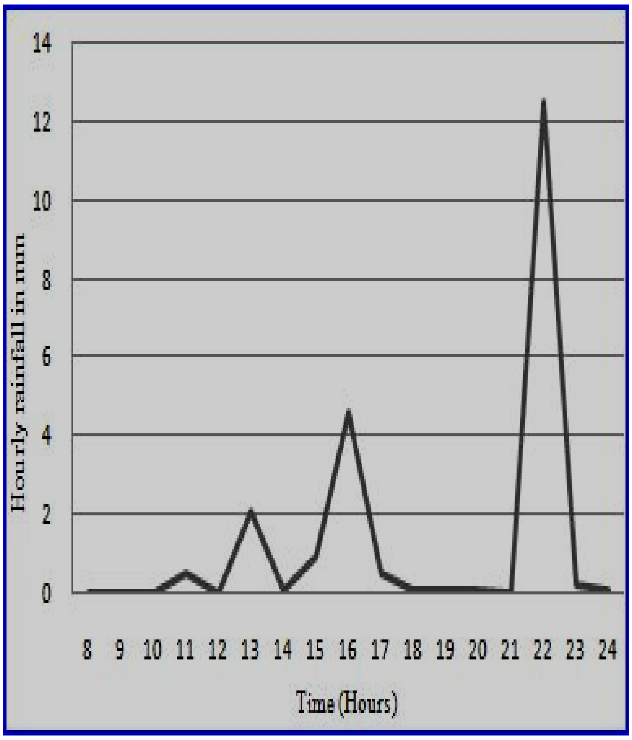

Figure 11: Hourly rainfall variation in 21st of July 2008 in Ratnapura district.

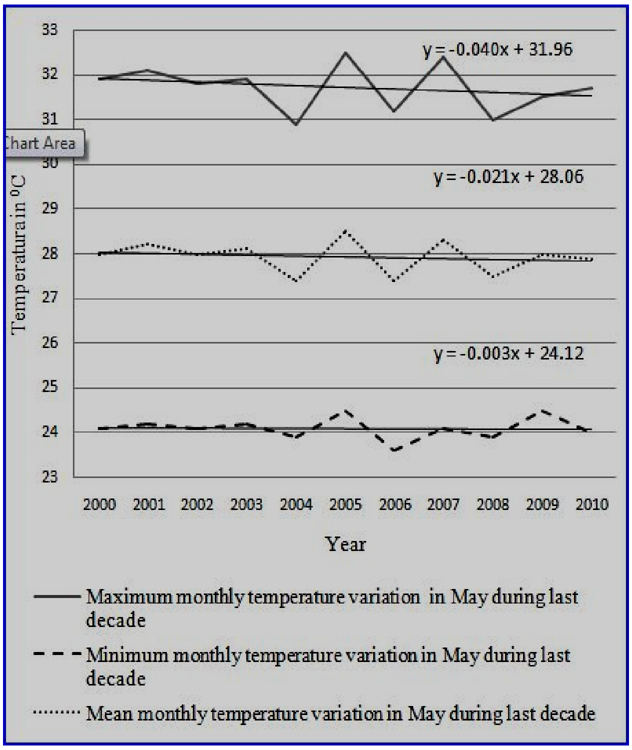

Figure 12: Maximum, Minimum and Mean monthly temperature variation in month May during the last decade in Ratnapura

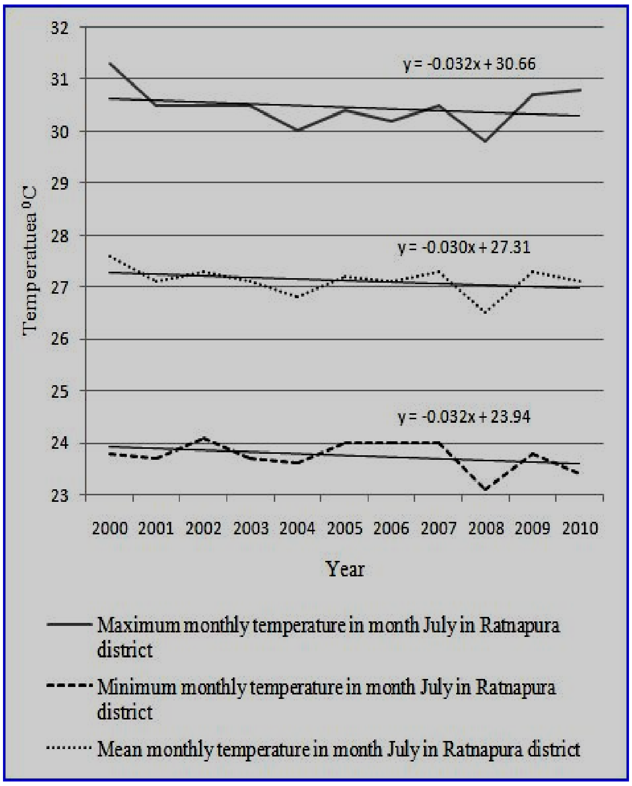

Figure 13: Maximum, Minimum and Mean monthly temperature variation in month July during last decade in Ratnapura district

The research has already analyzed two extreme events in Ratnapura and has come up with the possible trend patterns in both temperature and the rainfall.

The most significant conclusion emerging from this analysis is that although all landslide events reported in the paper happen to be associated with high intense prolonged rainfall. And it is clear that an increment in the shorter duration, high intense rainfall in Ratnapura district during the last decade. Some evident, such as annual rainfall variation, annual temperature variation including both maximum and minimum temperature variations and wettest month and driest month rainfall variations have clearly proofed that there may be an effect of global warming in Ratnapura district.

Due to global warming, the changes can be resulted in the loss of certain resisting forces available and incur additional driving forces for natural soil slopes. Natural slopes normally have a FOS marginally unity where the climate change effects possibly reduce the FOS, landslide can result. It is foreseen that global warming may cause an increase in antecedent rainfall and short term intense rainfall in many areas of the world. Increases in rainfall will also result in a greater water surplus in the catchment areas causing greater flows in water courses and extreme flooding. This process can trigger a landslide due to reduction of the toe resistance (Bo, M. W., et al, 2008).

4. CONCLUDING REMARKS

At a time when climate change and global warming issues are considered as hot topics, a research on "Effect of Climate change on landslide frequencies" could be treated as a timely research. This study looks at extreme rain conditions in the context of climate change in Ratnapura district. During the last ten years it has become clear that the most devastating landslide events tend to occur as a result of comparatively shorter duration, high intense rainfall compared to the previously had lower intense prolonged rainfalls. Since the both rainfall and the temperature trend pattern have shown a positive trend on the global warming effect in Ratnapura district. These types of studies would conclude that there could be a direct relationship between climate change and the frequency of landslide occurrences in the other part of Sri Lanka.

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