Journal of Mountain Science Vol **2** No 3 (2005): 218~224
http://www.imde.ac.cn/journal

Article ID: 1672-6316 (2005) 03-0218-07

Changing Rainfall and its Impact on Landslides in Sri Lanka

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Abstract: During the recent past the rainfall pattern in Sri Lanka has shown a noticeable change. This paper describes the effect of this change on the occurrence of landslides and their impacts to eco systems. This study shows that most of the landslides occurring in Sri Lanka during northeast monsoons, southwest monsoons and second inter-monsoon were located in three distinctively separated areas. Analysis of rainfall time series shows a trend of increased lengths of dry periods along with an increasing trend of rainfall intensity, especially after the late seventies. A strong relation is obtained between the location of landslides and the spatial distribution of areas where rainfall intensity is increased.

Keywords: Rainfall; landslides; Sri Lanka

Introduction

Landslides, floods and droughts are the most destructive type of natural disasters that often occur in Sri Lanka causing severe negative effects on livelihood of the people and the national economy. Landslides and floods with their rapid on setting feature are the natural hazards that cause significant number of deaths, severe damages of properties and infrastructure, disruption of livelihood, disruption of services. Essential relief works, setback to livelihood and need of repairs to services are the major socio-economic effects of these disasters. It is evident that both the frequency of occurrence of such disasters and their severity are increasing in the recent past especially in the central mountainous region of Sri Lanka. One of the major reasons for the higher severity is the increased population and their spatial migration, which cause increase both in the property damage and fatality. They also contribute to the increase of landslides and debris flows through disturbance to the natural grounds and increase of floods through encroachment of the flood plains. However, the triggering factor of all these disasters is the high rainfall. This article describes the impact of recent changes of rainfall pattern in Sri Lanka.

Rainfall is becoming an increasingly important component that needs to be taken into consideration as in the recent past it has significantly changed its patterns causing changes in the affected environments. While the temperature has shown an increasing trend globally, the behavior of rainfall varies depending

Received: 13 September 2005
Accepted: 23 September 2005

on the location. The global rainfall variation trend in the 20th century though small has been identified to be positive, nevertheless it, in large areas, has shown a negative trend (Houghton *et al.* 1996). The annual rainfall between 1961 and 1998 has been found to be decreasing for South East Asia and the South Pacific in general and the rainy days has decreased significantly throughout most of South Asia and the western South Pacific (Manton *et al.* 2001). According to a study by Groisman *et al.* (1999) an increase of annual rainfall is expected to bring about an increase of heavy precipitation as the shape parameter of the precipitation gamma distributions remained unchanged with the change of total rainfall, whereas the scale parameter was variable. However, they also found cases of increasing rain intensities while the total precipitation decreased, as in Siberia (Groisman *et al.* 1999). Brunetti *et al.* (2001a & 2001b) found that the decrease of rainy days is more significant than that of total rainfall for the 1834~1998 period in Italy, which means that average daily rainfall has increased over the past 150 years while the total precipitation has decreased. Herath and Ratnayake (2004) analyzed the rainfall trends in the central mountainous region of Sri Lanka using daily rainfall covering the period 1963~1993 and found that there is a decrease in the annual rainfall in the region, while different seasons show mixed results. The March–April 1st inter-monsoon period shows the highest decrease in rainfall and in addition to this, the rainy days have reduced, which gave rise to an increasing rain intensity trend. In order to understand better the changes to rain intensity-frequency relation, a universal multifractal analysis was carried out. The results showed that there was a decrease of inter-monsoon rainfall, while the intensities and return period of extreme events appeared to become shorter.

Natural disasters in Sri Lanka are increasing in intensity and frequency due to human intervention and climate changes. Almost all river basins are flood prone and are prevalent in wet zone. The increased frequency of the floods in recent years was attributed to climate, deforestation, and increased sediment runoff and silting of rivers. Landslides are the other major form of disaster. They generally follow intense and continuous rainfall exceeding a threshold between 350 to 400 mm within two days. The frequency of landslides has increased since the early eighties. Though Sri Lanka is outside the cyclone belt, the few cyclones it experienced were the reasons for extreme rainfall events. There are eleven cyclones and two storms recorded between 1845 and 1958 but several since then. (Ministry of forestry and environment 2000)

Landslides are the most significant natural hazards in Sri Lanka that second only to flood and cyclones. First eight decades of 19th century only six major landslide events were recorded in Sri Lanka but the two decades since 1981 five major occurrence of landslides were registered (Amaratunga 1994). The study of landslides in Sri Lanka showed that the incidents during the past decade (1983~1993) increased rapidly causing about 223 damaged villages, about 381 deaths and 1,370 displaced families (Kotapola 1994). Major part of central hills comprising seven administrative districts is prone to landslides. The present landslide density in the slide prone districts has been estimated to be in order of 1 to 2 landslides per square kilometer (Disanayake 1998). Kotapola (1994) concluded that there is a trend to accelerate the occurrence of landslides in the Sri Lanka in the coming years.

This paper analyses the rainfall trend in the whole country based on about 98 main rain-gauging stations. This trend is then related to the occurrence of landslides to see if the change in the pattern of rainfall has any spatial correlation.

1 Data

Based on the annual rainfall and it's seasonal variation, Sri Lanka is divided into two major climatic regions as Wet Zone and Dry Zone. The boundary is commonly defined as that separating an area receiving more than 1,905 mm (75 in) of rainfall as the Wet Zone. Various other definitions, such as those with respect to agroclimatalogical aspects and consecutive dry spells, have been proposed over the years. Domroes and Ranatunga (1993) summarized a number of such definitions currently being used. The climate of Sri Lanka is described by four seasons, namely two monsoon periods and two inter-monsoon periods. The central part of the country falls within the wet zone and receives the highest amount of rainfall. The

terrain is generally mountainous with the highest elevations covered with virgin forests and grasslands. Major portion of the central mountains is located from 300 to 2,500 m and is largely planted with tea. The steeper slopes of the mountains are not utilized for tea plantations and are either covered with virgin forests or re-grown pine plantations. Rock outcrops can also be seen on the steeper slopes. At the top of the ridges and around peaks, small patches of trees, scrub and grassland prevail. Areas surrounding the steeper drainage paths are covered with forest patches. The rainfall trends in this area, has major implications on the water resources of the country, tea-growing as well as hydropower. The tea estates maintain most of the available rain gauging stations and the data are collected by the meteorological department of Sri Lanka, which archives them.

The trends in the rainfall were evaluated for the entire country considering about 98 rain-gauging stations selected around the country. The selected rain gauges were the ones with least number of missing data per station. Also if the trend of a station showed a very localized effect with negative correlation with all the surrounding stations it was omitted from the analysis. Daily data from these stations were collected for the period from 1960 to 2001. The missing data were then filled based on the rainfall observed at the surrounding stations

2 Method

In order to find the change in the characteristics of rainfall occurrence, two different time series giving the lengths of wet spells and dry spells are calculated. The length of a wet spell is defined as the consecutive number of days with a significant rainfall. The minimum length of a wet spell is taken as one day. Similarly the lengths of dry spells are calculated. The wet spells and dry spells of the first half of the time series are then compared with the latter half of the time series to assess the trend in wet and dry spells. The average rainfall intensity is estimated by dividing the rain volume by the rain spell length. By comparing the average intensity of the rainfall during the first half of the total period with the second half the rainfall intensity trend is estimated.

The trend variations calculated above were plotted and the variation contours were drawn among the points using GIS. The landslide locations were overlaid to find the spatial correlations.

3 Results

Sri Lanka has two distinctive rain periods called Northeast monsoon and Southwest monsoon, which bring rain from the two respective directions. As the occurrence of landslides is directly related to rain, the locations of them can be zoned with relation to the time of occurrence. The Figure 1 shows the relief map of Sri Lanka and the locations of the Landslides that recorded since 1970. A landslide is recorded only if it has a significance based on the area affected or damage caused. There were 303 landslide records were available in the

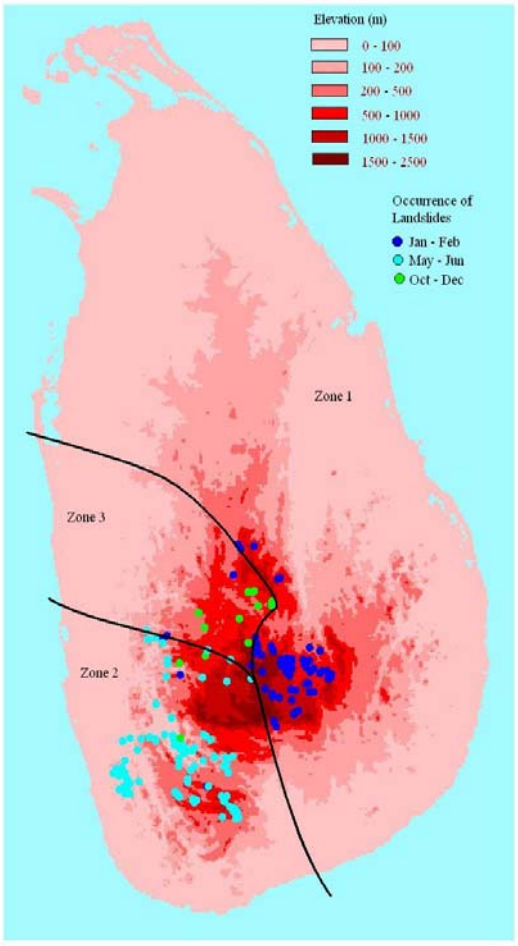
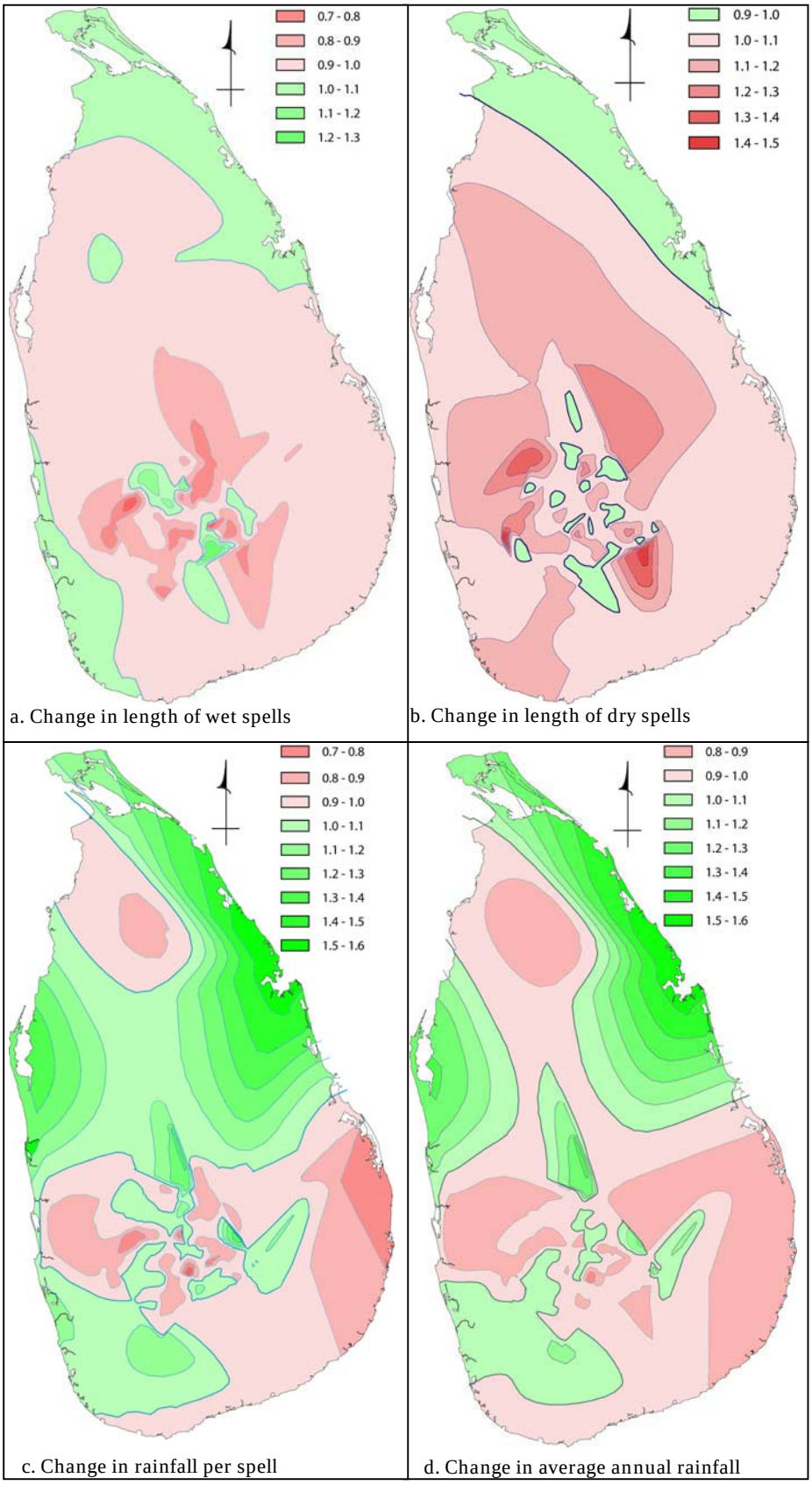


Figure 1 Zoning based on time of occurrence of landslides



a. Change in length of wet spells

b. Change in length of dry spells

c. Change in rainfall per spell

d. Change in average annual rainfall

Figure 2 Relative trend variation seen before and after 1978 in different rainfall characteristics

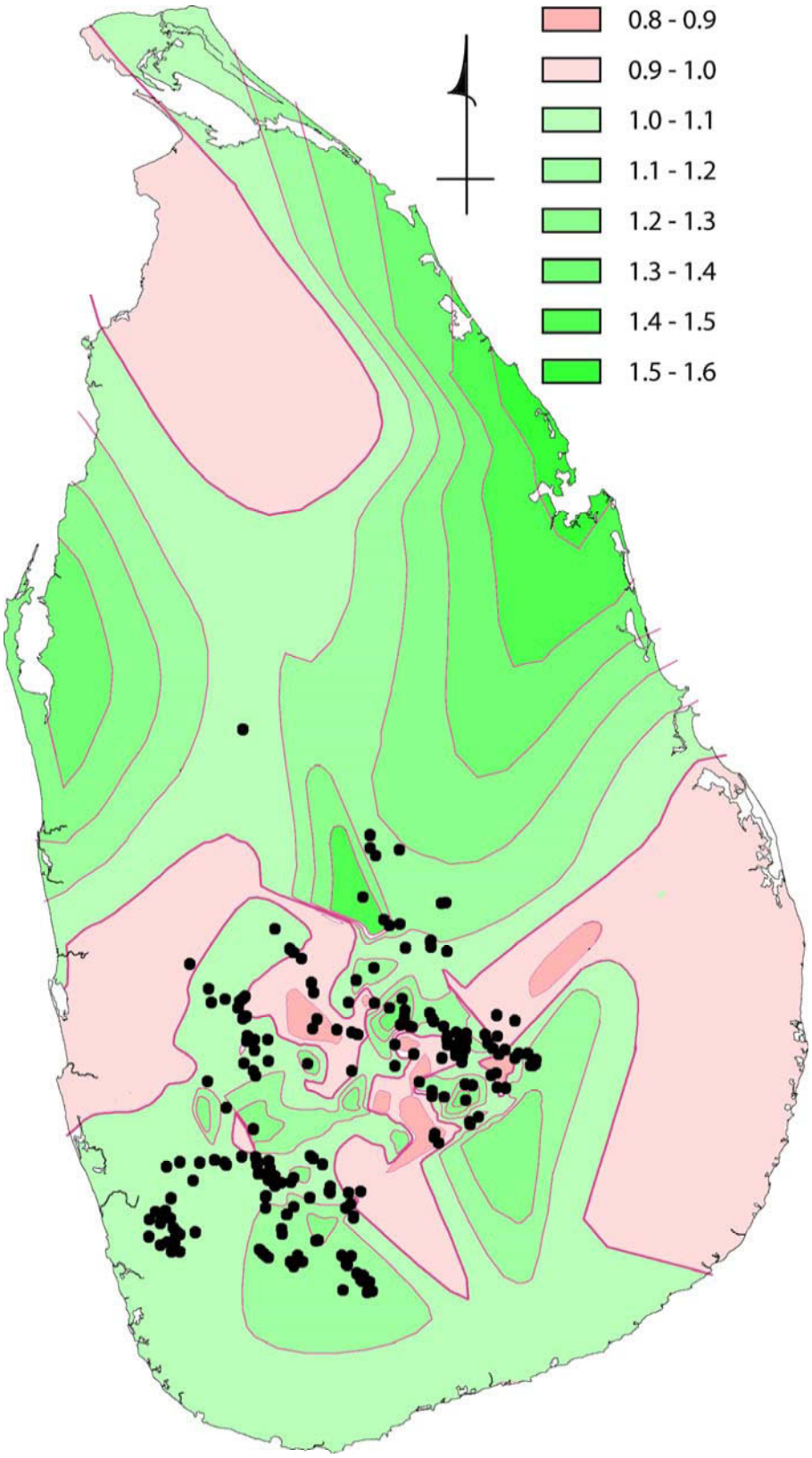


Figure 3 Trends of daily rainfall intensities and the locations of landslides

list. Most of them were not recorded with location coordinates and only those with specified locations are shown. Figure 1 also shows the zones according to the time of occurrence.

Five rainfall characteristics used in this time series analysis are defined as the total rainfall, lengths of wet spells, lengths of dry spells, amounts of rain per spells and amounts of rain per rainy days. Visual scrutinizing of the cumulative rainfall series plotted against the time for long-term trend clearly showed that a change had occurred in the late seventies (around 1978). Therefore, in this study the linear trends before 1978 were compared with the linear trends after 1978 (as a ratio) and the spatial distribution of the ratio of the trends are shown in the Figures 2 and 3.

The total rainfall shows both increasing and decreasing trends within the country and the spatial pattern and magnitude of this change is shown in Figure 2a. Northeastern and western regions experience increasing rainfalls while rest of the country experience a decreasing trend. It is also seen that the amount of rainfall received per spell has both increasing and decreasing trends and the spatial distribution of this change of trend is shown in Figure 2b. Interesting trends emerge when the lengths of wet and dry spells are investigated. The lengths of wet spells are decreasing and the dry spells are increasing all over the country and this trend change is shown in Figures 2c and 2d. Declining rainfall during first inter-monsoon is seen as the main reason. Such declining trends combined with decreasing monsoons would cause more droughts in the future during the same period. With comparison of the results given in Figures 2a and 2c, it is seen that though the lengths of wet spells decreased, the average rain received in a spell increased significantly. This change was prominent in the north-central and southwestern regions. Also, when the intensity of the rainfall is calculated as rainfall per rainy day, it shows an increasing trend of very significant order as shown in Figure 3.

In summary the daily rainfall intensities and the lengths of dry spell are increasing all over Sri Lanka while the lengths of wet spells are decreasing. The change has severely affected the central mountains of the country. Total rainfall and the rainfall per wet spell show both increasing and decreasing trends. The increased number of natural disasters is caused by the change in climate. As discussed the landslide hazard increases with the increasing rainfall received. Increasing intensity is known to trigger landslides and very high correlation is seen between the locations of the past landslides and the areas of increasing rainfall intensities as seen in Figure 3. Very few landslide events occurred in the areas of decreasing intensities. However, they were in the regions where rainfall received per wet spell showed an increase.

4 Conclusion

The climate of Sri Lanka has severely changed after the late seventies of the last century. The rainfall shows both increasing and decreasing trends specific spatial locations. This change is highly varied in space around the central mountains. Long dry spells followed by short and heavy rainy spells have significantly changed the vegetation and groundwater level in this region. Spatial locations of resent landslides are having very high correlation to the areas with increased rainfall intensities. Corresponding to seasonal changes the landslide locations can also be grouped in to three different zones.

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