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GIS-Based Situational Analysis of Cutaneous Leishmaniasis Disease (CLD) in Sri Lanka

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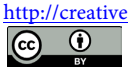

Abstract

Cutaneous Leishmaniasis (CL) is a severe health problem and a parasitic disease on human dermal and widely pervades tropical and subtropical developing counties. The study is mainly focused on Geographic Information System (GIS) based Situational Analysis (SA). The clinically recorded 394 CL patients' information was obtained from the District General Hospital of Polonnaruwa (DGHP) for 2017 and 2018. The spatial distribution of these patients was collected using Global Positing System (GPS). Moran's I Index spatial autocorrelation technique and Getis-Ord Gi were used to identify the study site's hot spot and cold spot areas. More than 75% of the CL patients' population were highly involved with agricultural activities, and they are the highly exposed group of the CL in the study area. Also, 75% of the CL population were men, and the highly vulnerable age group was 35 - 39 men and 40 - 44 women. The generated Moran's I Index indicates 0.0321, representing a randomly distributed pattern of CL patients over the District, and the **Getis-Ord Gi** Z Score value was >1.96 ($p < 0.05$). It is revealed that, during and in the post-harvesting periods of paddy cultivation, farmers are highly exposed to sandflies becoming CL patients. Due to this situation, the researchers observed that the highest number of patients have reported in May of both years and the infection period is two to four weeks earlier than the reported month. Hence to prevent the disease spread, it is essential to implement an awareness program regarding sandflies' behaviour and CLD.

Keywords

Sandflies Disease, Geoinformatics Techniques, Environmental Factors, Dry Zone

1. Introduction

Leishmaniasis is a global vector-borne disease affecting 88 countries from almost every continent, and more than 15 million people were estimated as already infected (Ostad et al., 2016). There are three primary forms of Leishmaniasis, namely, Visceral Leishmaniasis (VL), Cutaneous Leishmaniasis (CL), and Muco-Cutaneous Leishmaniasis (MCL) (Wijerathna et al., 2017). WHO (2020) revealed an estimation that 0.7 to 1 million new cases of Leishmaniasis occur annually. The disease became a global threat because it forced high risk over military operations, international mobility, and its coexistence with HIV (Wijesundera, 2001). Also, changes in the natural environment, like urbanization, make Leishmaniasis an emerging public health concern (Galgamuwa et al., 2018). Ostad et al. (2016) explained, Leishmaniasis is now considered a severe public health problem in developing countries.

In Sri Lanka, Leishmaniasis was an exotic disease before 1992 (Nawaratna et al., 2007). The first case of locally acquired Leishmaniasis (CL form) on the island was reported in 1992 (Athukorale et al., 1992). Since then, CL cases reported from different areas of the Dry Climatic Zone (DCZ) with an annual increase (Wijerathna et al., 2018). From 2009 to 2016, nearly 8487 new Leishmaniasis patients have been recorded (at least one case from one District out of 25 districts), and districts of Matara, Kurunegala, Anuradhapura, Polonnaruwa, and Hambantota of Sri Lanka have been identified as the endemic areas for the disease (Wijerathna et al., 2018). CL became the prominent Leishmaniasis form on the island than the other forms (Galgamuwa et al., 2018). Siriwardana et al. (2012) explained, with this situation, Sri Lanka has become the newly appeared cynosure for Leishmaniasis in the Indian subcontinent (**Figure 1**). In 2008, in collaboration with the Ministry of Health, other government and non-government stakeholders set an action plan to control Leishmaniasis in the country (Siriwardana et al., 2012).

Bergquist, 2006 (cited by Amoli, 2011) revealed that the geographical distribution of parasitic diseases and their vectors through cartographic representation has bloomed in the past 15 - 20 years. Hence, Geographical Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS) have become essential tools for disease mapping (Iliopoulou et al., 2018; Amoli, 2011). Palaniyandi et al. (2014) clearly explained the use of GIS and RS to predict vector-borne diseases. Likewise, many scholars used GIS as a tool for spatial analysis of Leishmaniasis (Abedi-Astaneh et al., 2016; King et al., 2004; Ostad et al., 2016; Amoli, 2011; Tsokana et al., 2016). It reveals that GIS has become a more robust and efficient tool to investigate spatial and temporal patterns of Leishmaniasis.

When focused on the current situation of Leishmaniasis in Sri Lanka, there is a need to conduct a GIS-based SA. It will provide a more advanced situation to identify its spatial and temporally dynamic patterns. Hence, this study has selected the District of Polonnaruwa to continue the GIS-based SA, depending on

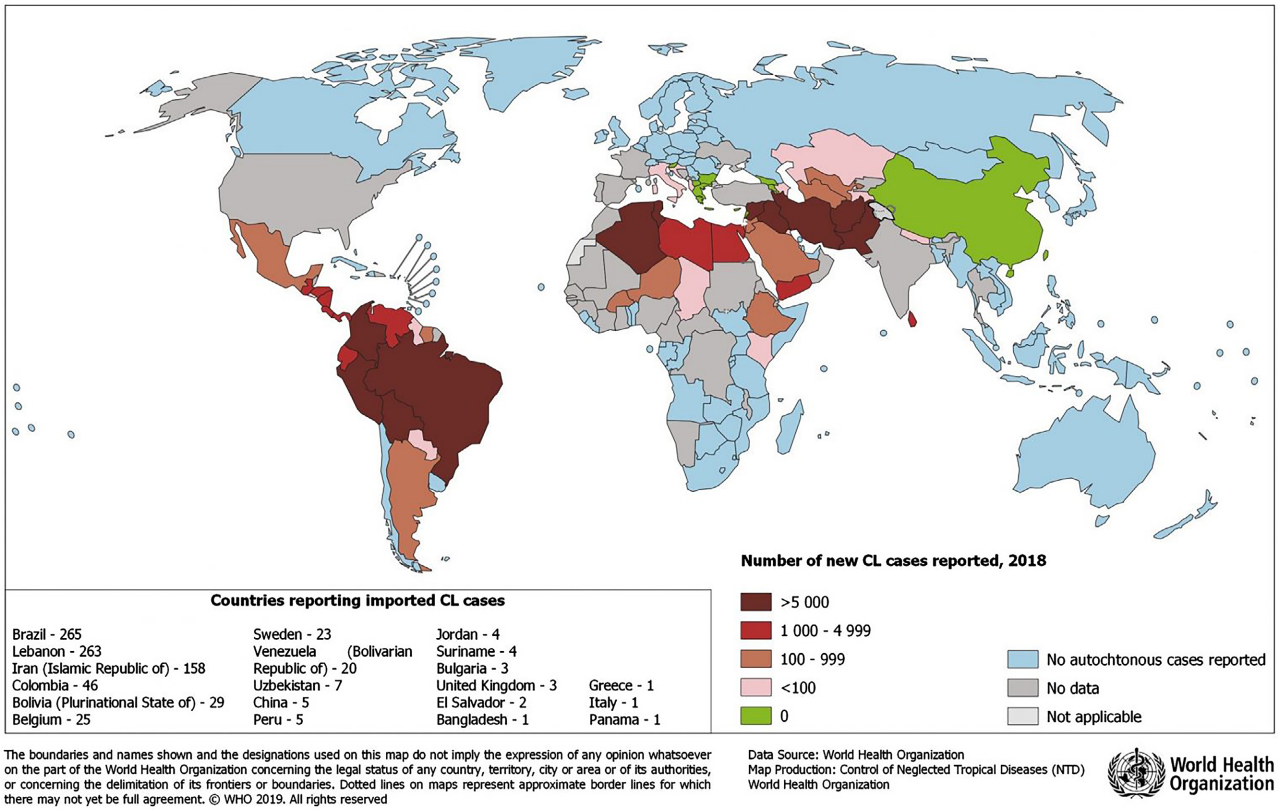

Figure 1. Number of new CL cases reported in 2018 (Source: WHO, 2018).

prominent patients' records on the island (Galgamuwa et al., 2018; Karunaweera et al., 2020).

When considering the Leishmaniasis situation in the Polonnaruwa district, there is a sharp increase from 2009 to 2016. Records of Leishmaniasis have quadrupled (34 patients in 2009 and 136 patients in 2016) in this period (Galgamuwa et al., 2018). Also, clinical information was available for three hundred and ninety-four (394) patients reported in 2017-2018 (DGHP). The mean annual incidents of Leishmaniasis between 2016 and 2018 for the District were 176 (DGHP). The case incidence gradually increased during 2017—191 patients and 2018—203 patients (DGHP). Accordingly, this study covers GIS-based Leishmaniasis SA for Polonnaruwa District by investigating the following specific objectives. 1) Identify the demographic characteristic of the CL patients, 2) Identify the spatial pattern of CL disease using hot spot and cold spot analysis, and 3) observe the interrelationship of environmental factors and patients' distribution. Hence, this study will create a background to identify the possible ways to overcome this disease becoming endemic to the country.

2. Material and Methods

2.1. Study Area

The study area of Polonnaruwa District (**Figure 2**) is situated in the DCZ of Sri Lanka. Hence the District experiences 28˚C - 32˚C as the mean annual temperature

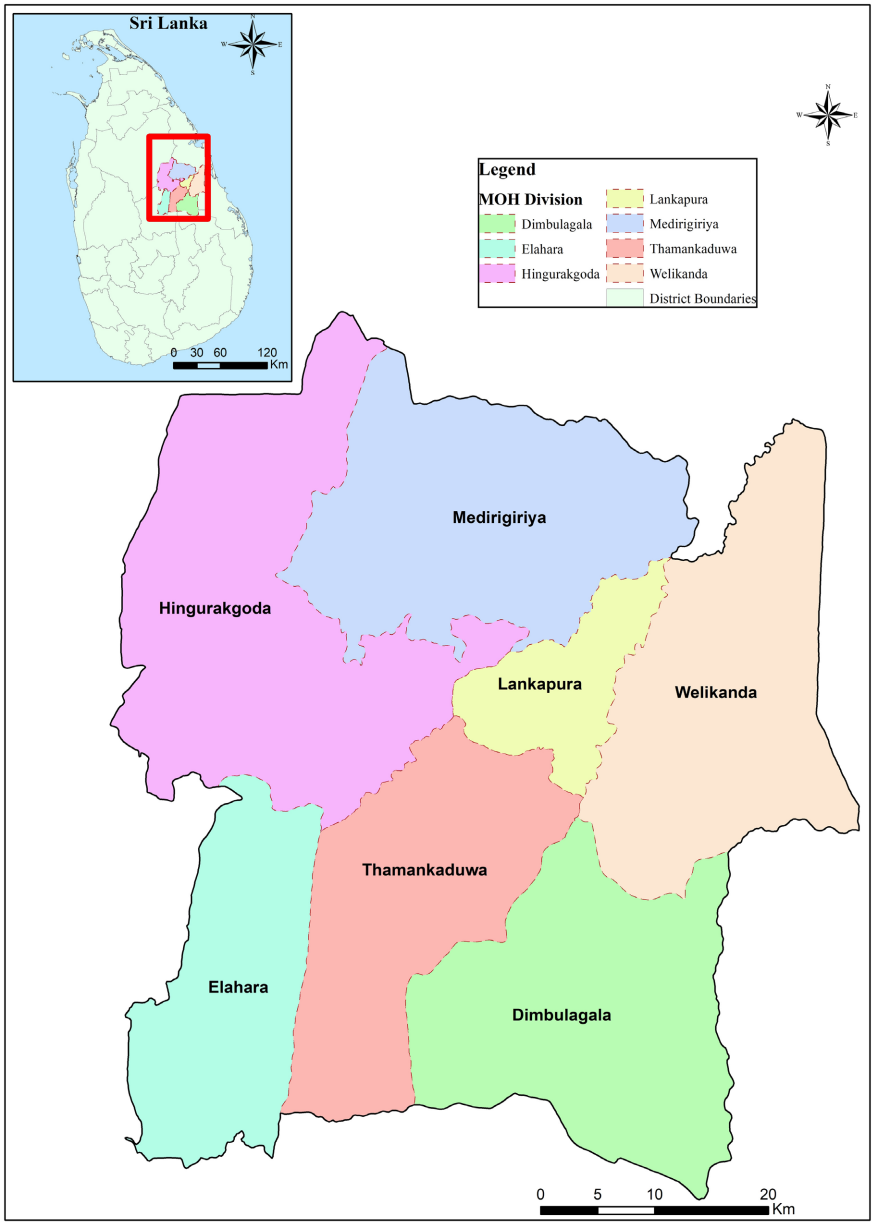

Figure 2. Location of the study area. Source: Epidemiology unit of DGHP, 2018.

and receives 1200 - 1800 mm rainfall throughout the year (Department of Meteorology, 2018). The District inherits 3293 km^2 (329,300 ha) land area with a population of just above 415,000 (by 2017, Department of Census and Statistics). In the 2010-2019 period, Polonnaruruwa District reserves 111410.3 ha as a persistent forest (Ranagalage et al., 2020). The District has rich ancient and modern irrigations schemes to distribute sufficient water supply for cultivation purposes and human needs (Piyadasa & Achala, 2020).

The District of Polonnaruwa has 07 Medical Officer of Health (MOH) areas. Those are Thamankaduwa, Hingurakgoda, Dimbulagala, Medirigiriya, Welikanda, Lankapura, and Elahara (Department of Health, 2018). DGHP is the only hospital with a dermatology clinic in this District, and any suspected case of Leish-

maniasis is referred to DGHP and treated by the dermatologist.

2.2. Data

The study sample included all the clinically recorded cases (394) of CL from 1st January 2017 to 31st December 2018, residing in Polonnaruwa District. These included cases reported to the Regional Epidemiologist of the Polonnaruwa District and all the confirmed cases register at the dermatology clinic of DGHP. Also, patients' locations identified using GPS with the support of the Public Health Inspector (PHI) in the District. The spatial data collected from the Department of Survey and necessary rainfall and temperature data obtained from the Department of Meteorology in Sri Lanka.

2.3. Methodology

Clarke, 2005 (cited by Pérez & Cannella, 2013) explained the importance of SA as a research method to illustrate patterns and positions of surrounding complex social situations as they change. Hence, the study used the SA method (**Figure 3**) with the help of GIS to identify the disease's spatial and temporal patterns.

Hot spot analysis is one of the widely used spatiotemporal analysis methods in GIS. It uses to identify the spatial phenomenon clusters depending on the points in a map and relate to events and objects' locations. Chakravorty (1995) explained that hot spot analysis progressed to detect the arrangement of point patterns in a space. Accordingly, this study analyzed CL hot spot and cold spot analysis with the collected patient data for 2017 and 2018. With the help of ArcGIS 10.4, the study integrated the points (patients' distribution) to collect the events of the CL layer. After that, Moran's I spatial autocorrelation, available in ArcGIS, was applied to the events layer for clustering the CL patients. The Moran's I index ranging from −1 to +1, where "positive values cannot a cluster of similar values around the target feature, zero shows spatial randomness of data, and negative values mean non-similar features surround a feature" (Abedi-Astaneh et al., 2016).

Following Moran's autocorrelation, 0.75 km distance (The travel radius of CLD Sand Fly, Orshan et al., 2016) band was chosen for hot spot analysis to indicate the clustering pattern of CL data. The study used the Optimized Hotspot Analysis tool of ArcGIS, which determines Getis-Ord Gi spatial statistics (Karunaweera et al., 2020) to decide those areas with high and low CL spatially. The study determined the hot and cold spots, respectively, depending on positive z-scores and negative z-scores. All the CL clusters' hot and cold spots significantly identified with 90%, 95%, and 99% confidence levels (**Figure 8**). After preparing the hot spot layer, the study created an Inverse Distance Weighted (IDW) layer, which can derive numerous tendencies of a density in an area using interpolation and visualize a different colour continuum (Mokhtari et al., 2016).

Galgamuwa et al. (2018) and Ranasinghe et al. (2013) indicated a significant trend in the male age group in 18 - 40 is highly vulnerable to CL. Accordingly,

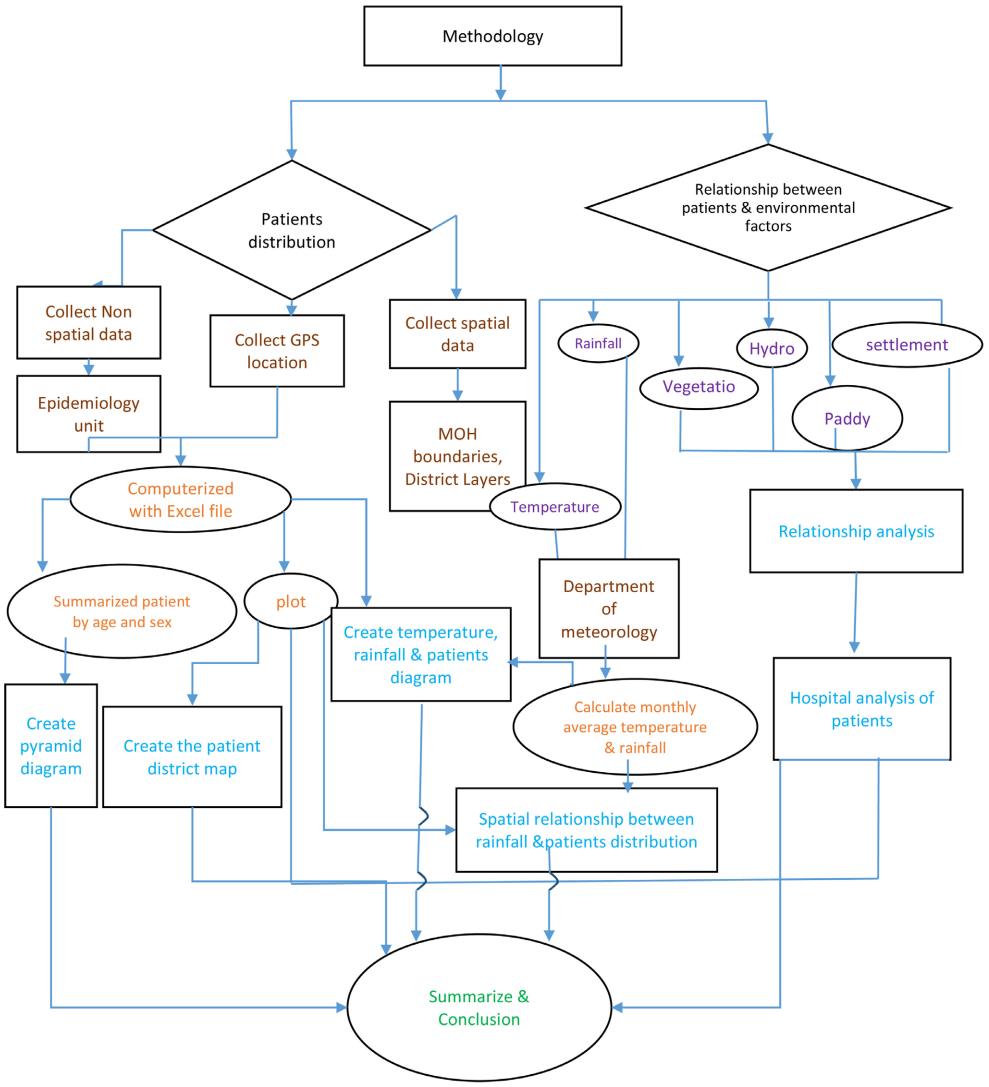

Figure 3. Flow chart of situation analysis.

this study tried to identify whether there is a similar trend in the CL population group. Environmental factors such as rainfall, temperature, vegetation, hydro, and settlement data have considered the relationship between CL distribution and the study area's environmental factors.

3. Results

During the considered period from 2017 to 2018, 394 (respectively 191 and 203 patients) confirmed CL patients reported from the Polonnaruwa District. According to **Figure 4**, the highest incidences recorded in three MOH areas: Thamankaduwa, Hingurakgoda, and Elahera. Thamankaduwa MOH area had a mean annual incidence of 51.5. Even though the Thamankaduwa MOH area aligned with Dimbulagala and Welikanda MOH areas, they decreased CL patients in 2018. Significantly, the Welikanda MOH area had reported only one CL record in 2018.

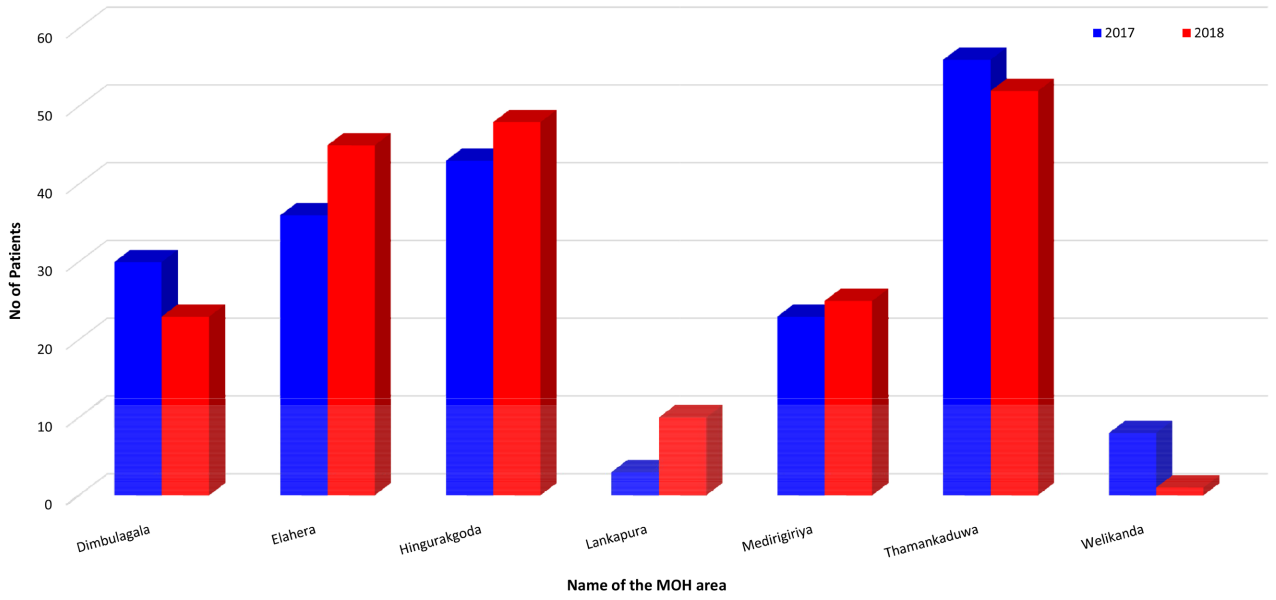

Figure 4. CL patient in 2017 and 2018. Source: DGHP.

Collected GPS points were plotted on the district map to detect the spatial pattern of CL patients. It was an irregular trend pattern over the District (Figure 5). In both years, most CL cases located in the Southeast, Southwest, and Central parts of the Polonnaruwa District. Especially in 2018, the Elahera MOH area shows a significant increase in patient distribution. Also, new CL cases were arising in far North and South Western margins of the Hingurakgoda MOH area in 2018. When focused on Welikanda MOH area, there is a remarkable decrease in 2018 (One patient) than in 2017 (Five Patients).

After detecting the spatial distribution of CL cases, the study attempted to examine the CL population furthermore. Also, the study revealed that there is a significant relationship between age and gender in the area. Below, Figure 6 shows the reported patients' information by age and sex.

Figure 6 clearly illustrates, there were male patients than females in the considered period. When considering the age, men who belong to the age group of 35 - 39 and women in the 40 - 44 age group are highly vulnerable to CL disease. Regardless of sex, most CL patients in this population belong to the (aged 20 - 60) labour force (75% were male patients).

Hot spot and cold spot analysis to detect CL distribution over the District

The study has generated spatial autocorrelation (Moran's I Index) for 2017 and 2018 separately (Table 1).

The Moran's I Index value for both the years concentrated around Zero (0). It denoted that in both the year's CL distribution in the District was a random pattern. Also, given z-scores indicated that the pattern does not appear to be significantly different than random. However, the Index value becoming positive in 2018. Accordingly, the study generated a single Moran's I Index to get a better idea about the distribution of both years. The results indicate that the cluster

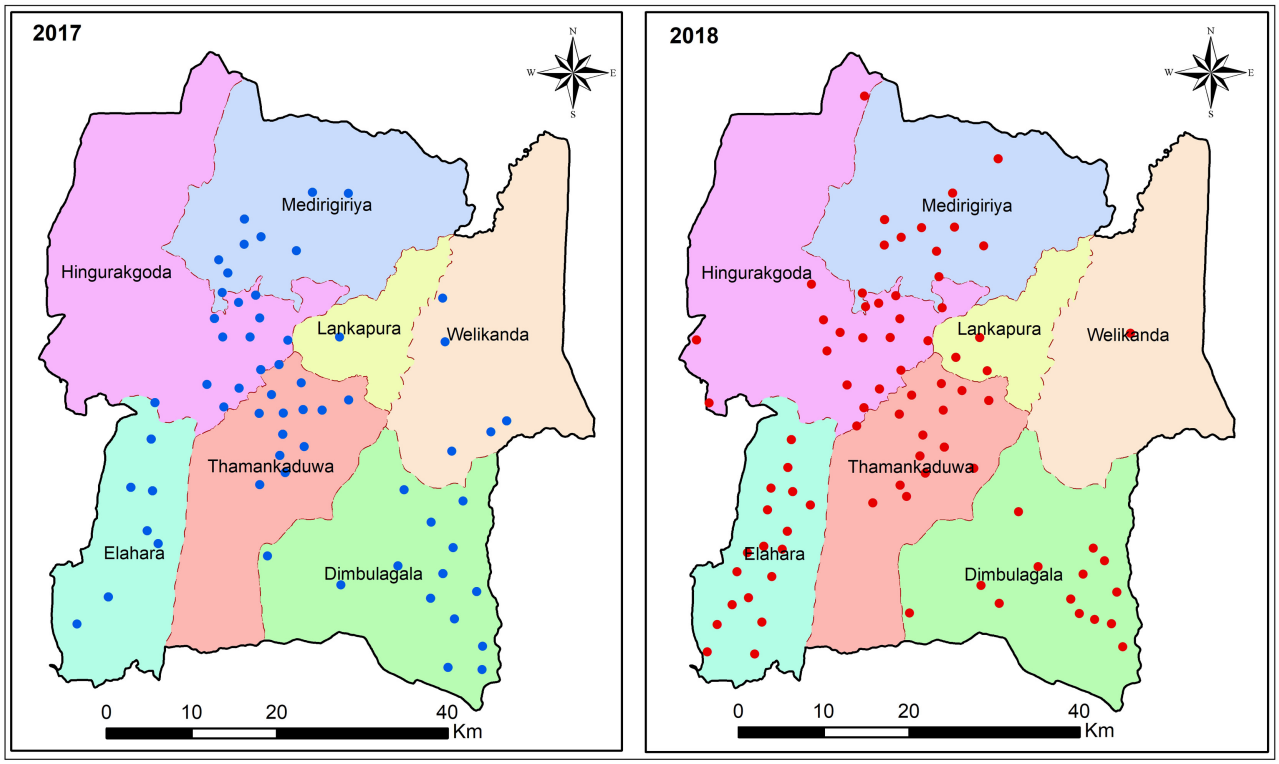

Figure 5. Spatial distribution of CL patients in MOH areas, year 2017 and 2018.

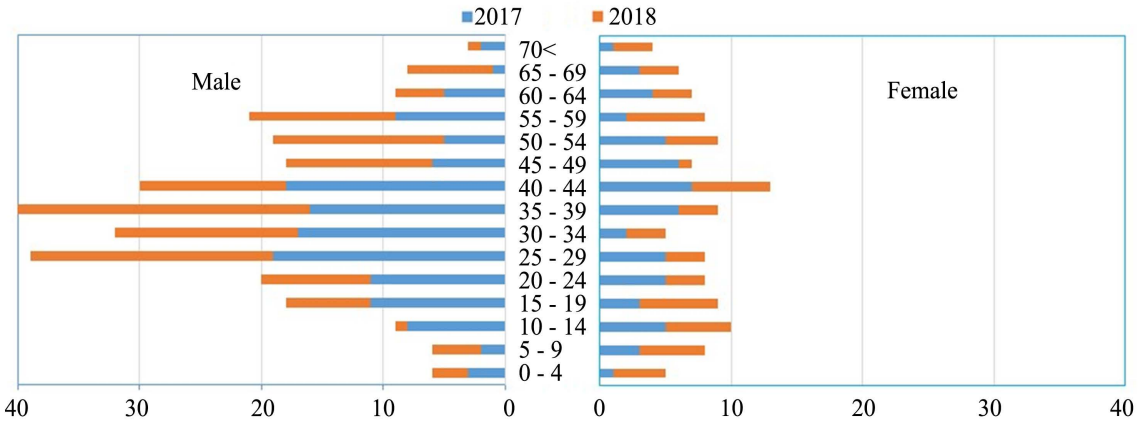

Figure 6. Age and sex composition of CL patients. Source: Epidemiology unit of DGHP.

Table 1. Generated Moran's I index value.

	2017	2018
Moran's I Index	−0.038157	0.005006
z-score	−0.790879	0.844252
***p*-value**	0.429015	0.398529

value is 0.0321, which is a randomly distributed CL patient pattern. Also, depending on the z-score of Moran's I Index, we can predict the CL patients' dis-

tribution pattern. Chang, 2008; Zhai et al., 2014 (cited by Fallahzadeh et al., 2018) explained, in Moran's I Index, when the z-score value is less than −1.65 denotes dispersed distribution, the value between −1.65 to +1.65 denotes random distribution, and the value more excellent than +1.65 denotes cluster distribution. Accordingly, the z-score computed for this dataset was 1.38625. At a 95% confidence level, it proved that this CL distribution in Polonnaruwa District was randomly distributed.

Hot spot and cold spot analysis are some of the most suitable analyses illustrating the spatiotemporal phenomenon in terrestrial space. Therefore, the study generated hot spot and cold spot values for the GPS location values for CL patients. After that, to determine the spatial pattern of the hot spot and cold spot values, the IDW method was used. Consequently, **Figure 7** shows hot spot and cold spot CL patients' distribution in the District.

It illustrated that the most infected areas are prominent in the central and western parts of the District in the considered years. The number of cases was higher in the central part where agricultural activities (paddy and home garden) are high. The red clusters of **Figure 7** show Getis-Ord Gi Z Score > 1.96 (p < 0.05). Comparatively, the eastern part of the District is minimum with CL patient distribution.

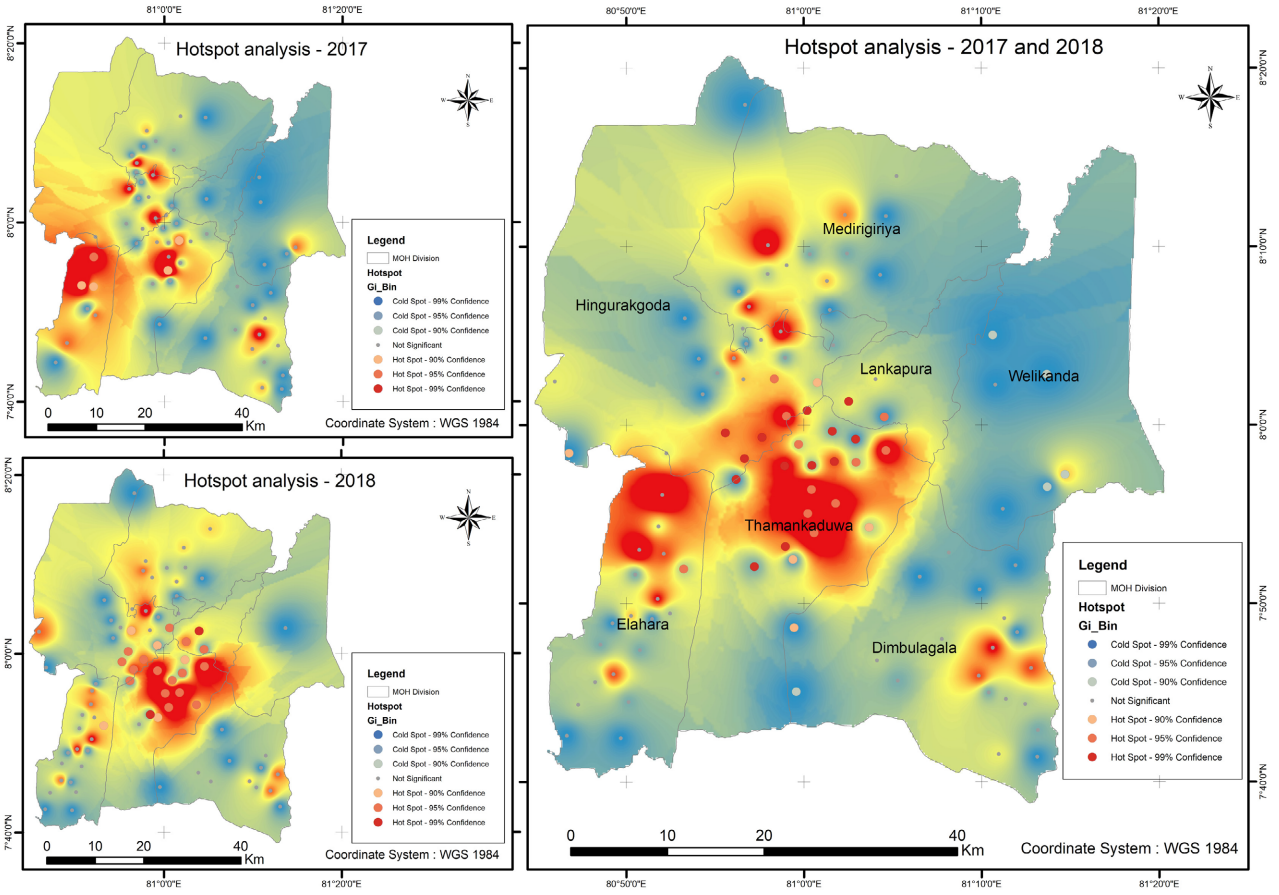

Figure 7. Hot spot and cold spot areas of CL distribution in Polonnaruwa district.

Observe the interrelationship of environmental factors and patients' distribution

Abdullah et al. (2017) revealed how CL spread across the borders according to the environmental factors (e.g. temperature, rainfall, cultivation, and vegetation cover) and human interventions (e.g. deforestation, the building of dams, and urbanization). Similarly, several studies have recently reported the influence of environmental and climatic conditions on the distribution of the Leishmaniasis vectors (Rossi et al., 2007). Further, Desjeux (2001) has widely explained how anthropic factors such as demographic pressure, urbanization, and exploitation of land for agriculture affect the Leishmaniasis distribution. Accordingly, the study focused on how paddy, home garden, vegetation, and drainage system relate to CLD distribution in the area (**Figure 8**).

There were significant correlations between selected environmental factors and CLD in the District. The Agricultural Household Survey 2016/17 reported

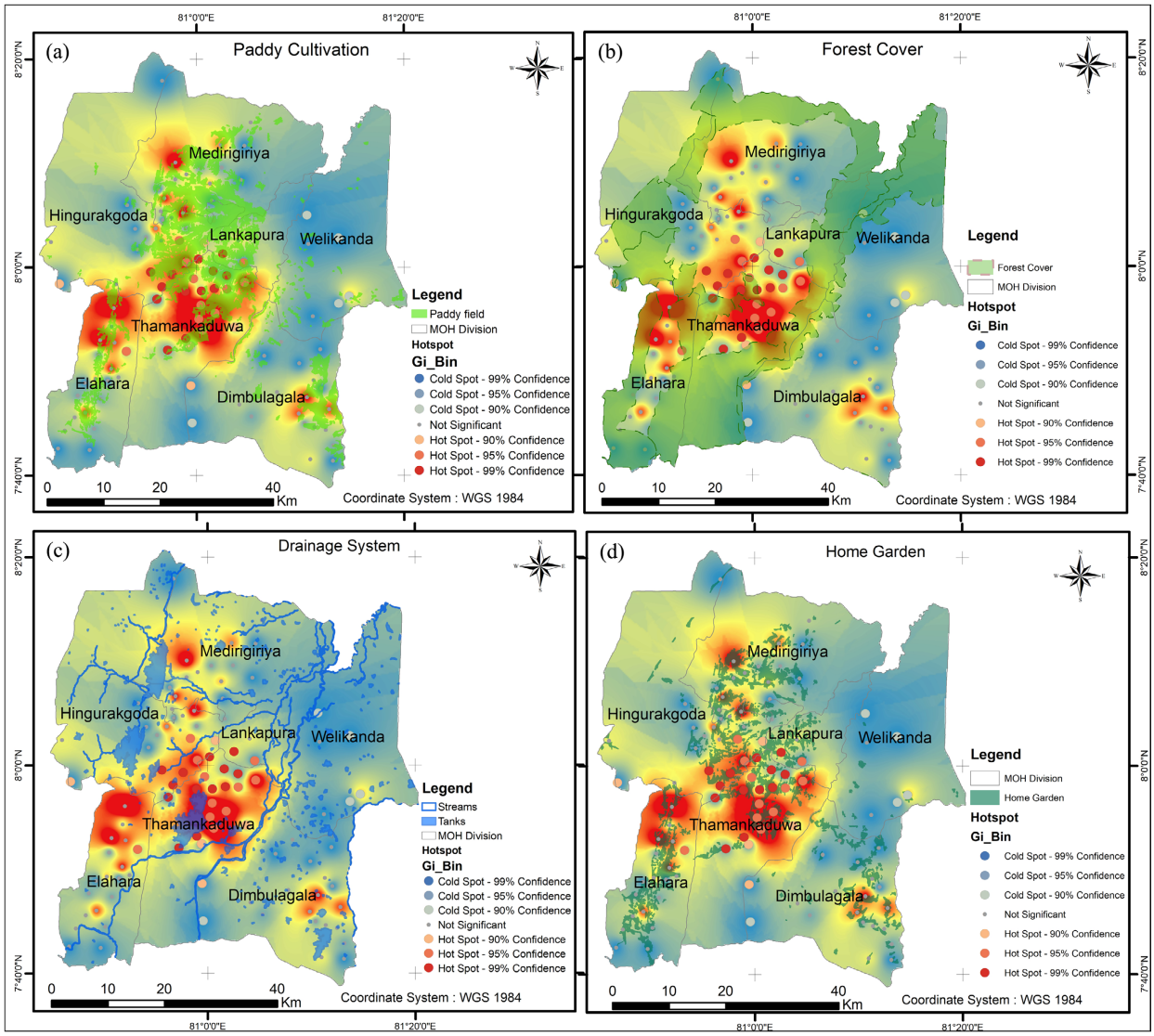

Figure 8. Relationship between environmental factors and CLD.

that 54.39% of the population engaged with the agricultural sector in the Polonnaruwa district. Thus, most of the CL patients (75%) in this study are highly involved with agricultural activities.

When considering the paddy cultivation and CL distribution in the area, central and western part shows CL hot spot value at 99% confidence level (**Figure 8(a)**). Also, in the same figure, at a 99% confidence level, the cold spot could be identified in the less cultivated areas of paddy. The results of the study revealed that farmers are the most vulnerable community to CLD. Similarly, the home garden of the study area (**Figure 8(d)**) is visible over 90% hot spot confidence level of the CLD. There were also 99% cold spot confidence levels visible in forest cover (**Figure 8(b)**) (including national parks called Wasgamuwa, Angamedilla, Somawathiya and Minneriya-Giritale sanctuary), while over 90% cold spot confidence level belongs to the drainage system.

Changes in precipitation and temperature regimes related to climate change have impacted CLD distribution (de La Rocque et al., 2008). Therefore, the study tries to identify the relationship in-between CLD and climatic factors such as rainfall and temperature. There are sessional trend can be identified in this disease (**Figure 9** and **Figure 10**). When considering both years, the highest number of patients recorded in May. For example, in 2018, there were 28 patients in May, which was the highest recorded month of the year. In this month, rainfall and temperature reported respectively 237.34 mm, 29.2˚C. In 2017, the first quarter of the year showed a high number of CLD patients than last quarter. When compared with the situation in 2018, an up and down pattern could observe in the second half of the year.

Below **Figure 11** illustrates the spatial relationship of CLD and rainfall in the years 2017 and 2018. When considering the spatial distribution of the factors

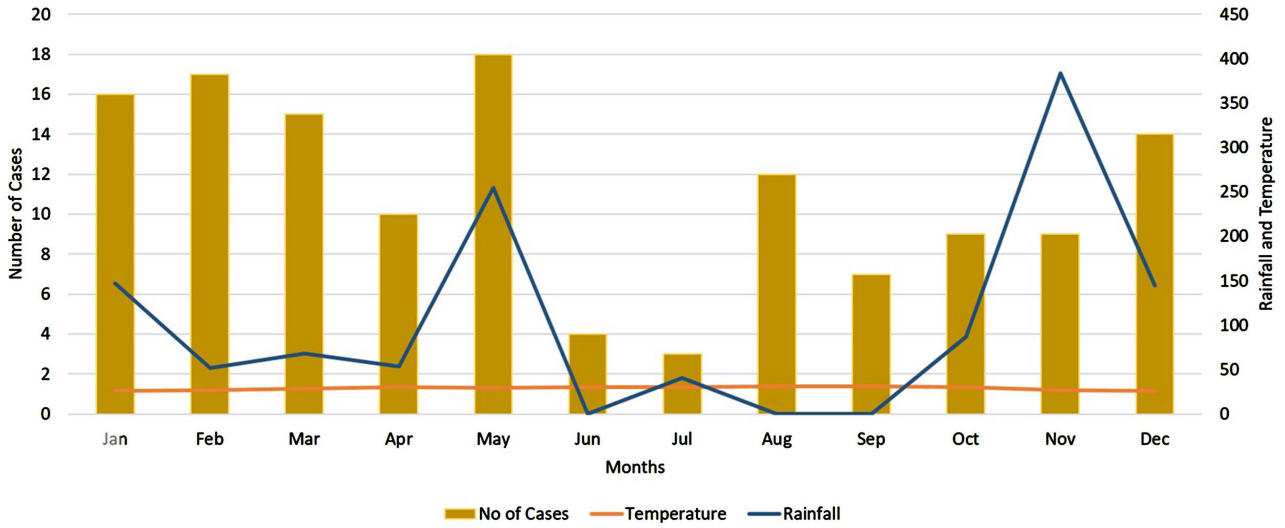

Figure 9. The relationship between monthly reported CL patients and climatic factors 2017. Sources: Department of Meteorology, 2018 and epidemiology unit of DGHP.

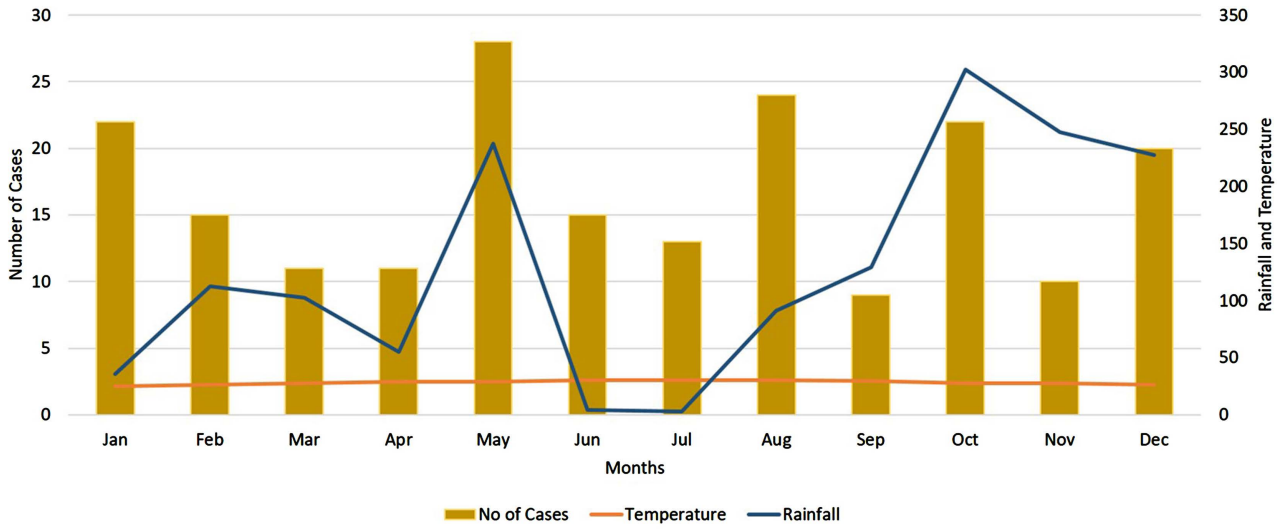

Figure 10. The relationship between monthly reported CL patients and climatic factors 2018. Sources: Department of Meteorology, 2018 and epidemiology unit of DGHP.

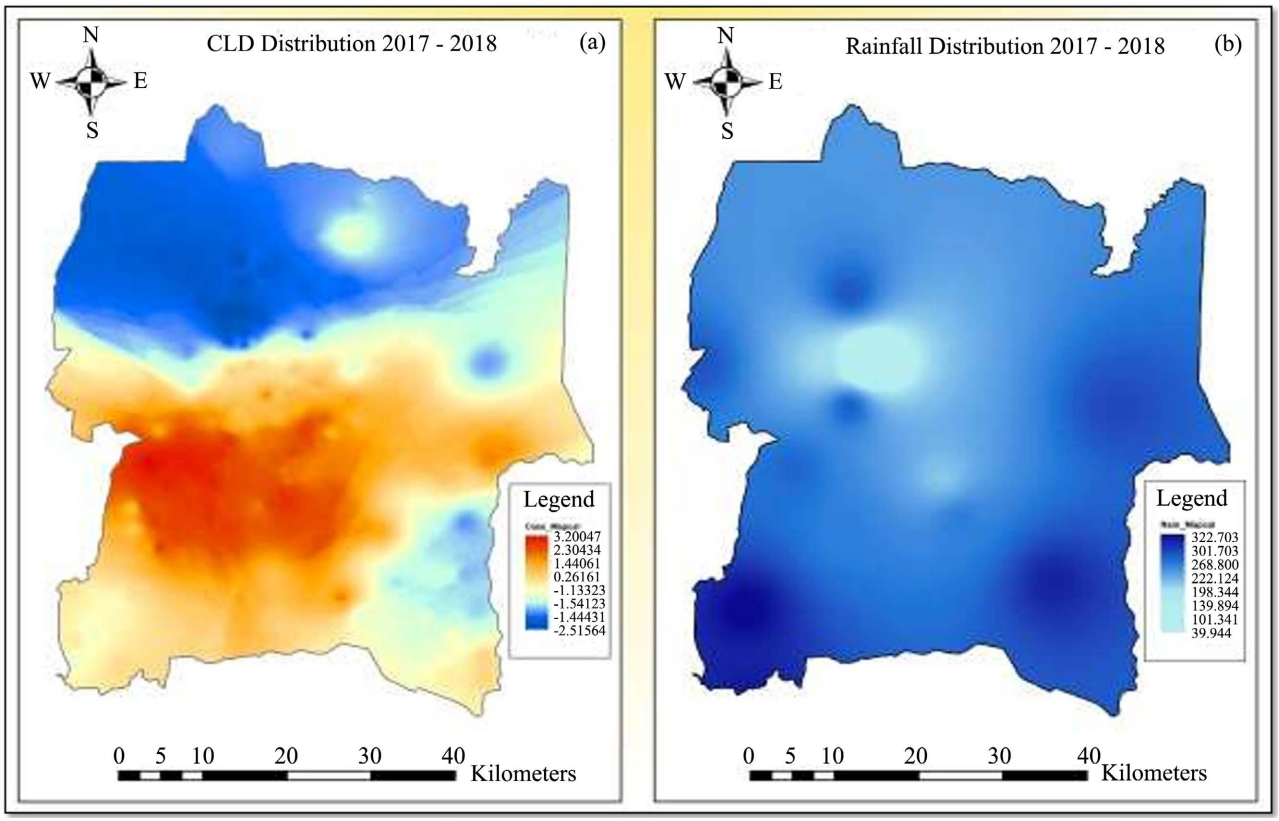

Figure 11. The relationship between patient distribution and rainfall. Source: Department of Meteorology, 2018 and epidemiology unit of DGHP.

mentioned earlier, the central part of **Figure 11(a)** shows the highest number of patients and **Figure 11(b)** shows the minimum rainfall in the same area. It revealed that there was a magnificent relationship between CLD patients and rainfall patterns.

4. Discussion

As Amarasinghe & Wickramasinghe (2020) revealed, the annual number of Leishmaniasis cases are getting increased. Hence numerous researches about Leishmaniasis have done for Sri Lanka in various aspects. These studies laid the path to take action to disseminate the knowledge about CLD in society. Accordingly, this study also tried how GIS can be used as a tool to conduct SA for CLD.

When considering demographic characteristics of the patient of both years, the majority of the patients were young male adults aged from 20 to 44. Galgamuwa et al. (2018) pointed out that previous CL studies in Sri Lanka also indicated that CL patients' sex and age categories are similar to our results. Also, researchers have shown that people engaged in farming activities are highly vulnerable to CL disease (Nouiri et al., 2015 and Torres-Guerrero et al., 2017). Generally, most of the males in the District, directly or indirectly involved with agricultural activities as income generated productive labour force in their families than females. Consequently, this young male adult age group is highly vulnerable to sandfly bites due to their highly active outdoor works. Likewise, there were low female CL patients recorded in both 2017 and 2018 in the District.

On the other hand, Okwor & Uzonna (2016) shows that recent studies revealed a similar rate in both groups over the general belief about more affected males than females. However, we may think that there may be some unreported CL cases among women yet to be investigated. Generally, women are exposed to causative agents than men due to livelihood supporting services. Nevertheless, the disease puts considerable pressure on their day to day life. When talking with some patients, they revealed that the remaining scars make their lives miserable in every way than men. Then the disease will create a new social issue with an unhappy lifestyle within the society. In this study, female patients in the 40 - 44 age group are significantly distressed by the CL. At ground level, most of the women in this age group are mothers, taking more responsibilities and tolerating family matters than younger ages. Also, with their life experience and background (education, income, etc.), they actively involve in outdoor activities than any other female age group.

In considered years, randomly distributed CL patients can observe in the study area (Moran's I Index, Z-score 1.38625). The study revealed that the land use and climate factors significantly affected the CL distribution in the Polonnaruwa district. When considering paddy cultivated areas, reported CL patients were considerably higher than other parts of the District. Therefore, we can predict a cluster distribution pattern close to paddy cultivation in future. Ranasinghe et al. (2013) also recognized that high CL patients distributed close to paddy fields.

Moreover, the spatial relationship between temperature and CL patients' distribution can be determined significantly. Polonnaruwa district located in the DCZ of the island has 25.3˚C to 31.5˚C temperature variation throughout

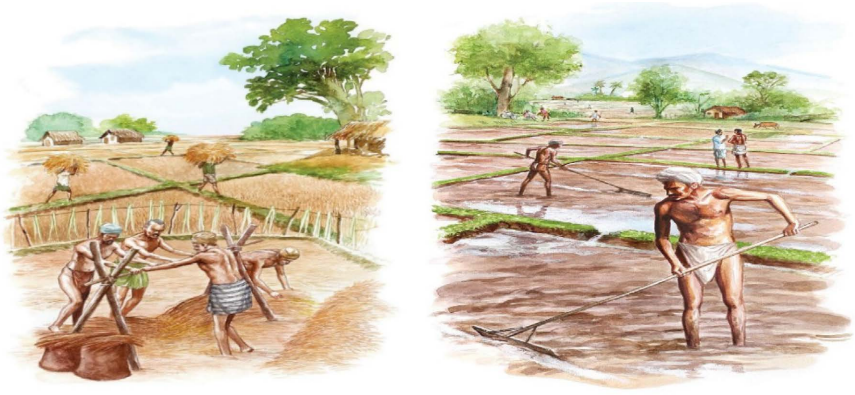

Figure 12. Tradition dress code of farmers in Sri Lanka by Udayakumarge. Source: shorturl.at/gkmEF, 2017.

the year. This temperature variation is ideal for sandflies growth. Accordingly, Prudhomme et al. (2015) explained that sandflies are characterized as thermophilic, requiring high temperatures for their development and survival. Therefore, due to the climatic conditions of this area, peoples are highly vulnerable to CLD.

The peak of reported CL patients can identify in *the Yala season* (March to August) and *Maha season* (September to February). Farmers engaged in agriculture activities try to use traditional dress for their comfort (**Figure 12**). This dress code almost covers only the lower part of the body and the upper part of the body is directly exposed to the environment that sandflies inhabit.

When considering the sand flies' habitat richness, organic matters like stubble and straw provide an ideal background for breeding and rest (Risueño et al., 2017). Accordingly, there is a high probability of sandflies bite during the period of harvesting. Therefore, it is essential to conduct an awareness program for the farmers to reduce the number of CL patients in the study area.

5. Conclusion

The research shows that CLD is increasing in the Polonnaruwa district, with precise spatial and temporal patterns. It clearly shows that the patients have spread in the most populated areas where paddy cultivation is high. It shows that the vector is sensitive to temperature and rainfall as the cases reported by months show peaks from April to June and August to November in 2017 and 2018. As a tropical island, the summer climate can see during the period mentioned above, and generally, paddy cultivation activities happened during this time. The study shows that the number of male patients is higher than the number of females as the high number of farmers are males and the age of farmers between 18 to 40 years. Hence, more studies are needed on vector behaviour and identifying possible outdoor biting incidents to control the disease. Especially it is important to study deeply the life circle of sandflies and people's exposure to this disease. There were several limitations such as patients were not recorded their issues in hospital reports, and lack of awareness about the disease. There-

fore, it is better to focus future studies on the above-mentioned areas. It will Furthermore, health education of the disease, both for public and health workers, identifying habitats hosts, and vector control will be essential to inhibit the distribution of this disease in Sri Lanka.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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