Use of geographical information system (GIS) and global positioning system (GPS) for dengue and dengue haemorrhagic fever control in Sri Lanka


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Abstract

The dengue virus causing dengue fever (DF) and dengue haemorrhagic fever (DHF) is transmitted by the female mosquitoes – *Aedes aegypti* and *Ae. albopictus*. Because DF/DHF is a local and focal disease, identification of finer-scale risk areas and application of vector control interventions in these areas are important actions for disease prevention and control. The present study was carried out to: (a) identify DF/DHF risk levels of different Grama Niladari (GN) areas under the jurisdiction of the Medical Officer of Health (MOH), Kadugannawa area, Kandy district; and (b) determine the impact of *Aedes* larval control in DF/DHF high-risk GN areas on the overall DF/DHF burden in the MOH area. *Ae. aegypti* and *Ae. albopictus* density (Breteau index) in each GN area of MOH Kadugannawa was determined by immature (larvae and pupae) surveys. Details of suspected and serologically confirmed DF/DHF cases were collected from MOH Kadugannawa and georeferenced using global positioning system (GPS) receivers. Data on *Ae. aegypti* and *Ae. albopictus* density and DF/DHF cases were analysed and mapped using the geographical information system (GIS) to identify the DF/DHF risk levels in different GN areas of the MOH. With reference to risk mapping, health education and source reduction (interventions) were carried out in high-risk GN areas (areas with DF/DHF cases and *Ae. aegypti* prevalence) in July 2008. Kandy district showed an increasing trend of DF/DHF since 2001. The MOH area Kadugannawa also followed the same trend from January 2004 to July 2008, contributing 18.8%–37.5% of the monthly case load in the district in the period January–July 2008. Following the intervention in July 2008, MOH Kadugannawa showed a decreasing trend of DF/DHF during August–December 2008 and contributed 22.7%–8.8% of monthly DF/DHF cases in Kandy district. We conclude that identification of finer-scale DF/DHF risk areas using GIS and GPS and application of vector control interventions in high-risk GN areas is very useful for DF/DHF prevention and control.

Keywords: GIS and GPS; DF/DHF control; Sri Lanka.

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Introduction

Dengue fever (DF), dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) are part of a disease complex caused by four serotypes – DENV 1-4. The virus is transmitted by female mosquitoes of *Aedes aegypti* and *Ae. albopictus*. Thus, the occurrence of DF/DHF depends on the presence of the dengue virus, the vector mosquito species and a susceptible human population.

In Sri Lanka, DF was first reported in the early 1960s. Since then, sporadic, progressively larger and more frequent DF/DHF outbreaks have occurred in the country. The morbidity, mortality and spatial distribution of the disease have increased considerably since 1995 with 15,434 suspected or serologically-confirmed DF/DHF cases and 88 deaths in the year 2004 alone. At present, many urban and semi-urban areas are endemic for DF/DHF while new areas are being invaded, making DF/DHF a major public health problem in the country.

Materials and methods

Study area

The area selected for the study was the MOH Kadugannawa area in the Kandy district of Sri Lanka. The MOH area consists of 95 GN areas with an estimated mid-year population of 101,677 for the year 2006. Kadugannawa area is endemic for DF/DHF with 49–194 cases reported annually during 2004–2007, contributing 7.9%–13.2% of the total annual case burden in Kandy district. The study area showed an increasing trend of DF/DHF from January 2004 to July 2008, based on both monthly and annual trends of DF/DHF in the district (Record at the Office of the Regional Director of Health Services in Kandy).

Prevalence of *Ae. aegypti* and *Ae. albopictus* in different GN areas of MOH, Kadugannawa

*Aedes* immature (larvae and pupae) surveys were carried out from January 2004 to December 2007 to detect the prevalence of *Ae. aegypti* and *Ae. albopictus* in each GN area of MOH Kadugannawa. During the surveys, a representative sample of 100 houses in each GN area was examined. All indoor and outdoor potential breeding habitats for *Ae. aegypti* and *Ae. albopictus* were examined, and up to 10 *Aedes* larvae and 10 pupae were randomly collected from each larvae/pupae positive container by dipping or pipetting, depending on the nature of the breeding habitat, for identification of the vector species.

If a particular container had <10 *Aedes* larvae/pupae, all larvae/pupae were collected. If a particular GN area did not report *Ae. aegypti* and *Ae. albopictus* in the first survey, two more surveys with 3–4 month intervals in...
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High dengue transmission periods were carried out in order to confirm the presence/absence of *Ae. aegypti* and *Ae. albopictus* in that area. *Aedes* larvae were identified at the larval stage and pupae were allowed to develop to adult stage and identified using standard keys. Ae. *aegypti* and *Ae. albopictus* density in each GN area was determined by calculation of the Breteau index (BI) for each species (number of *Ae. aegypti*/Ae. *albopictus*-positive containers per 100 houses) using multiple samples.

**Determination of GN area-level distribution of DF/DHF cases**

Details (name, age, sex and address) of all reported, suspected or serologically confirmed DF/DHF cases from 2004–2007 in the study area were collected in consultation with MOH Kadugannawa. These cases were georeferenced, using global positioning system (GPS) receivers, at the point of residence of the patient.

**Development of maps to identify the GN level-distribution of DF/DHF, *Ae. aegypti*, *Ae. albopictus*, and the DF/DHF risk levels of different GN areas in MOH Kadugannawa area**

Data for DF/DHF cases and Breteau indices of *Ae. aegypti* and *Ae. albopictus* at the GN area spatial scale were analysed using a geographical information system (GIS), ArcView 9.0 software. Jayasooriya et al. (2008) reported that there was a strong correlation between the Breteau index of *Ae. aegypti* and DF/DHF in the study area, but no similar correlation between BI of *Ae. albopictus* and DF/DHF cases was observed. Based on this information, MOH area Kadugannawa was stratified as high-risk, medium-risk and low-risk and mapped accordingly. The high-risk GN areas were the areas with DF/DHF cases and with *Ae. aegypti* prevalence. The GN areas that were situated adjacent to *Ae. aegypti*-positive GN areas would undoubtedly have been infested with *Ae. aegypti* adults having emerged from the adjacent GN areas. Thus, the GN areas that were situated adjacent to the *Ae. aegypti*-positive GN areas were classified as medium-risk. The low-risk GN areas were the areas with DF/DHF cases and with *Ae. albopictus* but without *Ae. aegypti* in either the GN area itself or in adjacent GN areas.

**Application of intervention (health education and elimination of vector breeding sites) in DF/DHF high-risk GN areas in MOH Kadugannawa area**

With reference to the DF/DHF risk map, health education and elimination of breeding sites of *Ae. aegypti* and *Ae. albopictus* (intervention) were carried out in July 2008 in the DF/DHF high-risk GN areas. Health education was carried out through house-to-house visits by a team comprising a trained entomological assistant, public health staff and village volunteers. During these visits, each household in the area was made aware of the DF/DHF situation in the area, types of *Ae. aegypti* and *Ae. albopictus* breeding sites, and suitable measures to be taken for the elimination of vector breeding sites on their premises. Mosquito breeding sites encountered during these visits were promptly eliminated by emptying water storage containers, burning and/or burying discarded containers and cleaning domestic appliances such as refrigerators.
Determination of the impact of intervention on overall DF/DHF incidence in the MOH Kadugannawa area

Annual data on DF/DHF from the MOH Kadugannawa area and the Kandy district area were plotted from 2004 to 2007 to identify the trends of DF/DHF in MOH Kadugannawa area and Kandy district. Monthly data on (a) DF/DHF cases in MOH Kadugannawa and Kandy district, and (b) per cent contribution of MOH Kadugannawa to the total disease burden in Kandy district were determined for the year 2008 to compare the (a) monthly trends of DF/DHF in MOH Kadugannawa and Kandy district, and (b) monthly percentage contribution of MOH Kadugannawa to the total DF/DHF burden in Kandy district, before and after the vector control intervention.

Results

Of the 95 GN areas in MOH Kadugannawa, neither *Ae. aegypti* nor *Ae. albopictus* were reported from three GN areas, namely, Haliyadda, Kirimetiya Estate and Pahalayatigammana. Only *Ae. aegypti* was found in one GN area (Walgampaya) and both *Ae. aegypti* and *Ae. albopictus* were found in 17 GN areas, namely, Arambegama-west, Danture, Edanduwawa-east, Edaduwawa-west, Gannoruwa-east, Gannoruwa-central, Gurugama, Ihala-alagalla, Kadawatgama, Kadugannawa, Kiribathkumbura-east, Kiribathkumbura-west, Kotabogoda, Munwathugoda, Pilimatalawa, Udaeriyagama-west and Waturakumbura. The remainder of the GN areas (n=74) reported only *Ae. albopictus* (Figures 1 and 2).

**Figure 1:** Distribution of *Ae. aegypti* and DF/DHF cases within the MOH Kadugannawa area by finer scale GN area
DF/DHF cases were reported from both GN areas where *Ae. aegypti* was present and where *Ae. aegypti* was absent, although there is a correlation \( r=0.5473 \) between Breteau index of *Ae. aegypti* and DF/DHF cases\(^6\). In our case, GN areas with *Ae. aegypti* contributed 44.9% to the total DF/DHF cases in MOH Kadugannawa with 11.3–12.0 cases per GN area, making these areas at high risk of DF/DHF (Table, Figures 1 and 3).

Apart from GN areas with *Ae. aegypti* present, the GN areas adjacent to areas with *Ae. aegypti* presence contributed 23.2% of DF/DHF cases, placing these areas at medium risk for DF/DHF. These areas, together with the *Ae. aegypti*-positive areas, contributed 68.1% of the total DF/DHF burden in the MOH area despite the fact that they constituted only 35 (36.8%) of the 95 GN areas (Figure 3).

**Table**: Number and percentage of DF/DHF cases from GN areas where *Ae. aegypti*/*Ae. albopictus* were present versus areas where not collected

<table>
<thead>
<tr>
<th>Aedes species</th>
<th>GN area with Aedes species</th>
<th>DF/DHF cases (%)</th>
<th>GN area without Aedes species (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ae. aegypti</em></td>
<td>1</td>
<td>12 (2.6)</td>
<td>12.0</td>
</tr>
<tr>
<td><em>Ae. aegypti</em> + <em>Ae. albopictus</em></td>
<td>17</td>
<td>192 (42.3)</td>
<td>11.3</td>
</tr>
<tr>
<td><em>Ae. albopictus</em></td>
<td>74</td>
<td>241 (53.1)</td>
<td>3.3</td>
</tr>
<tr>
<td>None</td>
<td>3</td>
<td>9 (2.0)</td>
<td>3.0</td>
</tr>
<tr>
<td>Total</td>
<td>95</td>
<td>454 (100)</td>
<td></td>
</tr>
</tbody>
</table>
Of the 454 DF/DHF cases reported in MOH Kadugannawa from 2004–2007, 142 (31.3%) cases were from GN areas where *Ae. aegypti* was absent but with *Ae. albopictus* presence, and that were situated outside the typical flying range (<200 m) of *Ae. aegypti*. Because there is a very poor correlation between BI of *Ae. albopictus* and DF/DHF cases \( (r=-0.0469) \), based on the study by Jayasooriya, et al. (2008), these GN areas were classified at low risk of DF/DHF (Figure 3).

Kandy district experienced DF/DHF epidemics in 2002, 2004, 2006 and 2008. MOH Kadugannawa area showed an increasing trend from 2001–2004. Since 2004, Kadugannawa has followed the same trend of DF/DHF as in Kandy district with epidemics in 2004 and 2006 (Figure 4). However, with the application of intervention (health education and elimination of breeding sites of *Ae. aegypti* and *Ae. albopictus* in 18 high-risk GN areas) in July 2008, MOH Kadugannawa showed a downward trend of DF/DHF. This was in contrast to the upward trend in Kandy district (Kandy district included the data for MOH Kadugannawa). The percentage contribution of MOH Kadugannawa to the total DF/DHF incidence in Kandy district was comparatively high and fluctuated over the months from January to July 2008, ranging from 18.8% to 37.5% (before intervention). However, with the intervention in July 2008, the percentage contribution of MOH Kadugannawa to the total DF/DHF incidence in Kandy district decreased over the months July–December 2008, ranging from 22.7% to 8.8% (after intervention) (Figure 5).
**Discussion**

The incidence of DF/DHF in an area depends on the occurrence and density of the vector species and serotype-specific herd immunity. In the present study, a high percentage (44.93%) of DF/DHF cases was observed in the GN areas where *Ae. aegypti* was present. The presence of a high correlation between BI of *Ae. aegypti* and DF/DHF cases indicated that 18 GN areas in MOH Kadugannawa were at high risk of DF/DHF transmission. Thus, application of uninterrupted larval control measures in these 18 GN areas was of utmost importance for the prevention and control of DF/DHF.

High incidence of DF/DHF was also observed in the GN areas that were situated adjacent to the *Ae. aegypti*-prevalent GN areas. These GN areas contributed 23.2% cases to the total DF/DHF cases in MOH Kadugannawa, making these GN areas – together with *Ae. aegypti*-prevalent GN areas – contributing 68.13% to the total DF/DHF cases in the MOH area. The GN areas that are situated adjacent to the *Ae. aegypti* (immatures)-positive areas are within the typical flight range (<200 m) of *Ae. aegypti*, thus enabling *Ae. aegypti* adults to invade these GN areas.

This resulted in a high DF/DHF transmission in the adjacent GN areas of *Ae. aegypti* immatures-positive GN areas, even in the absence of *Ae. aegypti* breeding sites, making these areas vulnerable to DF/DHF.

This indicated the necessity of adult vector control measures for DF/DHF prevention and control in such areas irrespective of the absence of *Ae. aegypti* breeding sites. With the impending socioeconomic changes, the spread of *Ae. aegypti* is most imminent in
such GN areas. Thus, periodic entomological investigations in these GN areas are necessary to monitor the potential breeding sites of *Ae. aegypti* and for taking remedial measures.

Since there is a poor and negative correlation between BI of *Ae. albopictus* and DF/DHF cases, this species is less important as a vector of DF/DHF in MOH Kadugannawa. However, *Ae. albopictus* was reported to be naturally infected with dengue virus. Apart from being a vector of DF/DHF, *Ae. albopictus* is an important vector of chikungunya that emerged in an epidemic form in the country in 2006-2007. Some GN areas of MOH Kadugannawa were also affected by the recent outbreak of chikungunya in 2007 (Regional Epidemiologist, Kandy, pers. com.). This shows that MOH Kadugannawa area is highly vulnerable to chikungunya as well as that 92 GN areas (96.8%) were infested with *Ae. albopictus* and/or *Ae. aegypti*. Thus, continuous disease and vector surveillance and community-based vector control interventions are necessary for the elimination of potential breeding sites of *Ae. albopictus* and *Ae. aegypti* in order to prevent and control the occurrence of chikungunya in this MOH area.

From 2001-2007, the MOH Kadugannawa area contributed 7.73%–21.35% cases to the total DF/DHF cases in Kandy district. MOH Kadugannawa area always followed the trend of DF/DHF in Kandy district, especially during the epidemic periods. Since mid-2008, Kandy district showed an increasing trend of DF/DHF; accordingly, MOH Kadugannawa also showed an increase of DF/DHF in July 2008. Application of health education and source reduction in the high-risk 18 GN areas resulted in (a) downward trend of DF/DHF in Kadugannawa area as against the upward trend in Kandy district; and (b) a reduction in percentage contribution of MOH Kadugannawa to the total DF/DHF cases in Kandy district for the rest of the year.

During this intervention the GN area-wise distribution of DF/DHF, the presence of *Ae. aegypti/* *Ae. albopictus*, and the risk levels of DF/DHF in different GN areas were identified using GIS and GPS technology. These maps were very convenient in the identification of DF/DHF risk areas because: (a) they gave visual information on the DF/DHF risk levels of different GN areas that could be understood even by a non-technical person; and (b) these maps could be updated easily.

GIS-based dengue risk maps were developed in dengue endemic areas of South-East Asia and the Americas at spatial scales ranging from village, town, district to country. Some of these studies reported the feasibility of using *Aedes* larval indices for prediction of spatial risk for dengue transmission while others failed to find significant associations between *Aedes* larval density and spatial patterns of dengue incidence. However, the present study shows the feasibility of using epidemiological and entomological data for finer scale spatial risk mapping and control of DF/DHF in Sri Lanka. Incorporation of entomological indices (Breteau indices of *Ae. aegypti* and *Ae. albopictus*) gave an advantage over the use of only DF/DHF case data in spatial risk mapping.

In MOH Kadugannawa, there were 33 GN areas with DF/DHF cases and *Ae. albopictus*. The DF/DHF cases in these GN areas were sporadic and were reported with longer time intervals, indicating that these cases were not of indigenous origin (imported cases from other dengue transmission areas). Another 27 GN areas reported *Ae. albopictus* but there was no DF/DHF case. Incorporation of entomological data in risk mapping helped
to classify these GN areas as at “low risk” of DF/DHF. However, if only DF/DHF case data were used in risk mapping, these GN areas would have been identified as “high-risk” and recommended for more costly DF/DHF control measures such as space spraying and larviciding with insecticides. Incorporation of entomological data helped to identify the actual risk of DF/DHF transmission in each GN area, thus facilitating the application of DF/DHF control measures in a cost-effective manner.

In the preparation of risk maps, accuracy of entomological data is of utmost importance. During the present study, trained entomological teams were deployed for entomological surveillance. These teams surveyed a representative sample of houses in each GN area and included all high-risk premises/institutions of vector breeding, such as schools, offices, religious places, tyre shops, city transport bus depots, etc. Furthermore, if *Ae. aegypti/Ae. albopictus* immatures were not encountered during the first survey, two more such surveys were carried out in that particular GN area in order to confirm the presence/absence of *Ae. aegypti/Ae. albopictus*. Thus, it is very unlikely to get a negative result for a GN area that has the presence of *Ae. aegypti/Ae. albopictus*. However, regular entomological investigation in GN areas that are hitherto negative for *Ae. aegypti* and updating the risk maps accordingly is important as vector mosquitoes infest new GN areas when environmental conditions become conducive for vector breeding.

In conclusion, GIS and GPS is a useful tool in DF/DHF prevention and control. These technologies can be used not only for risk mapping but also for spatial and space-time modelling to visualize and analyse mosquito vector and epidemiological data in operational dengue vector control programmes. Geographical information system softwares are becoming more user-friendly and now are complemented by free mapping software that provide access to satellite imagery and basic feature-making tools facilitating the generation of static maps as well as dynamic time-series maps. This will also enable disease control programmes to generate risk maps for other parameters such as exposure to dengue virus, to develop priority area classifications for vector control, and explore the socioeconomic associations of dengue risk.

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**References**


