# 06 Lightning


## 6.1 Background

"Lightning" is an unpredictable disaster. A large thunderstorm can produce over 100 lightning flashes within a minute, and even a modest thunderstorm can generate the energy of a small nuclear power plant (a few hundred megawatts!). Globally, every year more than 20,000 people are affected by lightning and several thousands give way to their injuries. Lightning injuries and deaths are always not accurately reported. The main reason is that, lightning most often strikes to individuals and not to large groups and therefore information is scattered and mostly uncounted.

Amount of lightning related casualties of a given region is an important factor to determine disaster preparedness activities which lead to mitigate lightning hazard in that region. Presently very few countries have statistics on lightning. Even in countries where lightning related deaths are available, except for few developed countries in the world, information is not reliable and most often offers an under estimation of lightning victims.

Literature of studies in this field reveals that the characteristics of lightning flashes depend on a number of parameters like longitude, latitude, altitude, soil conditions, topography and vegetation of a location. Therefore, the characteristics of locations with frequent lightning incidents should be surveyed, studied and understood thoroughly before concluding the reasons for damages caused by lightning in those locations.





Not all lightning strikes the ground but, when it does, that energy can be devastating. As far as the industries are concerned, one of the most significant loses that lightning may cause is the downtime. A couple of hours of standstill of normal operation or a loss of some important data stored in a computer may cause a company an economical loss of several millions. Until relatively recent time, there was little that could be done to mitigate this risk. Lightning can strike at any time anywhere.

There is no question about the hazards posed by lightning strikes and their associated effects. Fires, injuries or loss of life, damage and destruction of property, and the significant downtime and outage-related revenue losses due to equipment damage all make lightning a serious threat. While the direct effects of a lightning strike are obvious, the secondary effects can be just as devastating. This is especially true for electrical power lines and facilities with sensitive electronic equipment.

### 6.1.1 Causative Factors of Lightning & Thunder

#### 6.1.1.1 Lightning

Under the favorable conditions, electrical discharges occur from a charge center in a cloud either to the induced charge on the earth, or to charge centers of another cloud or to a charge center of the same cloud. Accordingly, lightning may be categorized mainly into two types –

- Ground Flash – Discharge between a cloud and the earth
- Cloud Flash– Discharge within a cloud or between clouds

In a Ground flash, the electrical discharge usually occurs between the negative charge of the cloud and the induced positive charge on the ground or structures on the ground (Fig 6.1). A ground flash is completed through a number of steps and strokes. A complete lightning discharge is called a lightning flash. A lightning flash usually comprises of a number of several individual discharges which are called strokes. Characteristics of individual step are different from stroke to stroke.

The polarity of the prevailing cloud charge defines the polarity of the lightning current. The discharge of a positive cloud to earth is called a positive flash while the discharge of a negative cloud is termed a negative flash.

The direct effects of a lightning strike are physical destruction caused by the strike and subsequent fires. When a direct strike hits a facility where flammable materials are present, the flammables may be exposed to the lightning bolt itself, the stroke channel, or the heating effect of the lightning strike. Lightning current

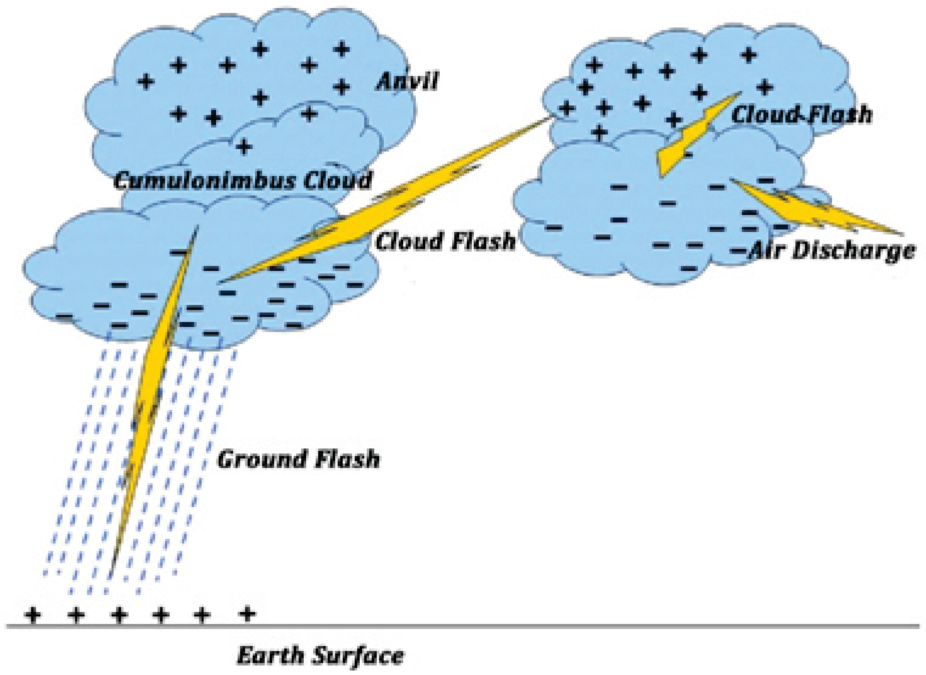



*Fig 6.1: Electrical Discharges in Charged Cumulonimbus*

reaches a peak value of about 30,000 Amperes (Abhyasingha 1986) on average but currents in the range of 200,000 Amperes are also reported. The lightning current heats its path to a temperature of about 30,000 0C. The enormous current involved with the lightning flash may destroy the entire power and communication networks in a building including all the equipment connected to the networks. The high temperature resulted by both the current that flows in the lines and the sparks that jump in between different parts of the building may trigger fires that will completely burn out the installation. Direct lightning including side flashes cause damages at a very rapid rate so that once the building is struck by lightning; it is very unlikely that one can prevent any of the damages to the equipment and human injuries (Kumarasinghe 2011).

#### 6.1.1.2 Thunder

Thunder is the acoustic wave resulted by the sudden expansion of the air within and around the path of a lightning flash.

The power of a ground flash heats up the air along the path of the flash to high temperatures of about 6000 degrees Celsius or more in a short duration of the order of 20 ms (1 ms = 0.001 second). This sudden heating causes sudden expansion of the heated-up air which will produce a vibration wave. During its traveling the vibration wave converts into a sound or acoustic wave which we can hear and it is called thunder.





Thunder is not hazardous as lightning but it may result in property damage and injuries to hearing system of human and animal when it happens at close locations. The damage depends on the intensity of the vibration wave.

### 6.1.2 Impacts

This section describes the impacts of lightning on human casualties, the secondary major impacts and effects on power & communication lines.

#### 6.1.2.1 Impacts on Human Casualties

In examining the data for the last decade, it has been clearly noticed that the enhancement of the effects of lightning related electrical environment to the civil life and the industrial sector in Sri Lanka. Most importantly lightning affect the human casualties. Lightning ignites fires that may bring an entire building or a house down to ashes. At a lower degree of damage, the lightning current may destroy electrical, electronic and communication equipment beyond repair.

Reported deaths due to lightning in recent years are shown in Table 6.1. In year 2011, 51 deaths were reported and more than Rs. 300 million worth property damages and amount of losses due to downtime and data loses have occurred. In year 2012, up to October, 43 deaths have been reported and only in October 2012, 8 deaths were reported. A country that is marching towards to achieve a rapid industrialization is unavoidably become vulnerable to lightning related hazards. Increasing number of deaths and property damages in recent years due to direct or indirect effects of lightning has been one of the hot topics among scientific community and the general public as well.

*Table 6.1 Reported Lightning Deaths in Recent Years*

| | Year | Reported Lightning deaths* |
|---|---|---|
| 1 | 2008 | 26 |
| 2 | 2009 | 14 |
| 3 | 2010 | 33 |
| 4 | 2011 | 51 |
| 5 | 2012** | 43 |

* Source: Department of Meteorology, Sri Lanka
** Up to October 2012

#### 6.1.2.2 Secondary Impacts

The secondary effects of a direct or nearby strike include the bound charge, electromagnetic pulse, electrostatic pulse, and earth currents. The bound charge (and subsequent secondary arc) is the most common. The electrostatic and electromagnetic pulses induce high-voltage transients onto any conductors within their sphere of influence. These transients will cause arcing between wires, pipes and earth.

Again, arcs in the "right" place initiate both fires and explosions. The secondary effects are not always easily identified as to cause or mechanism. This mode of interruption of the lightning current cause less damages than a direct strike, yet service lines are subjected to lightning strikes much more frequently than buildings themselves.

The lightning current that flows from cloud-to ground is a good emitter of Electromagnetic (EM) radiations. Thus once a lightning flash hits a nearby object (say around 500m distance away) even the building is exposed to a strong portion of EM radiation. When this EM radiation passes through electronic equipments such as computers, medical equipments, military equipments etc. the sophisticated parts of them can be destroyed. In addition, the trend toward micro-miniaturization in electronic systems development brings an increasing sensitivity to transient phenomena. However, the probability of ordinary electrical equipments getting damaged due to such EM radiation is slight.

#### 6.1.2.3 Impacts on Power and Communication Lines

Power line voltage fluctuations and interruptions are the greatest source of destructive and disruptive phenomena that electrical and electronic equipment experience in day-to-day operations. Power and communication lines get affected by secondary effect of lightning. A direct strike to the power line at the service entrance can cause significant damage inside unprotected or improperly protected facilities. A facility adequately protected against lightning is also protected against other anomalies.

While the causes of power line anomalies may vary significantly with location, the results are the same. Either the equipment will fail immediately or degrade over a period of time. The failures may be catastrophic or some form of momentary or long-term lockup, requiring replacement, repair, reprogramming, or rerun of the program in progress. Any of these events can result in losses of time and money. All of these events can be totally eliminated with the appropriate power conditioning equipment, properly installed and maintained. Most of these events can be eliminated through the correct use of relatively inexpensive protection equipment.

### 6.1.3 Period of Occurrence

The weather experienced during a 12 month period in Sri Lanka can be categorized into four (4) seasons as follows.

i. First Inter Monsoon season March - April
ii. South West Monsoon season May - September
iii. Second Inter Monsoon season October- November
iv. North East Monsoon season December – February

Lightning activity over Sri Lanka is comparatively high during two Inter-monsoon periods, March-April and October-November. During these periods





convective clouds develop over most parts of the island, mostly during the afternoon or evening. The well-developed convective clouds produce thunderstorms. Thunderstorms are often associated with hazards such as lightning and sometimes with tornado. Special attention should be paid to two Inter-monsoon periods when consider the lightning hazards.

## 6.2 Scope of the Study

The scope of the present study consists of two major aspects namely; conducting awareness programs to general public based on the information gathered through this study and prepares lightning hazard maps for the relevant stakeholders to plan mitigation activities in potential hazard areas.

Mitigation of lightning hazards in Sri Lanka is mainly based on awareness of general public during last three decades. Awareness programmes (Kumarasinghe, 2008) for different categories of people have been launched by different institutes such as Department of Meteorology (DoM), Disaster Management Centre, Ministry of Science and Technological and various other state and non-governmental organizations over the past years. The DoM includes lightning warnings in their daily weather forecast when it is imminent. Even though the awareness programmes and warnings are relatively high in numbers as compared to the past, considerable number of victims due to lightning strikes is still reported. The information collected through this study will be utilized in awareness programs.

It is needed to identify vulnerable areas for lightning activities and reasons for the vulnerability to introduce mitigatory options in order to minimize the human and animal death toll and property damages. To fulfill this requirement, it is proposed to map high risk lightning areas in Sri Lanka. This will be helpful for current and future economic development planning such as resettlement programmes, industrialization and construction activities.

## 6.3 Methodology

The DoM Sri Lanka maintains 22 meteorological stations representing districts except Kegalle, Matara and Matale districts and collects information such as rainfall, temperature, pressure, thunder days .etc. Thunder days observed by 20 stations during the period of 30 year 1961 – 1990 are used for this study.

Generally lightning flash density (number of lightning strikes per year per square kilometer) shall be used in this type of studies (Jayarathne & Samaranayaka 1995), but due to unavailability of lightning flash counter network (Adegboyega & Odeyemi, 2012) and lightning detection instruments in Sri Lanka, the parameter 'thunder day"' is used in estimating the frequencies of lightning activity in a particular area.

Thunder day is defined as 'a calendar day during which thunder is heard at a given location'. The international definition of lightning activity is given as the number of thunder days per year. This is also called isokeraunic level.

Isokeraunic level is obtained by meteorological observers at different stations. The observer records a certain day as a "thunder day" if he or she hears thunder at least once on that day.

The ground flash density is an important parameter in lightning protection because risk evaluation in lightning protection procedures is based on this parameter. It is defined as the number of lightning flashes that strike a unit area in a given region in a year. Lightning flash density in different parts of the world can be calculated from satellite pictures. In this estimation it is difficult to separate ground and cloud flashes and therefore the total lightning-flash density in different regions of the world can be obtained. It is also not correct practice to provide contour maps of Isokeraunic level as such information is unrealistic unless a large number of observational points are placed in a grid-like structure of the region (Gomes & Kadir ,2011).

As Sri Lanka is not equipped with lightning flash counter network or a lightning detection system, thunder- heard day is the only reliable parameter which can be used in lightning related studies. Thunder day data (DoM, Sri Lanka) for the period of 1961-1990 is used for this study. The main parts concerned of the study are;

i. Lightning phenomena in Sri Lanka based on monthly behavior using thunder day data collected in 20 meteorological stations.
ii. Lightning phenomena in Sri Lanka based on yearly behavior using thunder day data collected in 20 meteorological stations.
iii. Include the study conducted by Abhayasingha (1986, 1998) on the pattern of lightning activity over Sri Lanka in time and areal scales during 1978-1985.
iv. Mapping of lightning hazard areas in Sri Lanka for 12 months using ArcGIS software. Point data constructed with latitude and longitudinal pairs were ingested into ArcGIS.
v. Develop composite annual map of lightning hazard areas in Sri Lanka.

## 6.4 Hazard Profile

The hazard profile developed under this study will provide information on the regions where the lightning occurs frequently and therefore the Department of Meteorology can warn and prescribe the precautionary measures to people to prevent from lightning hazard during heavy rains in such areas. Stakeholders also can use these maps as a tool to develop precautionary measures and to develop suitable mitigatory measures in the identified areas on short term and long term basis.

Both monthly and annual lightning hazard maps show the behavior of lightning activities in Sri Lanka. These maps offer more comprehensive information on lightning activities in an area or as district wise.

Lightning activities are shown in monthly charts clearly indicate that it is more during two inter monsoon periods, March-April and October –November and also showed that lightning activities are more in April in most parts of the country. It is seen that during each monsoon season (South West monsoon and North East monsoon), maximum lightning activity is confined to sector of Sri Lanka that lies opposite to the monsoon sector. Lightning activity during both inter monsoons seasons is fairly widespread with maximum activity occurring in parts with elevated lands witnessing the enhancement of Cumulonimbus clouds by orography. Generally, the annual lightning distribution is so that the peak activity is confined to southern part of the island with elevated land masses.
The results are in agreement with the previous study of identifying lightning prone areas in Sri Lanka (Abhayasingha 1998). Results obtained from this study, especially monthly and annual lightning hazard maps can be used for planning of outdoor activities. Potential areas can also be identified by using these maps and accordingly risk reduction and preparedness programmes can be organized.

### 6.4.1 Lightning Phenomena in Sri Lanka

#### 6.4.1.1 Monthly Behavior

Average thunder days in each month for a period of 30 years (1961 – 1990) were calculated and given in Table 6.2. Thunder day data was available only at 20 meteorological stations during the above period. Monthly behavior of lightning activity in Sri Lanka is shown in Fig, 6.2 and Fig. 6.3.

#### 6.4.1.2 Yearly Behavior

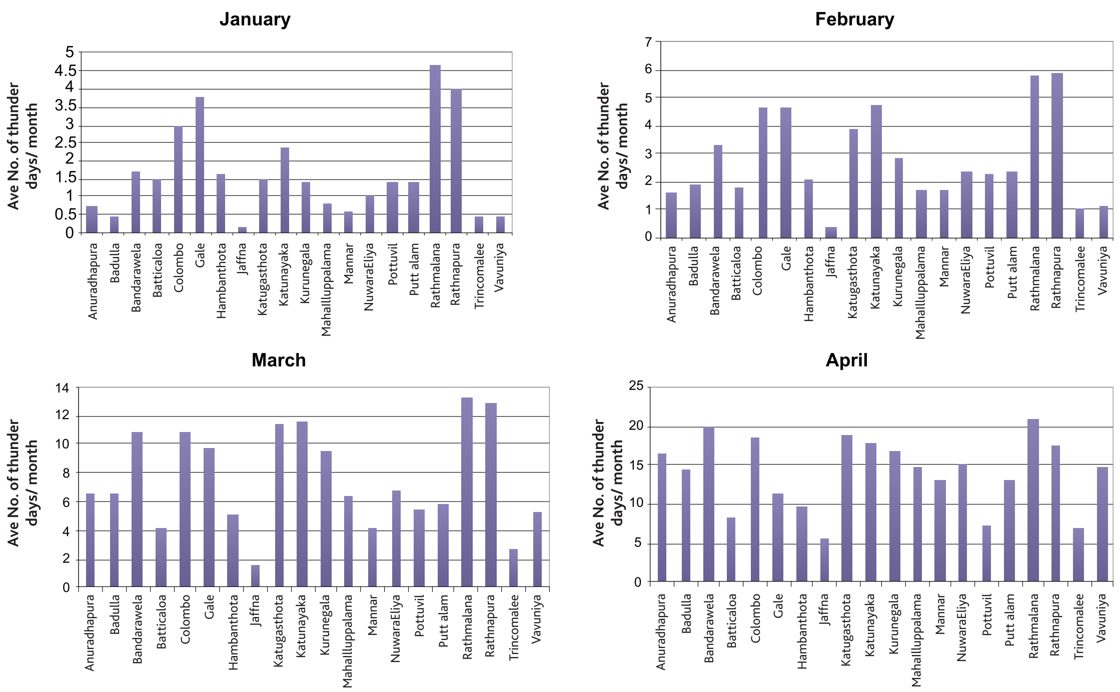
Average thunder days for a period of 30 years (1961 – 1990) were calculated and shown in Table 6.3. Yearly behavior (1961-1990) of lightning activity in Sri Lanka is shown in Fig. 6.4.

### 6.4.2 Lightning Activity in Sri Lanka During a Thunder Day

Mr. K. R. Abhayasingha Bandara, former Director of Meteorology carried out a study to verify the behavior of lightning activity on a thunder day. Eight (8) years data were used during the period of 1978-

Table 6.2 Monthly average thunder days during 1961 - 1990

| No. | Station | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Anuradhapura | 0.7 | 1.6 | 6.5 | 16.4 | 6.8 | 0.7 | 2.6 | 3.1 | 5.1 | 11.5 | 7.3 | 1.8 |
| 2 | Badulla | 0.5 | 1.8 | 6.6 | 14.6 | 10.4 | 4.3 | 6.8 | 7.7 | 9.5 | 11.6 | 6.5 | 2 |
| 3 | Bandarawela | 1.7 | 3.3 | 10.8 | 19.7 | 13.5 | 4.8 | 6.9 | 7.3 | 10.7 | 14.8 | 11 | 4 |
| 4 | Batticaloa | 1.5 | 1.7 | 4.1 | 8.1 | 8.6 | 4.4 | 6.2 | 6.7 | 8.8 | 10.9 | 6.7 | 2.4 |
| 5 | Colombo | 3 | 4.6 | 10.9 | 18.3 | 11 | 3.6 | 2.4 | 2.1 | 3.2 | 9.4 | 10.9 | 7.9 |
| 6 | Galle | 3.7 | 4.6 | 9.7 | 11.2 | 6.3 | 1.7 | 0.9 | 0.6 | 1 | 4.2 | 7.3 | 7.1 |
| 7 | Hambanthota | 1.6 | 2 | 5 | 9.7 | 4.9 | 1.4 | 1.4 | 1.1 | 2 | 7.2 | 7.4 | 4 |
| 8 | Jaffna | 0.2 | 0.4 | 1.5 | 5.5 | 3.7 | 0.7 | 1.2 | 2 | 2.8 | 6.1 | 4 | 1.6 |
| 9 | Katugasthota | 1.5 | 3.9 | 11.4 | 18.8 | 10.8 | 3 | 3.8 | 3.5 | 5.9 | 13.1 | 10.8 | 4.6 |
| 10 | Katunayaka | 2.4 | 4.7 | 11.6 | 17.8 | 11.6 | 4 | 2.6 | 2.2 | 3.2 | 10.2 | 11.3 | 6.5 |
| 11 | Kurunegala | 1.4 | 2.9 | 9.5 | 16.6 | 9.4 | 2.6 | 2.1 | 2.4 | 4.6 | 10.3 | 8.3 | 3.3 |
| 12 | Mahallluppallama | 0.8 | 1.6 | 6.3 | 14.8 | 5.9 | 0.5 | 2.5 | 2.4 | 4.6 | 10.8 | 7.8 | 2.7 |
| 13 | Mannar | 0.6 | 1.7 | 4.2 | 12.9 | 4.8 | 0.4 | 1 | 1.3 | 2.6 | 8 | 6.9 | 2.2 |
| 14 | NuwaraEliya | 1 | 2.4 | 6.7 | 15.1 | 9.3 | 2.5 | 3.2 | 4.1 | 6.2 | 9.1 | 4.8 | 1.7 |
| 15 | Pottuvil | 1.4 | 2.3 | 5.4 | 7.4 | 6.7 | 3.6 | 5.9 | 6.8 | 6.5 | 10 | 8 | 2.2 |
| 16 | Puttalam | 1.4 | 2.3 | 5.7 | 12.9 | 6 | 0.7 | 1.3 | 0.9 | 1.9 | 8.8 | 9 | 3.5 |
| 17 | Rathmalana | 4.6 | 5.8 | 13.3 | 20.8 | 13.2 | 5.1 | 2.8 | 2.7 | 3.7 | 10.4 | 13.3 | 10.1 |
| 18 | Rathnapura | 4 | 5.9 | 12.8 | 17.6 | 10.7 | 3.1 | 2.2 | 1.8 | 3.3 | 8.9 | 9.8 | 6.9 |
| 19 | Trincomalee | 0.4 | 1 | 2.6 | 7 | 7.3 | 2 | 4.5 | 5.9 | 8.3 | 8.7 | 4.9 | 1.8 |
| 20 | Vavuniya | 0.4 | 1.1 | 5.3 | 14.6 | 7.5 | 1.2 | 4 | 4.9 | 6.9 | 10.1 | 4.9 | 1.3 |







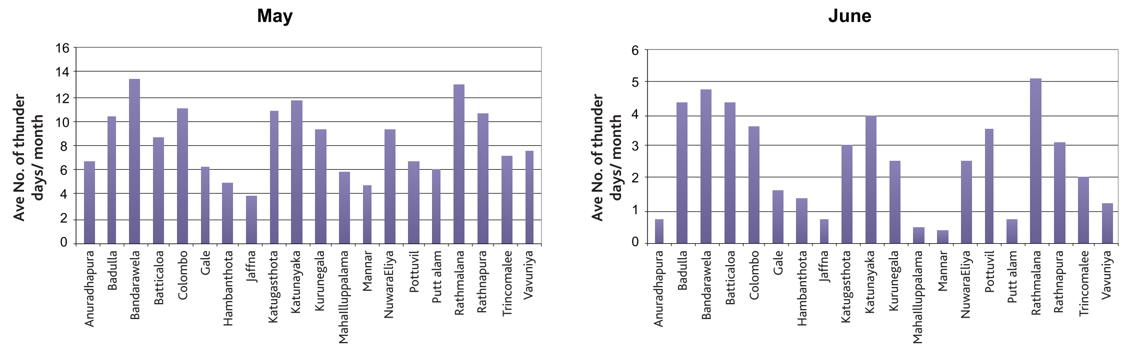




Fig. 6.2 Monthly behavior of lightning phenomina in Sri Lanka January –June (1961-1990)

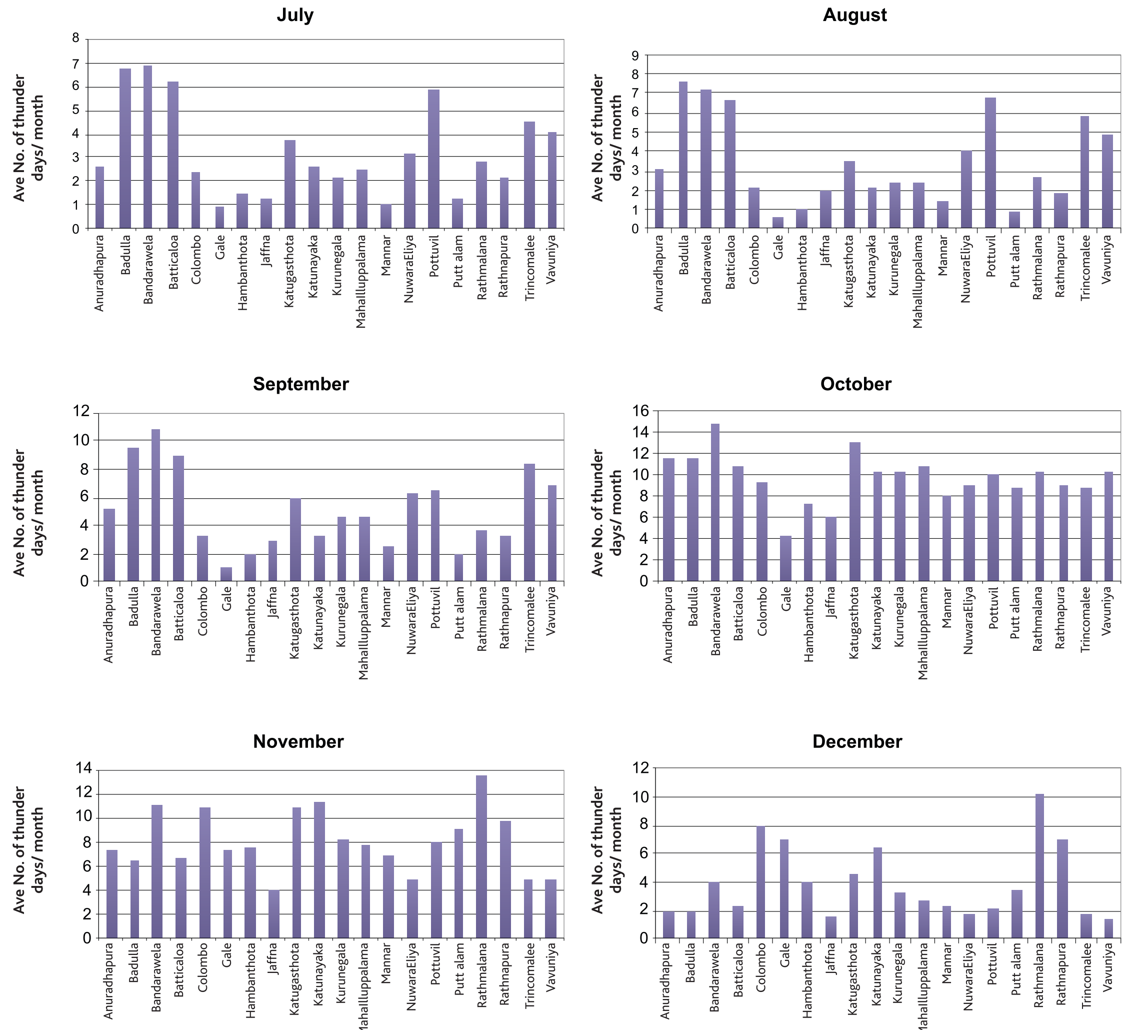



Fig. 6.3 Monthly behavior of lightning phenomina in Sri Lanka July- December(1961-1990)

*Table 6.3* Average thunder day data 1961 - 1990

| Month | Jan | Feb | Mar | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Thunder Days | 1.67 | 2.85 | 7.57 | 14.07 | 8.50 | 2.53 | 3.27 | 3.51 | 5.08 | 9.78 | 8.11 | 3.93 |

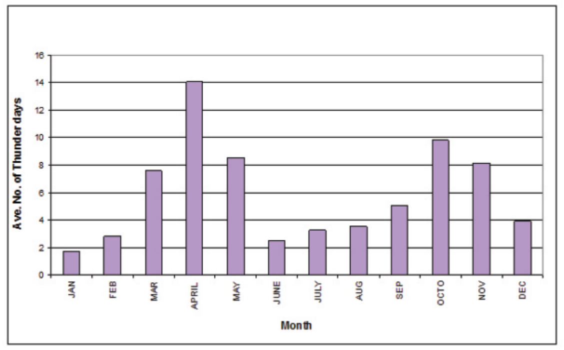



*Fig. 6.4* Yearly behavior of lightning phenomena based on average thunder day data (1961-1990)

1985. Half hourly thunder day observations were done during this period. Percentage of thunder activities were recorded in 20 meteorological stations every half an hour. Hourly distribution of lightning activity over Sri Lanka is shown in Fig. 6.5.

### 6.4.3 Hazard Maps

Two types of hazard maps were prepared under this study namely; maps illustrating monthly variations in lightning and generalized average annual thunder frequency hazard map for Sri Lanka.

#### 6.4.3.1 Monthly Lightning Hazard Maps in Sri Lanka

It is worth mapping the monthly behavior of the lightning phenomena in Sri Lanka. Higher the lightning activity the probability of lightning hazard is significant. These maps can easily identify the spatial distribution of lightning hazards in the country. These maps are shown in Fig 6.6 and Fig. 6.7.

#### 6.4.3.2 Annual Thunder Frequency Hazard Map

Spatial distribution of lightning phenomena is shown in Fig. 6.8. This will help to get an overall picture of lightning activities in the country. These hazard maps can be used for disaster mitigation activities in the country.

## 6.5 Conclusions

It is clearly showed as expected; lightning activities are higher during the months of March – April and October – November which is Inter monsoon periods. Month of April has significant amount of lightning activities in most parts of the island compare to other months. During the month of April Inter Tropical Convergence Zone (ITCZ), the zone where northern and southern hemispheric winds meet together, is over the Sri Lankan latitudes and therefore more convection occur and ultimately more lightning activities are experienced.

Analyzing monthly lightning hazard maps, it is noticed that more lightning activities



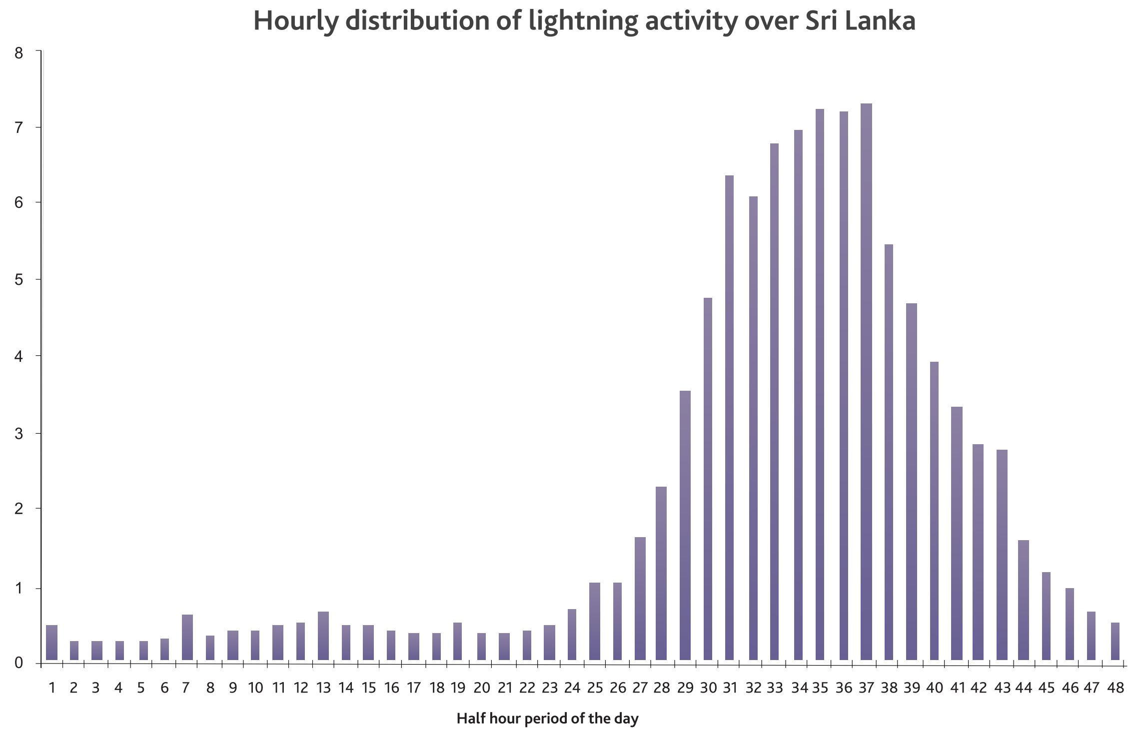



*Fig. 6.5* Lightning activity during a thunder day

are likely occur in South Western and North Western parts of the island. This can be further confirmed by more comprehensive studies with more accurate spatially distributed lightning data. Results obtained in this study can be used as guidance in lightning disaster management in Sri Lanka.

The probability of lightning occurrence is high during 2 -7 p.m. in a day (Abhyasingha 1986, 1998).

## 6.6 Recommendations

The hazard profile developed under this study provides information on the periods of the year during which the lightning hazards have frequently occurred and the potential hazard areas of the country through maps. Therefore the responsible authorities could use this information and the maps to forecast the hazard potential areas to people during severe rainy seasons to follow preventive measures to protect from this hazard and to avoid damages to their properties in such areas. Also the DoM can use this information to use in awareness programs to people to give details on the potential lightning hazard areas and give suitable instructions to prevent from lightning.

The following suggestions are recommended to improve the quality of lightning data and accuracy of spatial distribution of lightning activities in Sri Lanka.

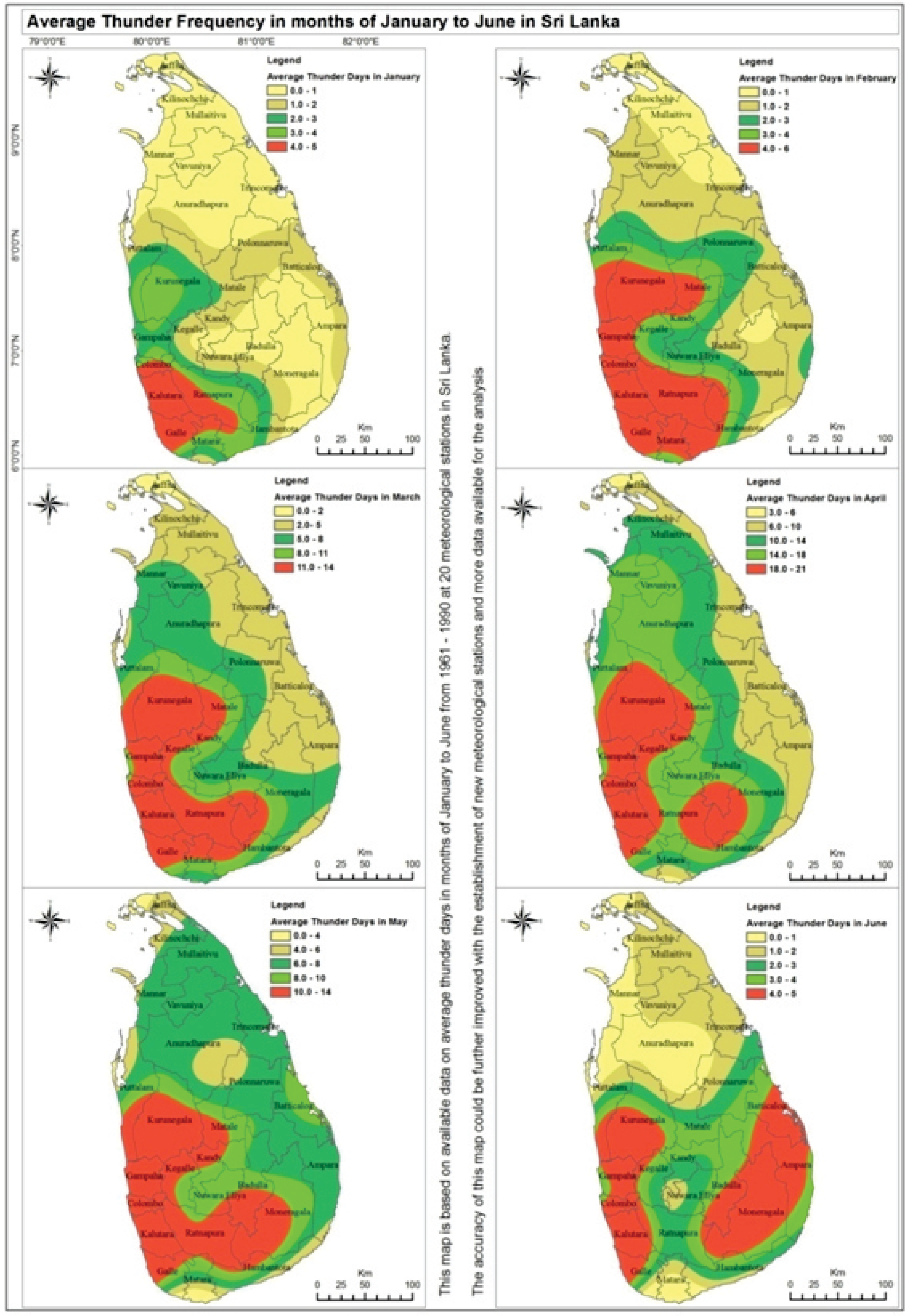



*Fig. 6.6 Monthly lightning hazard maps in Sri Lanka (January – June)*





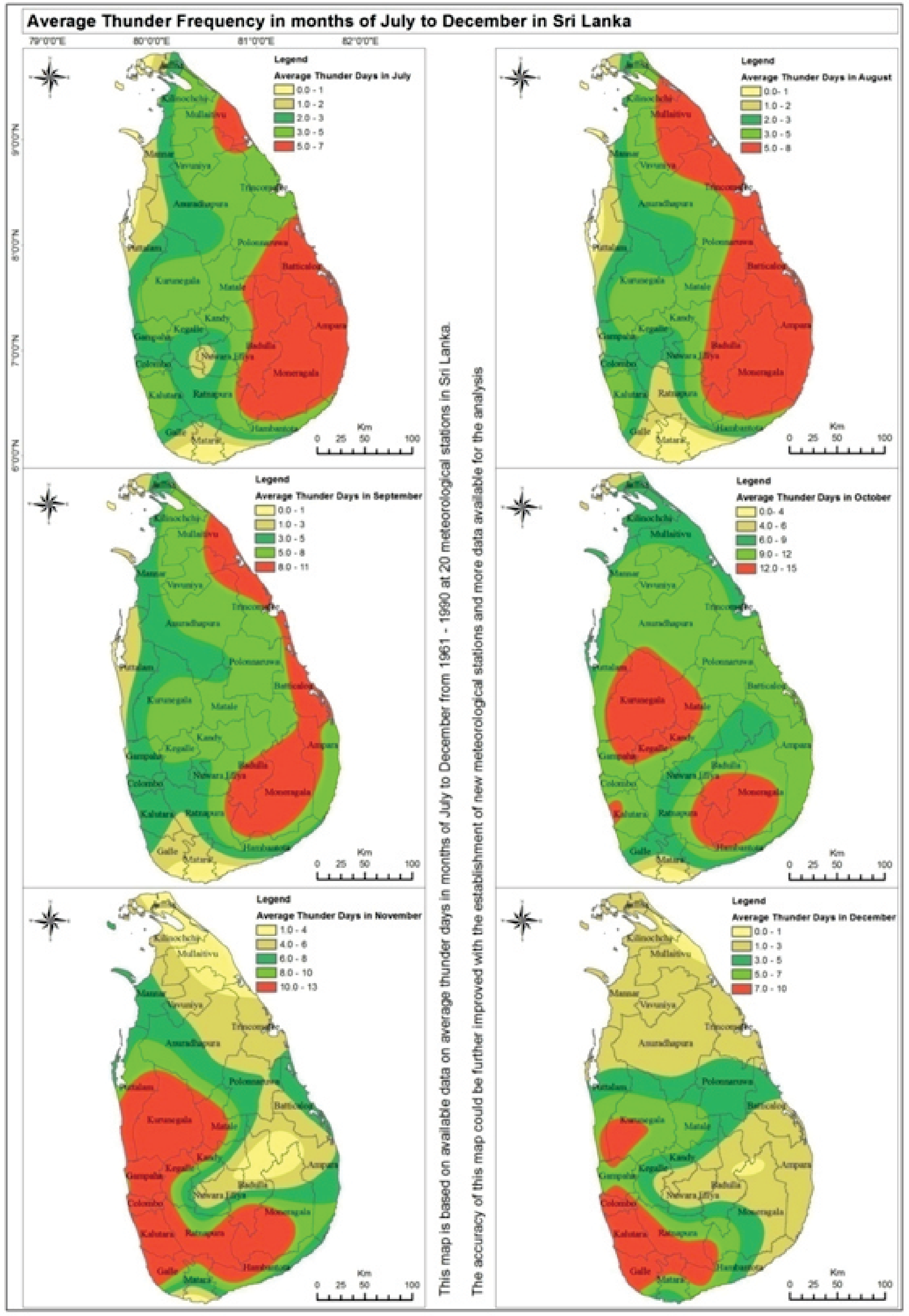



*Fig. 6.7 Monthly Lightning Hazard Maps In Sri Lanka (July – December)*

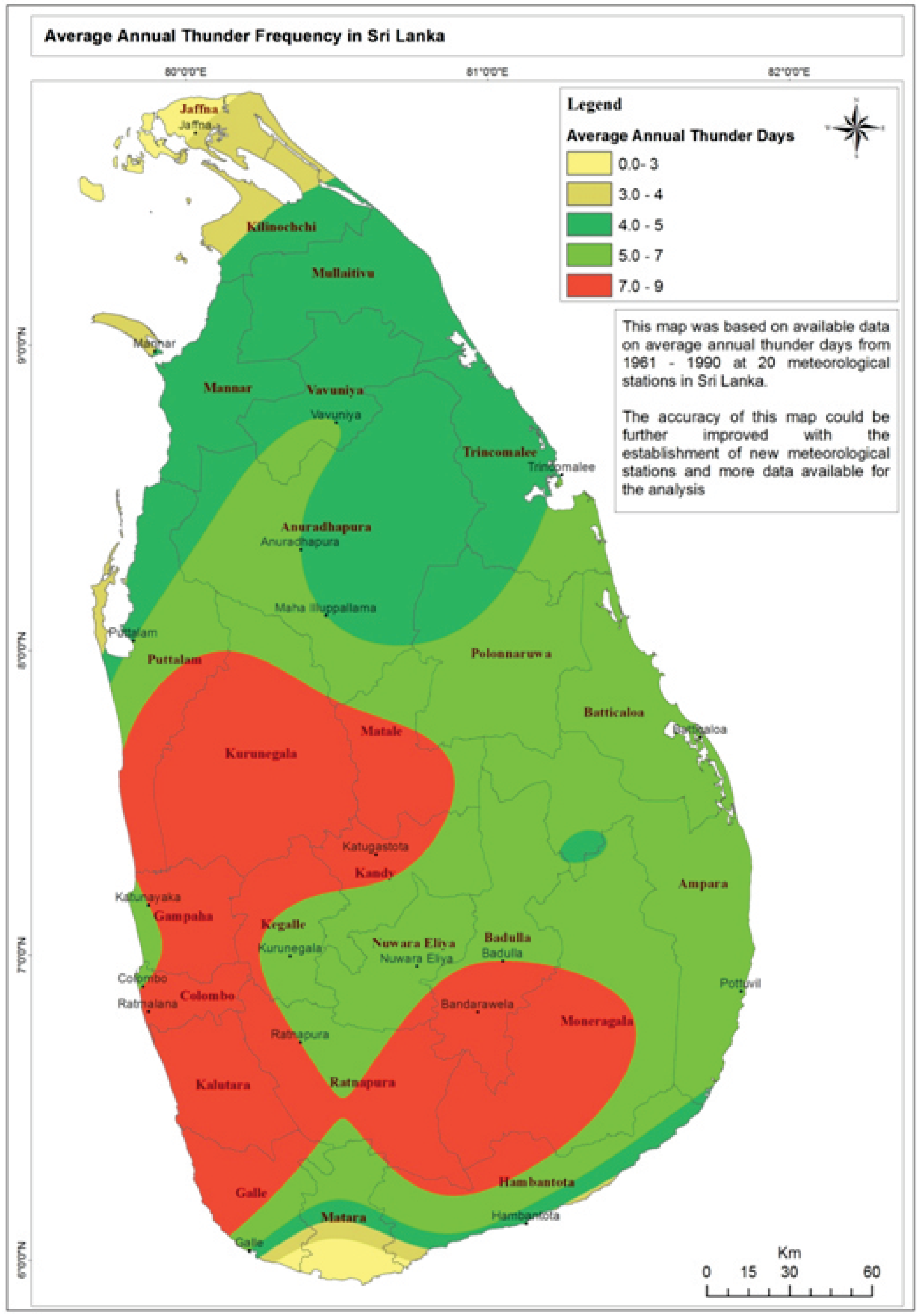



*Fig. 6.8* *Annual thunder frequency map of Sri Lanka*

## 6.7 Limitations

Lightning ground flash density, which is number of cloud-to-ground flashes in km-2 yr-1 is the key parameter in lightning related studies. It is necessary to have network of lightning flash counters and/or lightning detection systems to obtain the number of lightning flashes in the area concerned. Only an estimation of lightning flash density can be done as thunder heard day is used for this study. Therefore accurate data on number of lightning flashes are not included in this study.

The accuracy on the spatial distribution is limited due to the observation of thunder day data only at 20 meteorological stations. The quality and accuracy of the data entirely depends on the experience and effectiveness of the observer. More data points in smaller areas are required to improve the accuracy of the maps because thunder is usually not well heard at distances more than about 20 kilometers from the occurrence of lightning.

i. Establish lightning flash counter network and lightning detection system in Sri Lanka at least with four lightning sensors.

ii. Conduct lightning studies to collect lightning data (thunder day) with more locations in the country.

iii. Study and analyze weekly lightning data to generate high resolution lightning calendar.

iv. Conduct island wide survey to collect past lightning incidents in the country and together with past media reports, vulnerability maps can be developed.

v. Study soil structure of the lightning prone areas.

vi. Investigate the increasing (or decreasing) tendency of lightning activity over the island.

vii. Use available satellite data to study the vertical profile of the thunder clouds.

## 6.8 References

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