GEOGRAPHIC INFORMATION SYSTEM (GIS) MAPPING OF LYMPHATIC FILARIASIS ENDEMIC AREAS OF GAMPAHA DISTRICT, SRI LANKA BASED ON EPIDEMIOLOGICAL AND ENTOMOLOGICAL SCREENING

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Abstract. The objective of this study was to develop a site directed geographic information system (GIS) map of lymphatic filariasis (LF) in Gampaha District, Sri Lanka as a guide for targeted control activities. Epidemiological and entomological screening of LF was carried out in nine pre-identified endemic areas in Gampaha District, using night blood screening and pool-screening PCR-ELISA. In total, 1,073 subjects (286 children, 787 adults) from 9 sites were examined. Positive cases were detected at 2 sites, with prevalence rates of 0.5% (Hekiththa) and 3.4% (Peliyagoda); the prevalence of microfilaria (mf) among adult *Culex quinquefasciatus* mosquitoes surveyed was 30%. The overall prevalence of mosquitoes with L1-L2 larvae of *W. bancrofti* ranged from 0% to 8.31% using dissection and point estimates of infection prevalence, and ranged from 0 to 32.4% using PCR-ELISA. The largest number of human cases was found at altitudes of 2.5-3.5 m in highly populated areas, where transmission appears to have taken place. Questionnaires indicated that limited community awareness of LF may be a reason for the fairly static infection prevalent among the local population. The GIS mapping of LF cases shows a considerable prevalence of LF and marked variability by geographic site in Gampaha.

Keywords: *Wuchereria*, filariasis, entomology, epidemiology, geographic information system

INTRODUCTION

Lymphatic filariasis (LF), a mosquito vector-borne disease, is a major public health problem in many parts of the world and has an impact on local economics (Ramaiah *et al*, 2000). The Global Programme to Eliminate Lymphatic Filariasis (GPELF) depends upon Mass Drug Administration (MDA) to interrupt transmission (Shanmugavelu *et al*, 2006). In Sri Lanka, LF is endemic in 8 districts distributed throughout 3 provinces in southern and western coastal areas. According to the recent estimates, about 9.5 million people are at risk in these 3 provinces (AFC, 2010a). The first

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MDA program, in the national program to eliminate LF aimed at covering the entire endemic region (Sharmini *et al*, 2007) was carried out in 1999 using diethylcarbamazine (DEC) only. The coverage achieved was 62.7%. In 2000, 2 rounds of MDA in endemic regions were carried out using only DEC, first in April with a coverage rate of 68.2% and the second in November covering 70.5%. In May 2001, a trial using a combination of DEC and Albendazole was conducted in Colombo District with a coverage rate of 76.7% (Sharmini *et al*, 2007). In the other 7 districts, DEC only was administrated. MDA efforts were hampered by the lack of coordination and education. Weerasooriya *et al* (2007) found drug compliance has a significant positive correlation with awareness of the MDA program.

Following the tsunami in December 2004 in Sri Lanka, control of neglected diseases, such as LF, faced more challenges than before. However in August 2005, even in tsunami affected areas, LF control program team carried out MDA because of the health benefits and improved nutrition that results from the antifilariasis control (AFC) program. After the tsunami the AFC program in Sri Lanka increased its efforts in vector control and continuously maintained anti-filariasis clinics in tsunami-affected areas. However, monsoon rains and a compromised infrastructure resulted in additional mosquito breeding sites, increasing the risk for higher rates of LF, malaria, and dengue infections in these areas. In response to this, insecticide-impregnated bed nets were distributed to affected families by the AFC program and Ministry of Health in collaboration with the World Health Organization (WHO) and other local non-profit organizations. Thermal fogging was used as a means of vector control close to temporary camps. The AFC program made additional commitments to disability management programs in the coastal areas to ensure infected individuals continued to receive relief for their LF symptoms to prevent disability(AFC, 2005). Despite these additional requirements, the AFC program was able to successfully carry out their 5 year MDA program in 2006.

The study site, Gampaha District, is located in Western Province, Sri Lanka. The population of Gampaha District is 2.063 million, which represent 44.5% of the Western Province population. Malaria, Japanese encephalitis (JE), dengue and filariasis are major vector borne diseases seen in the district. Filariasis is endemic mainly in coastal part of the district, including Wattala, Negambo, Kelaniya, Attanagalle, Gampaha, Ja-ela, Katana and Mahara. Although there has been a significant reduction in disease since initiation of the control program by the AFC program, it has not sufficient to eliminate the disease from the community. The introduction of MDA using 2 drugs in 2002 was a land mark step in the elimination of the disease (AFC, 2005). Four rounds of MDA were conducted between 2002 and 2005 using DEC and Albendazole. The entire district was satisfactorily covered during those efforts (AFC, 2008).

After completion of a 5 year MDA program it is important to survey the current status of LF transmission, to modify control efforts. Although time consuming, and labor intensive we used night blood screening to determine the prevalence of LF. Entomological screening of vector *Culex quinquefasciatus* mosquitoes was also carried out using traditional dissection techniques and PCR-ELISA. Since LF can vary with local environmental conditions (Shanmugavelu *et al*, 2006), geo-environmental and climatological data were collected as well. A geographic information system (GIS) was used to compile the data and compare cases with environment factors and prevalence of *W. bancrofti* larvae among mosquito vectors.

Because of its abilities, there has been growing interest among ministries of health in various countries to use GIS as a tool to strengthen monitoring, analysing and decision-making in public health (Pan American Health Organization, 2004). Although, there are number of ongoing health studies using GIS mapping for the vector control among public health teams in Sri Lanka, no studies have been carried out using GIS to evaluate LF following MDA. This data should be useful for initial LF prevalence mapping to guide control programs.

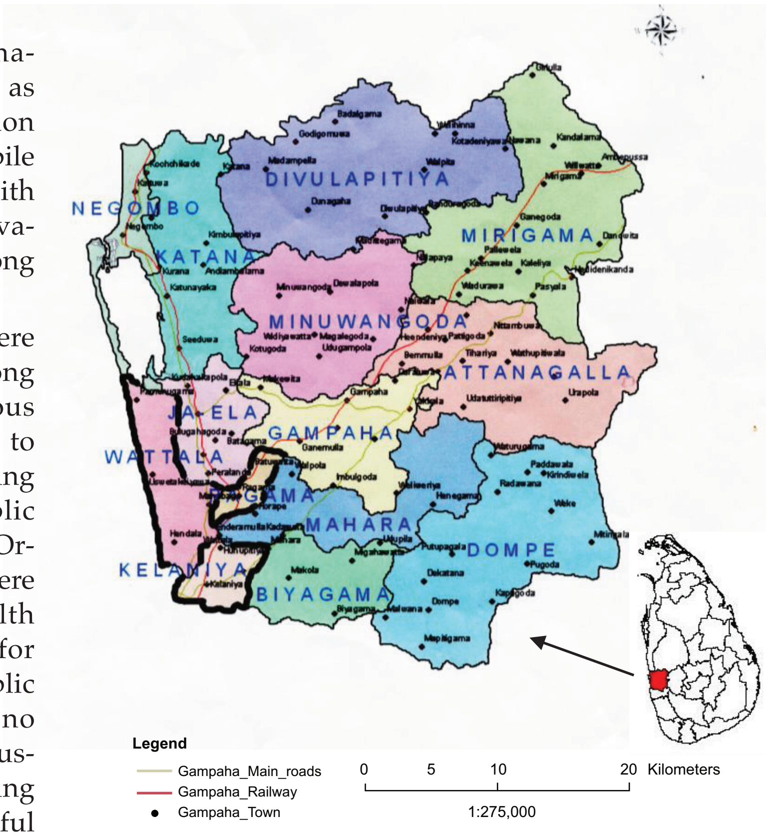

Fig 1–Map showing study sites in Gampaha District. Thin black lines indicate ministry of health boundaries and thick black lines indicate the study areas.

MATERIALS AND METHODS

Study area

Gampaha District in the Western Province of Sri Lanka has a wide range of geo-environmental features. Human LF cases and mosquito vectors infected with *Wuchereria bancrofti* were investigated within the Gampaha District the geographical distribution of human infection and vector mosquito population with *Wuchereria bancrofti* was investigated while selecting the three different endemic Medical Officer of Health (MOH) areas. Each MOH area included two sentinel and one non-sentinel site (Fig 1).

GIS data

Digital site maps of the three study areas were constructed. The GIS database was developed using a Garmin 12 GPS for mapping data receiver (Garmin eTrex GPS receiver; Garmin, Olath, KS) and the image processing software, ArcGIS 9.3. Data were taken from nine pre-selected sites: Peliyagoda (06º 58′ 03.5″N, 079º 53′ 07.7″E), Pethiyagoda (06º 56′ 59.5″N, 079º 54′ 09.3″E) and Meegahawaththa (06º 58′ 12.9″N, 079º 53′ 28″E) in the Kelaniya MOH area and Alwis town (06º 59′ 56″N, 079º 53′ 29″E), Hekiththa (06º 58′ 88″N, 079º 53′ 20″E) and Weliamuna Road (06º 59′ 27″N, 079º 52′ 97″E) in Wattala MOH area and Horape (07º 01′ 113″N, 079º 55′ 85″E), Batuwaththa (07º 02′ 67″N, 079º 55′ 97″E) and Siriwardana place (07º 01′ 3.9″N, 079º 55′ 30″E) in Ragama MOH area.

Geo-environmental and climatological data

As described by the Shanmugavelu *et al* (2006). The possible geo-environmental risk factors likely to influence the occurrence of LF (either directly or indirectly) were determined (Shanmugavelu *et al*, 2006). Altitude, temperature, rainfall, relative humidity, soil type and land use/land cover were also determined. Data regarding the soil and agro-ecological features were obtained from the Land Commissioners Department, Sri Lanka. Weather data was obtained from the Sri Lanka Meteorological Department, Colombo.

Epidemiological survey

Subjects >3 years old were screened for *W. bancrofti* microfilaria (mf) via thick blood films (TBF) at all study sites. The clinical manifestations of LF were also looked for an examination. Knowledge level regarding LF and its treatment were determined among subjects >15 years old using an interviewer administered questionnaire. Areas within 500 meters from previous LF cases were covered (data obtained from the AFC). Ethical clearance was obtained from the Institutional Ethics Committee. The children were screened after obtaining informed consent from their parents or guardians.

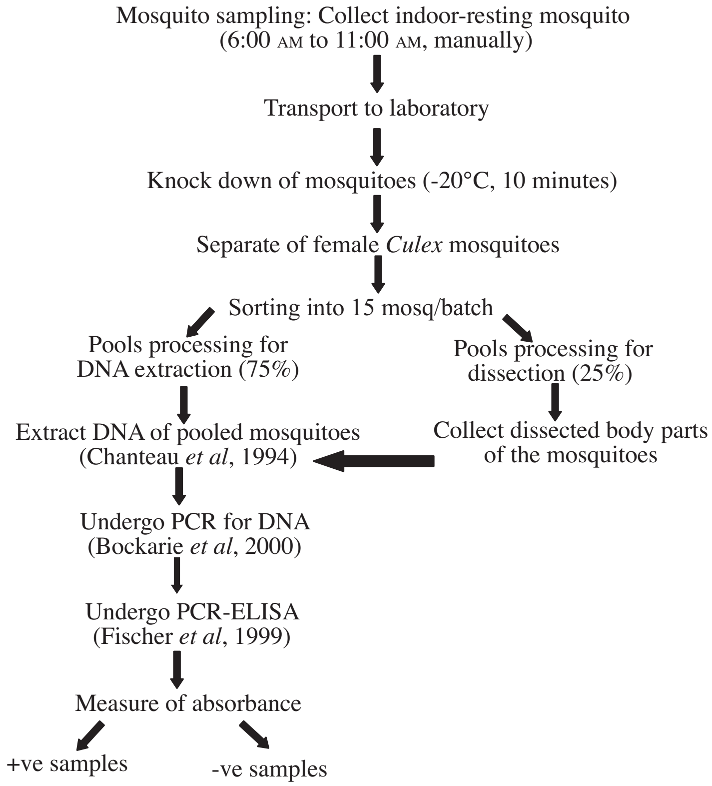

Fig 2–Laboratory evaluation of transmission levels of vector mosquitoes.

Entomological survey

The main vector for *W. bancrofti* in Sri Lanka is *C. quinquefasciatus* (Abeyewickreme *et al*, 1992). Some transmission occurs year round. Therefore, monthly mosquito collections were carried out for twelve months at each of the 9 sites (30 households/site). The process used to determine the presence of *W. bancrofti* larvae among studied mosquitoes in shown in Fig 2.

Statistical analysis

The data obtained from this study was used to determine (a) the transmission potential and (b) infection rate among the vector population. Prevalence rates from dissection data and PCR analysis were calculated and compared using Epi-Info, version 3.2 (developed by the Centers for Disease Control and Prevention in collaboration with the Global Program on AIDs and the WHO). The sample size was selected to give significance. Infective rates among the

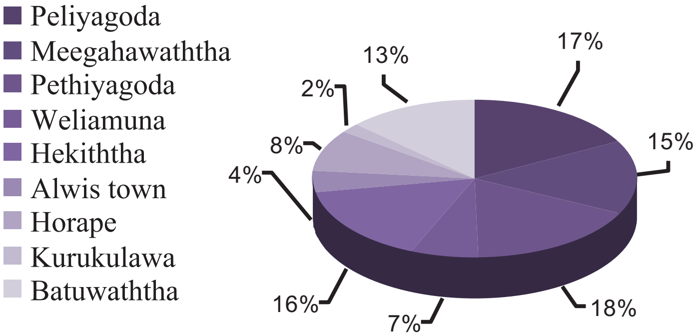

Fig 3–Percent of adult subjects per study site.

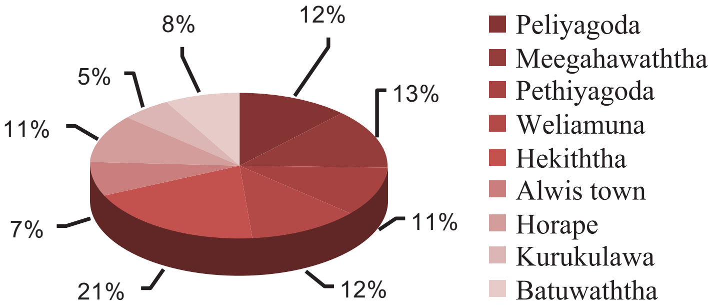

Fig 4–Percent of child subjects per study site.

parous vector populations were also determined. Infective mosquitoes were defined as those containing L3 larvae in any body part. Mosquitoes having L1, L2, or L3 larvae were defined as being infected.

RESULTS

Epidemiological survey

Of 1,073 subjects (286 children, 787 adults) (Figs 3, 4 and 5) screened, 6 were positive for mf at 2 sites giving mf positivity rates of 0.5% and 3.4% at Hekiththa and Peliyagoda, respectively (Fig 6); the mean mf densities (mf/60 1 blood) were 2 and 7, respectively (Fig 7). Of the 1,073 participants, 78% were aware of the MDA program for LF, 65% had received drugs and nearly 50% had taken drugs. Out of those who had taken the drugs, only 34% had taken them continuously for five years. Of the 1,073 participants, 3% and 1% had lymphedema and hydrocele, respectively. All mf positive subjects were from sentinel sites, which were considered LF risk areas by the AFC program.

Entomological survey

The numbers of mosquitoes collected at non-sentinel sites (Alwis, Mewella and Kurukulawa) were relatively low compared to sentinel sites (Fig 8). An exponential growth of *C. quinquefasciatus* mosquito population densities was observed at all sites from December to February during the study period. The maximum densities occurred in January and decreased from March until July; it increased again during August then decreased until December. The maximum *C. quinquefasciatus* density was seen at Hekiththa and ranged from 22 to 89 mosquitoes/man-hour; the minimum was at Kurukulawa and ranged from 1 to 6 mosquitoes/man-hour. Climatic data suggests temperature and rainfall were limiting factors for *C. quinquefasciatus* population growth (Fig 9, 10). The overall prevalence of mosquitoes with L1-L2 larvae of *W. bancrofti* ranged from 0-8.31% by dissection; point estimates of infection prevalence, using PCR-ELISA, ranged from 0-32.4%.

GIS data

The GIS data showed substantial variation of LF by study site. The highest number of LF cases was found at

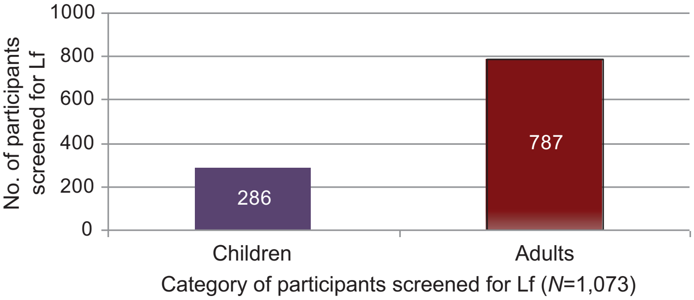

Fig 5–Number of participants screened for LF by age category.

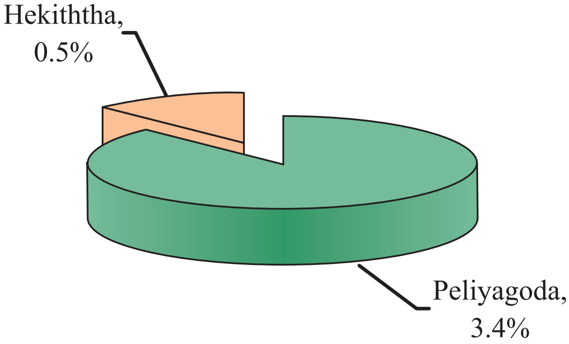

Fig 6–mf positivity at study site (out of 9 sites).

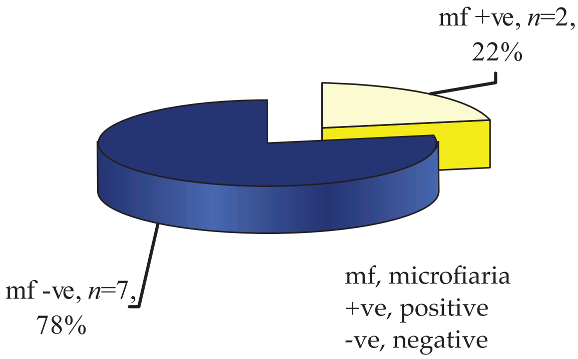

Fig 7–mf prevalence at positive sites.

altitudes of 2.5-3.5 m and in highly populated areas where transmission appears to be taking place (Figs 11, 12). Furthermore, maps point out the distribution of three study sites within each MOH area were not identical thus indicating the pattern of LF disease distribution was not influenced by the site selection method (Fig 13).

DISCUSSION

This study was conducted to assess LF disease transmission levels following a MDA program in an endemic population of Gampaha District. Adult *C. quinquefasciatus* mosquitoes were collected from 84.4% of examined households in the study area. There was no significant co-relation between entomological findings of adult *C. quinquefasciatus* mosquitoes and the finding of breeding sites at each site ($p = 0.05$). The average mosquito density per man-hour was 15 (range 0 to 70, compared with an AFC program finding of 22. Adult *C. quinquefasciatus* mosquitoes were more prevalent than expected based on the number of breeding sites. This may be due to higher productivity (larger number of adult mosquitoes produced per breeding site at one time). The above data highlights the importance of implementing proper control measures to reduce vector populations. Similar *C. quinquefasciatus* population density patterns were seen at all study sites but with enormous variation, probably due to different local conditions and a community awareness program conducted to control dengue infection in Gampaha District during the study period.

Comparing mosquito dissection with PCR-ELISA revealed using PCR-ELISA was more practical than dissection since parasite preva-

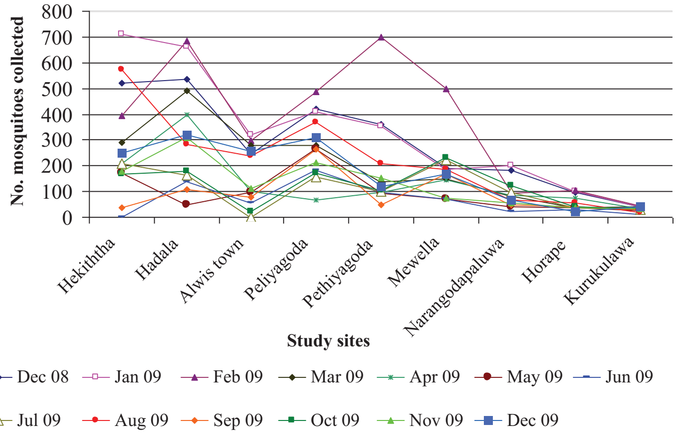

Fig 8–Mosquitoes collected by location and month.

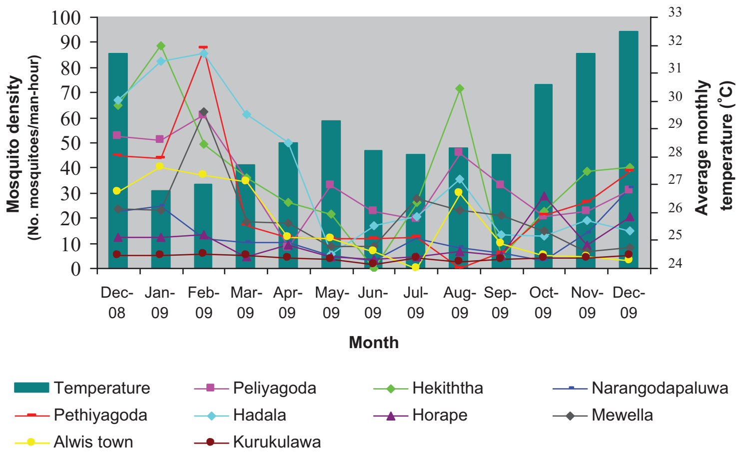

Fig 9–Correlation between monthly mosquito density and temperature by study site.

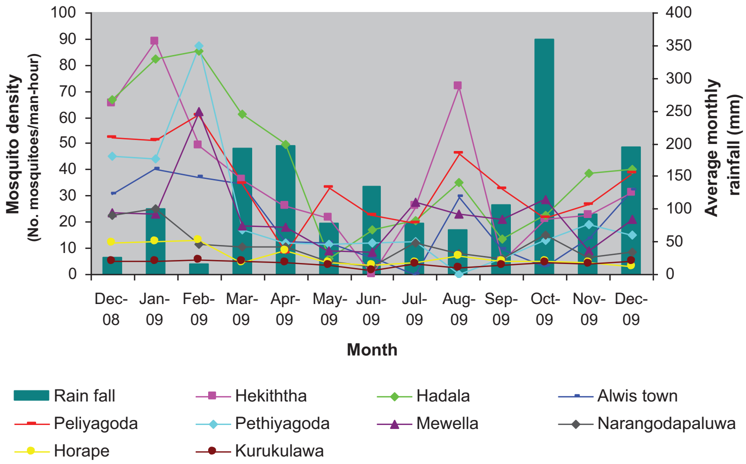

Fig 10–Correlation between monthly mosquito density and rainfall by study site.

lence was difficult to determine by dissection alone. Since there were no similar studies from this area, our results were compared with entomological data generated by mosquito dissection from the AFC program in Sri Lanka. The results show, despite MDA in Gampaha District in the AFC program from 2002 to 2006, *C. quinquefasciatus* was still actively transmitting *W. bancrofti*, revealing deficiencies in vector control in this area. Effective vector control and monitoring programs are needed to interrupt transmission. The prevalence of LF in this study population was greater than the currently reported national prevalence of 0.18%. An intensive MDA program is recommended to contain the spread of LF in this area.

GIS is a powerful tool for understanding spatial relationships between different phenomena. It combines data obtained from local studies with geographic mapping to give a visual presentation of the location and data (ENVIS Centre for Bioinformatic Vector Control, 2004). The GIS can reveal trends, dependencies and interrelationships which are difficult to discern in tabular format, such as disease-specific information and its relationship to population settlements, surrounding social and healthcare services and the natural environment (Raju and

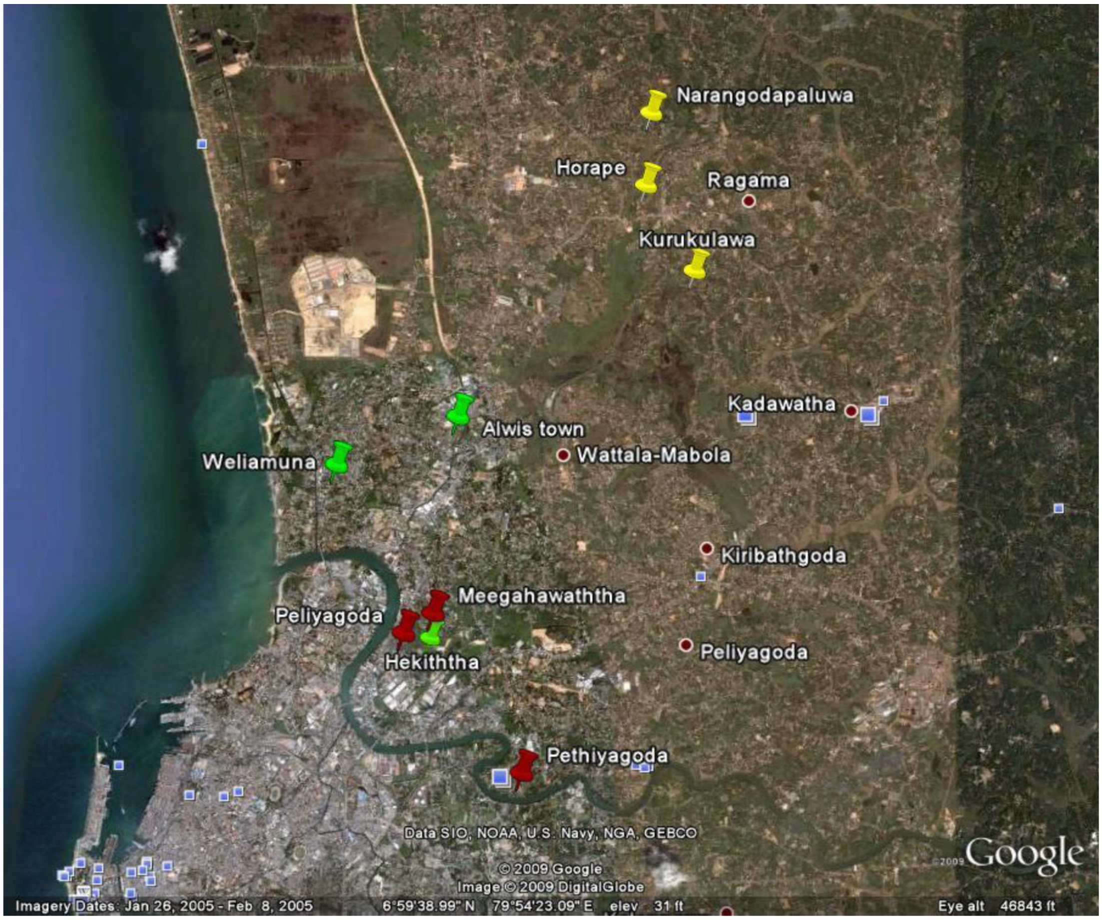

Fig 11–Google map with overlay GIS map showing study sites in Gampaha District.

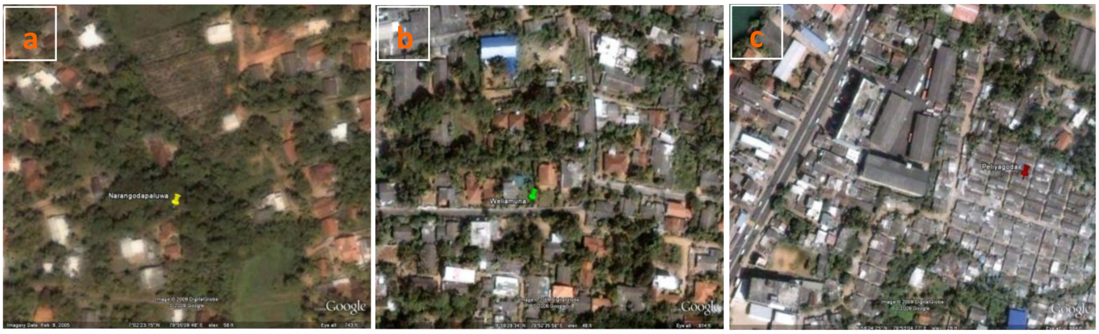

Fig 12–Google map with overlay GIS map showing ecological diversity of study sites; a. Ragama MOH, b. Wattala MOH, c. Kelaniya MOH.

Sabesan, 2007). Simple maps can be used to identify patterns of disease spread, identify sources, determine target areas and assess epidemic risk (WHO, 2006).

Shanmugavelu *et al* (2006) found LF transmission is dependent on geo-

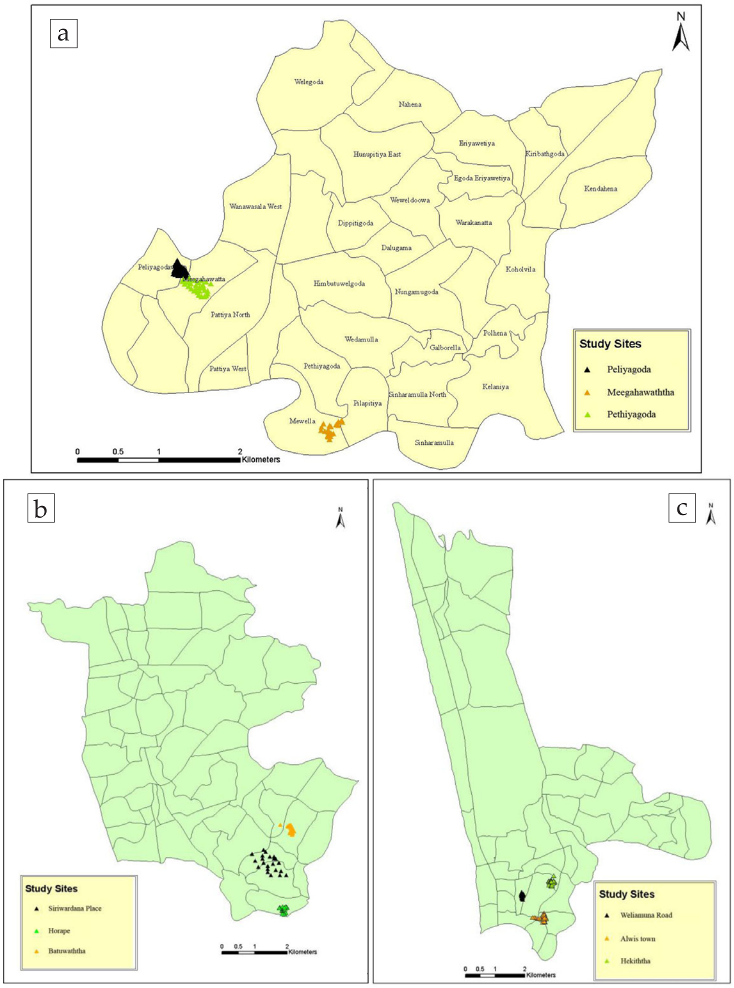

Fig 13–GIS map showing study sites in a) Kelaniya MOH area, b) Ragama MOH area and c) Wattala MOH area.

environmental variables (physiographic and climatic). Physiographic factors contributed to vector density; whereas climatic factors influence incubation periods of parasites and vector survival. Once environmental conditions are conducive, human (demographic) factors become determinants of LF occurrence. It is evident from our findings that a number of factors are responsible for prevalence of LF (Shanmugavelu *et al*, 2006).

In spite of a 5 year program of MDA, LF was still prevalent and transmission was still occurring. Evaluation AFC revealed some of the community did not receive MDA; even though the drugs were distributed they were not taken. There were several reasons for this, such as worries about adverse effects of drugs, other prevailing diseases or contraindications due to interactions with other medications. Some LF subjects in nearly every district refused to take the drugs and some were not present at the time of drugs distribution.

In this study, possible reasons for inadequate coverage of MDA program were explored in Gampaha District. Possible reasons for this include bad weather being prevalent during the period the drugs were distributed, inadequate manpower (AFC, 2008) and inaccessibility to some house holds at the time the drugs were distributed.

There has been limited adoption of the GIS in the health sector at local levels, primarily due to limited access to commercial GIS programs, their cost, complexity, and limited availability of analytical techniques and methods for problem solving in epidemiology and public health. To overcome these problems, sophisticated GIS software, such as MapInfo, ArchInfo and Geomatica, are required for high level planning and epidemiological analysis, mapping tools and methods for statistical spatial data analysis in different environments are in high demand (Pan American Health Organization, 2004) and training to use them is needed.

This study focused on LF disease transmission in Gampaha District. The results help public health officials to develop more effective control measures to stop the spread of LF.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial assistance provided by the WHO/SEARO/TDR (grant no. SN 1152) and University of Kelaniya (Research grant no. RP/03/04/06/01/2006) and also International Atomic Energy Authority (IAEA) for the equipment received through a technical co-operation program.

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