THE APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM TECHNOLOGY TO THE STUDY OF *AEDES ALBOPICTUS* (SKUSE) BREEDING SITES AND ITS IMPLICATION TO DENGUE TRANSMISSION (IN LUNDU DISTRICT, SARAWAK)

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ABSTRACT

THE APPLICATION OF GEOGRAPHICAL INFORMATION SYSTEM TECHNOLOGY TO THE STUDY OF *AEDES ALBOPICTUS* (SKUSE) BREEDING SITES AND ITS IMPLICATION TO DENGUE TRANSMISSION (IN LUNDU DISTRICT, SARAWAK)

Dengue fever (DF) and Dengue haemorrhagic fever (DHF) are gaining an ever-increasing foothold in Asia and the Americas. The present *Aedes* vector surveillance system and the use of "classical" *Aedes* indices remains an issue to resolve. Geographical Information System (GIS) is thought to be a new *Aedes* surveillance tool with the most potential as the data management system can gather all the information needed for dengue outbreak prediction. This study used GIS technology on *Aedes albopictus* in the rural dengue transmission area of Lundu District, Sarawak to achieve two main goals : a) To elucidate the association of various risk factors with dengue cases reported in Lundu district, 1999, and b) to design and develop a dengue surveillance system for the monitoring the vector *Ae. albopictus* in potential outdoor breeding sites.

Seven villages were chosen based on the high number of dengue cases reported. A total of 551 households were surveyed. An overall description of the socio-demographic background and basic facilities was presented together with entomological and geographical profiles. For serological and ovitrap studies, systematic random sampling was used. Serological tests indicated that 23.7% of the 215 samples had experienced asymptomatic dengue infection. Two samples (0.9%) were confirmed by IgM positivity and 49 samples (22.8%) had IgG responses. A total of 32,838 Aedes eggs were collected in 56 days of trapping. Cluster sampling was also done to determine whether any of the risk factors (entomological or geographical) were influenced by geographical location. These clusters were defined as border villages and roadside villages. The data collected were analyzed using SPSS version 10.01. Desciptive analysis using frequency, means, and median were used. To determine the association between variables and dengue cases reported, and to describe the differences between the two clusters of villages, two sample *t*-test, and Pearson's Chi-Square were used.

This research integrates GIS as a tool to improve the current dengue surveillance system. It provides some guidelines on how to build a data management system, which is the fundamental basis for active disease surveillance. Ideally, when the data are properly kept and managed, a prediction model can be produced for predicting dengue outbreak. However, due to the shortcomings of the data collected, it would be difficult to predict without a comprehensive mathematical modeling and testing. Accurate maps were produced with overlay and density function, which facilitates the map visualization and report generating phases. This study also highlights the use of differential Global Positioning System in mapping sites of 1m accuracy.

Analysis of the data revealed there are significant difference in clusters of villages attributable to container density, house density, distance of the house from the main road, and number of *Ae. albopictus* eggs from ovitraps set indoor, outdoor and in dumping sites (Person's Chi-Square=6.111, df=1, $p<0.01$). Further analysis using *t*-test showed that house density, container density, indoor mosquitoes egg count, outdoor mosquitoes egg count, and dumping sites mosquitoes egg count were higher at the roadside villages compared to border villages. A number of potential risk factors including those generated from GIS was investigated. None of the factors investigated in this study were associated with the dengue cases.

ABSTRAK

PENGGUNAAN TEKNOLOGI SISTEM MAKLUMAT GEOGRAFI DALAM MENGKAJI TEMPAT PEMBIAKAN *AEDES ALBOPICTUS* (SKUSE) DAN IMPLIKASINYA TERHADAP TRANSMISI DENGGI (DI DAERAH LUNDU, SARAWAK)

Insiden penyakit deman denggi dan deman denggi berdarah semakin berlipat ganda di Asia dan Amerika. Sistem pengesanan vektor *Aedes* yang digunakan sekarang dan indeks *Aedes* yang klasik masih merupakan isu yang perlu dikaji semula. Sistem maklumat geografi dianggap sebagai satu alat pengesanan *Aedes* yang baru dan berpotensi dalam berfungsi sebagai sistem pengurusan data yang mengumpul segala maklumat dalam meramalkan wabak denggi. Kajian ini menggunakan teknologi sistem maklumat geografi untuk mengkaji *Aedes albopictus* di kawasan transmisi denggi – daerah Lundu, Sarawak. Dua matlamat utama adalah 1) mengkaji hubungan antara faktor-faktor risiko dengan kes denggi yang dilaporkan di Lundu, 1999; 2) merekabentuk dan membangunkan satu sistem pengesanan denggi bagi memantau vektor *Aedes albopictus* di kawasan pembiakan yang berpotensi di luar rumah.

Tujuh (7) kampong telah dipilih berdasarkan bilangan kes denggi yang tertinggi. Sejumlah 551 rumah telah ditinjau. Semua deskripsi tentang latar belakang sosio-demografi dan kemudahan asas telah dibentangkan bersama profil entomologikal dan geografikal. Untuk kajian serologi dan ovitrap, kaedah persampelan sistematik secara rawak telah digunakan. Ujian serologi menunjukkan 23.7% daripada 215 sampel pernah mengalami jangkitan denggi tanpa apa-apa gejala. Dua sampel (0.9%) disahkan mempunyai IgM positif dan 49 sampel (22.8%) mempunyai IgG positif. Sejumlah 32,838 telur *Aedes* telah dikutip dalam 56 hari kerja lapangan. Persampelan kluster telah digunakan untuk menentukan samada faktor risiko (entomologi atau geografi) dipengaruhi oleh lokasi geografi. Kluster-kluster ini terdiri daripada Kampong di sempadan dan Kampong di tepi jalan. Data yang dikumpul dianalisa menggunakan SPSS versi 10.01. Analisis deskriptif yang digunakan terdiri dari frekuensi, purata dan median. Untuk menentukan hubungan antara faktor risiko dengan kes denggi, dan membezakan faktor-faktor risiko antara kelompok kampong, ujian *t* dua sampel dan *Pearson's chi-square* digunakan.

Kajian ini mengintegrasikan sistem maklumat geografi sebagai satu alat untuk memperbaiki sistem pengesanan denggi. Ia memberi garispanduan bagaimana membina satu sistem pengurusan data yang merupakan asas kepada pengesanan penyakit aktif. Sepatutnya, apabila data disimpan dan dikendali dengan baik, satu model ramalan penyakit denggi dapat dihasilkan. Akan tetapi, atas kekurangan data yang dikutip, agaklah sukar untuk meramal wabak penyakit denggi tanpa proses modeling matematik yang betul. Peta yang tepat dihasilkan dengan menggunakan fungsi "*overlay*" dan fungsi "*density*". Semua ini menyenangkan kefahaman peta dan penjanaan laporan. Kajian ini juga menekankan penggunaan GPS dalam menghasilkan peta yang mempunyai ketepatan 1 m.

Hasil analisis menunjukkan terdapat perbezaan yang signifikan antara kelompok kampong dalam faktor kepadatan bekas pembiakan, kepadatan rumah, jarak rumah ke jalan raya utama dan jumlah telur *Aedes albopictus* dari ovitrap yang dipasang di dalam rumah, luar rumah dan tempat buangan sampah (*Pearson's Chi Square*=6.111, df=1, p<0.001). Analisis ujian *t* selanjutnya menunjukkan kepadatan rumah, kepadatan bekas pembiakan, jumlah telur dalam ovitrap di dalam rumah, di luar rumah dan tempat buangan sampah lebih tinggi di kelompok kampong tepi jalan. Faktor-faktor risiko yang dijana dari sistem maklumat geografi tidak menunjukkan hubungan yang signifikan dengan kes denggi.

DEDICATION

To my late Father,

My Mother,

Petrus,

Aaron & Abel

And most of all

Thank you GOD
for your unfailing presence and blessings to me and my family

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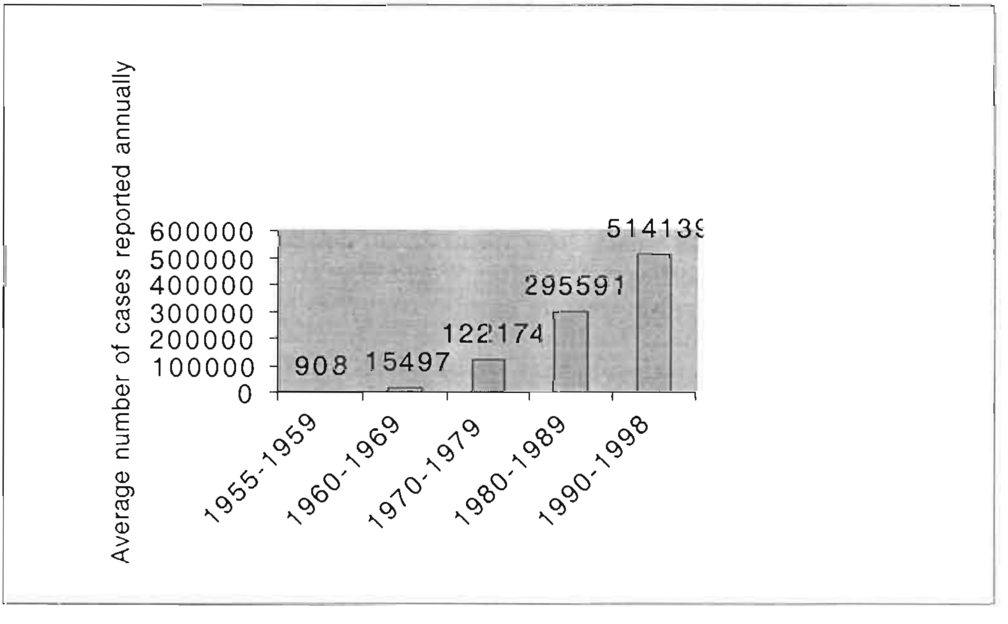
CHAPTER 1

INTRODUCTION

1.1. Background

Dengue fever (DF) and dengue haemorrhagic fever (DHF) are the most common arthropod-borne diseases worldwide with an increasing incidence (Figure 1.1) in the tropical regions of Asia, Africa, and the Central and South America (Gubler & Clark, 1955). They are acute mosquito-borne viral diseases, characterised by fever, headache, muscle and joint pains, rash, nausea, and vomiting. Some infections result in DHF, a syndrome that in its most severe form is life threatening. Affected persons normally have high fever (lasting 2-7 days), haemorrhagic phenomena (including vascular leakage of plasma), low numbers of platelets and sometimes circulatory failure. Some patients progress to shock, known as dengue shock syndrome (DSS), which can be rapidly fatal. The case fatality rate in patients with DSS can be as high as 44% (Rigau-Perez, 1998). Multiple infections are possible because immunity to one virus serotype does not provide immunity to the others.

Fig 1.1 Dengue/DHF, average annual number of cases reported to WHO, 1955-1998



Source: WHO Report on Global Surveillance of Epidemic-prone Infectious Diseases at (http://www.who.int/emc-documents/surveillance/docs/whocdscsrisr2001.pdf/dengue.pdf)

DF and DHF are caused by one of four closely related but antigenically distinct, virus serotypes (DEN-1, DEN-2, DEN-3, and DEN-4). According to Gubler (1998), previous infection from one dengue serotype or a sequence of infections can contribute to the risk of contracting the more severe DHF. However, a study done by Douglas et al (1999) in Iquitos, Peru showed that secondary infection by the American DEN-2 genotype did not cause DHF and DSS.

Dengue viruses are transmitted to human beings through the bite of infected *Aedes* mosquitos, principally *Aedes aegypti*. In some regions other *Aedes* species such as *Aedes albopictus* and *Aedes polynesiensis* are also involved. Once infected, a mosquito remains so for life, transmitting the virus to susceptible individuals during probing and feeding. Humans are the main amplifying host of the virus but some studies have shown that monkeys, in some parts of the world, may serve as a source of virus for feeding mosquitos (WHO, 1997).

1.2. Epidemiology

The first reported epidemics of dengue fever occurred in 1779-1780 in three continents; Asia, Africa and North America (Pepper, 1941; Howe, 1977). This indicated the closely simultaneous occurrence of outbreak demonstrated a worldwide distribution in the tropics for more than 200 years. The earliest record found was from the Chin Dynasty (265 to 420 A.D.). The Chinese at that time believed that water poisoning was the causal factor of the disease, the vector being flying insects that niched on water sources. There were other outbreaks in the French West Indies in 1635, in Panama 1699, Indonesia 1779, Egypt in 1779 which could also have been dengue.

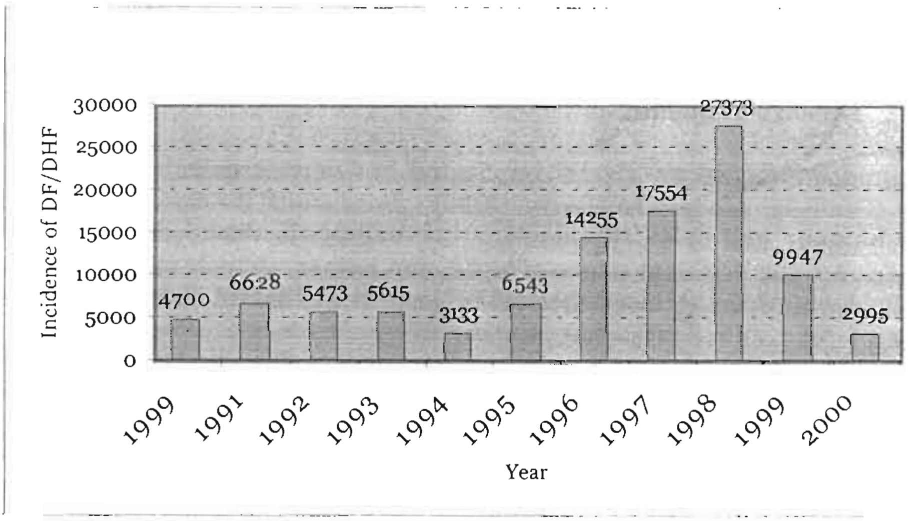
During the last 15 years, the number of dengue cases has increased tremendously in Southeast Asia after World War II. Epidemic DHF emerged as a major public health problem in most countries of South-east Asia and by 1975, it had become a leading cause of hospitalisation and death among children in many countries in that region (WHO, 1986).

The first epidemic of DHF was discovered in Manila (1953) and the disease remained locally in Southeast Asia through the 1970s (Hammon, 1973; Halstead, 1980). Since 1953, the DHF epidemic has spread into India, Pakistan, Sri Lanka and the Maldive Islands, and east into China (Gubler, 1998).

In the Americas, the first large epidemic of DHF occurred in Cuba in 1981 (Kouri et al., 1989) followed by Brazil in 1986-1987 (Gubler, 1993). In 1988, an outbreak of DF was reported in Mexico. By 1990, almost 25% of the 300,000 people living in Peru, had contracted DF (Kautner et al., 1997).

The first description DF and DHF in Malaysia was reported by Skae (1902) and Rudnick et al (1965a). In 1962, Penang was the first state in Peninsular Malaysia reported to have the first appearance of DHF, followed by Kuala Lumpur in 1963. It was in November 1962, that the first Malaysian case reported in Penang was confirmed by laboratory testing. Of 61 laboratory-confirmed cases in this outbreak the median age was 7.5 years and the case fatality was 8%. The incidence of DF/DHF increased between 1990 and 1991, but decreased about 21.1% in 1992. Fig. 1.2 Incidence of DF/DHF in Malaysia (unpublished data) showed there are irregularities in number of dengue cases until 1996, where the increase is more than 100%. Another increase of 56% was found in 1998.

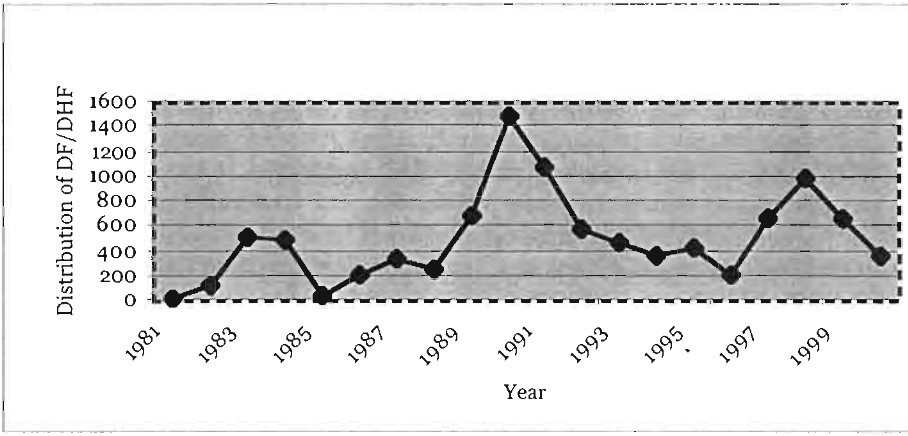
Fig 1.2 : Incidence of DF/DHF in Malaysia (1990-June 2000)



(Source : Ministry of Health, 2000)

In Sarawak, the first endemic classical dengue was reported by Surtees (1970), and *Aedes albopictus* was suspected to be the only vector involved. However, *Aedes aegypti* also played an important role as the known DF vector in most of the major towns of Sarawak (MacDonald & Rajapaksa, 1972). Sarawak encountered its first epidemic in 1982 with 120 suspected cases, 41 serologically confirmed (Chang, 1981). Since 1981, the incidence of DF/DHF has shown a different pattern from Peninsular Malaysia. Most DF/DHF occurred in 1990, 1991 and 1998 with the figures as stated in Fig. 1.3.

Fig 1.3 Distribution of DF/DHF in Sarawak 1981-June 2000.



(Source : Sarawak Health Department, Ministry of Health, 2000)

1.3 Disease Transmission

The predominant vector species implicated in dengue transmission are *Ae. aegypti* and *Ae. albopictus* (Barry, 1996). Because of its close association with humans and their environment, *Ae. aegypti* is the most important; humans are the principal source of blood, and human utensils (anything that will hold water) are primary sites for oviposition and larval development. In parts of Asia and South America and West Africa, *Ae.albopictus* is an important vector because it utilizes both natural and artificial larval habitats. Recently it has spread as far as Europe and the United States, via by shipments of used automobile tyres (Gubler, 1997). This is causing concern among health personnel.

Ae. aegypti was introduced into Malaysia during the 19^{th} century and the spread occurred only in the coastal cities due to the sailing ships. Studies by Macdonald (1956), and Rudnick (1986) showed distribution in the interior towns in West Malaysia. Surveys done in Penang (Paramaevaran, 1965) showed that *Ae. aegypti* was more common in low-cost housing and in crowded, central areas of the city compared to *Ae. albopictus*. The latter was more common in middle and high-cost housing, in gardens, parks and in the outer urban and suburban areas.

In Sarawak, Chang and Nagum (1982) discovered that *Ae. aegypti* can mostly be found in the coastal villages, where a piped water supply is not available. As for cities and town, it is more visible in the squatter houses and slum areas. *Ae. albopictus* is however, more widespread in primary and secondary forests, as well in as rural towns and plantations.

1.4 Distribution of *Ae. aegypti* and *Ae. albopictus*

Ae. aegypti is a domestic mosquito and breeds both indoors and outdoors in variety of artificial containers like water storage tanks, drums, tyres, tins, pots, pans, cups, bowls, clay ware and ant traps.

Ae. albopictus, on the other hand, is found more widely outdoors, in tree-holes, bamboo stumps, fallen leaves, leaf axils, fallen coconuts and cocoa husks. This explains why *Ae. albopictus* could have originated in the forests. However, it is not known what is the exact timeframe during which *Ae. albopictus* developed the ability to colonize in man-made containers. The toleration capacity of *Ae. albopictus* in polluted water is better than *Ae. aegypti*. The eggs of *Ae. albopictus* can resist desiccation for several months because it has a photoperiodic egg diapauce, allowing colonization of temperature regions (Hawley, 1988). Chang & Nagum (1994) in their study discovered that household septic tanks in the urban towns are also a good breeding ground for *Ae. albopictus*. In the rainy season, larger number of potential *Ae. albopictus* larva habitats are produced. This is why the density of this species is more influenced by rainfall than *Ae. aegypti* (Gubler & Kuno, 1997).

In Asia, *Ae. albopictus* has been implicated as a vector of DF epidemics (Russell et al., 1969, Chan et al., 1971b). Dengue virus has been repeatedly isolated from field collected *Ae. albopictus* (Chow et al., 1998). *Aedes albopictus* is capable of the transovarian and venereal transmission of dengue virus (Rosen et al., 1978). However, in most discussions on dengue, *Ae. albopictus* is viewed as an unimportant dengue vector and sometimes is not even mentioned. This is because *Ae. aegypti* was observed to be the only vector in urban southeast Asia. *Ae. albopictus* is usually viewed as a rural vector, although in some of the urban outbreaks, it has a role. In Malaysia, it is reported that in most rural areas where *Ae. albopictus* is more common than *Ae. aegypti*, the inhabitants show higher prevalence of dengue antibody than those in the urban areas (Smith, 1956). This suggests that, in rural areas, *Ae. albopictus* is the vector that transmits mild or asymptomatic dengue infections.

1.5 Research Problem

The epidemiological importance of *Ae. albopictus* in dengue transmission is evident in the recent outbreaks in Singapore and Malaysia. It is estimated that the biting density of this species away from the housing was in a ratio of nearly 1 *Ae. aegypti* to 6 *Ae. albopictus* (Chang et al., 1999). In a study carried out in Singapore (Chow et al, 1998), the infection rates of field caught *Ae. aegypti* and *Ae. albopictus* in a dengue transmission site were almost equal. There is also evidence that this species is also slowly replacing *Ae. aegypti* as a vector in areas where previously two species co-exist (Rai, 1999). The aggressive dengue vector control programme implemented in Malaysia will only eliminate the indoor species – *Ae.aegypti*. This will be replaced by the more dominant *Ae. albopictus*.

Furthermore there is no specific treatment for DF. Protection against only one or two of four different dengue serotypes might actually increase the risk of more serious disease. Thus, the development of vaccines for specific serotypes difficult. At present, the only method of controlling or preventing DF and DHF is to combat the vector mosquito which, in Asia, breeds primarily in man-made containers such as domestic water storage vessels, bottles, cans, used tyres and other items that retain water.

The WHO Special Programme for Research and Training in Tropical Diseases (TDR) on dengue recognises the need to improve current tools for surveillance, notably surveillance of its vector by using new approaches such as the Geographic Information System (GIS). One of the current dengue vector surveillance system used by dengue endemic countries worldwide is the house-to-house larval survey as recommended by the WHO (1972). There are many problems associated with the routine, repetitive nature of these surveys for *Ae. aegypti* and other vectors of DF. One of the main problems is that the survey teams may become less meticulous in their search for breeding sites. This is reflected in underestimation of larval prevalence (WHO, 1999). Furthermore, the house-to-house survey (house inspection) carried out by the team is unable to locate the *Ae. albopictus* breeding sites. This species is less associated with indoor containers and tends to colonize outdoors, in abandoned breeding sites. That explains the lack of reliable measurement of density for this species. The degree of shading and distribution of such containers and their relative abundance may show strong correlation with both the proportion of positive premises and the numbers of *Aedes* infested containers therein. More sensitive and comprehensive indicators should be developed and incorporated into the current surveillance system and perhaps it will be more appropriate to design a new surveillance system that caters specially for this species.

The ability of a dengue control program to respond to epidemics in a timely manner should be examined with a view to improve indicators and surveillance systems to ensure that the information is relevant and available for decision making purposes. Currently, the data management system relies very much on conventional data keeping, using manual input, and databases used have no interactive function. Report generating often takes a long time because information need to come from various sources. It also is not linked to any geographical information, which can play an important role in decision making. A delay in decision making process hampers the control of DHF epidemics.

Another deficiency is there is the lack of a mapping system. A good mapping system will facilitate the work of tracing the residential houses with dengue cases and to find out the location of other possible breeding sites like dumping site, vacant or abandoned or waste land, and construction sites. All these elements are important for planning surveillance activities.

A new surveillance system should be developed to meet the above requirement. GIS is thought to be suitable as its data management system can gather all the information needed for further analysis of risk factors. Vital information on *Aedes* breeding sites can be gathered through the use of GIS, and such information is of paramount importance to understand the basic ecology of *Aedes* mosquitoes, particularly *Ae. albopictus*. Information required includes are house position, shrubbery shading, position of dumping site, distance from house to dumping site, distance house from the main road, density of houses within a range, population density and other related environmental factors.

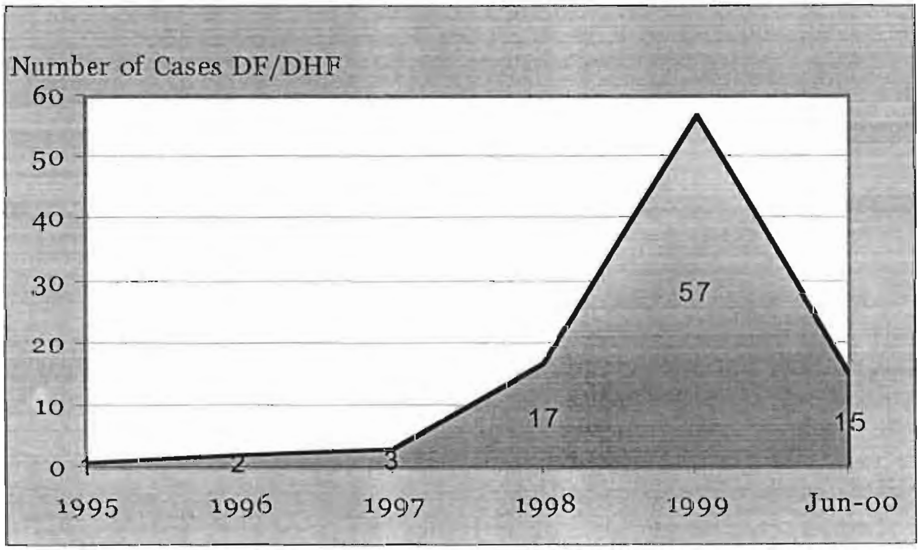
1.6 The Case Study-Lundu

Lundu, one of the districts located in the Kuching division of Sarawak, lies between a latitude of 2° 1/6' north and longitude of 109° 15' east, bordering Kalimantan, Indonesia to the east.

Geographically, the district consists of hill forestland. The population consists of different ethnic groups with Bidayuh as the majority.

The dengue incidence in Lundu remained minimal until 1998 when there was an increase of 14 cases reported, compared to the year before. In 1999, an outbreak occurred with 57 cases reported. The details of the outbreak is are Fig. 1.4.

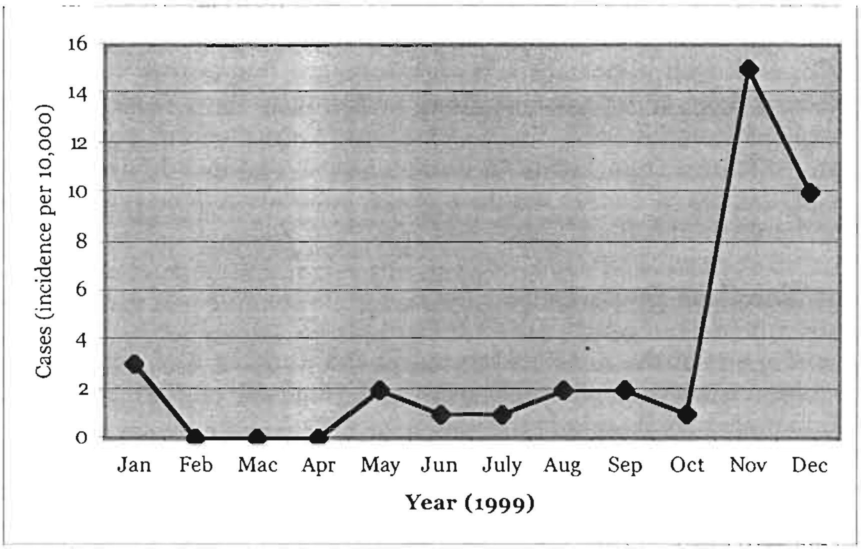
Figure 1.4 Dengue cases in Lundu 1995-June 2000



(source : Sarawak Health Department, Ministry of Health, 2000)

The three main areas where the outbreak occured were Stommuda, Pasir Ulu/Biawak and Sematan. The monthly and daily occurence of dengue cases by locality is shown in Fig. 1.5 and Table 1.6.

Fig. 1.5 : Monthly Distribution of DF/DHF cases in Lundu, Sarawak (1999)



(source : Sarawak Health Department, Ministry of Health, 2000)

Out of the 57 cases reported, 34 cases were serologically confirmed. The first three cases were reported in the month of January in Kampong Stungkor Lama but they were serologically negative. The first serologically confirmed was from Kampong Sileng Dayak. After one to two cases reported in the next three months, the disease reached its peak with 45 reported cases in November and December 1999. Admission and management of the patients was done through the Lundu district hospital, Kuching General Hospital and Bau District Hospital. All serology tests were done at the Sarawak General Hospital.

Fig. 1.6 : Daily Distribution of DF/DHF cases in Lundu 1999 (During the outbreak October-15 December 1999)

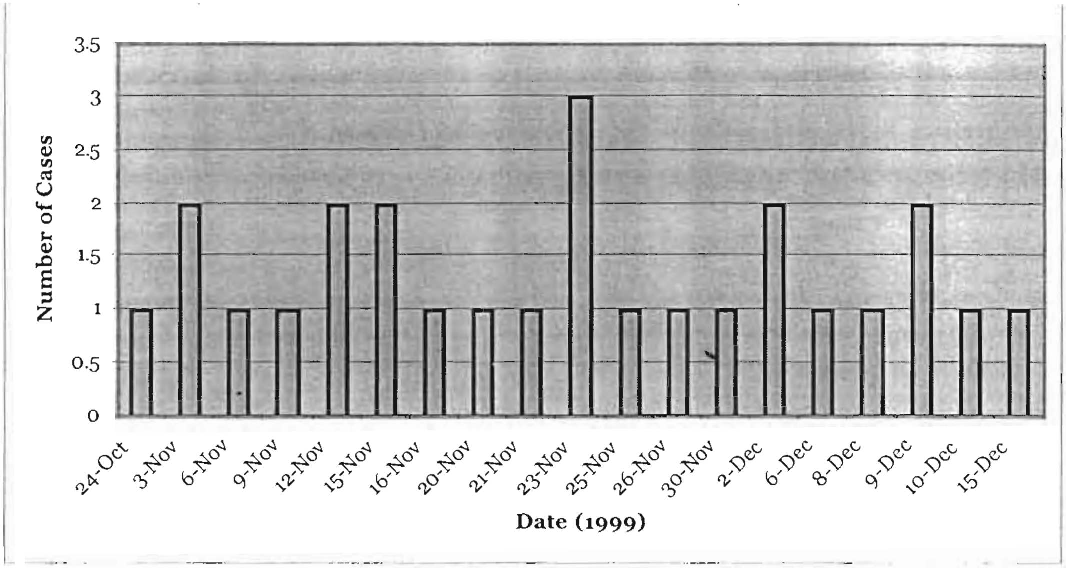
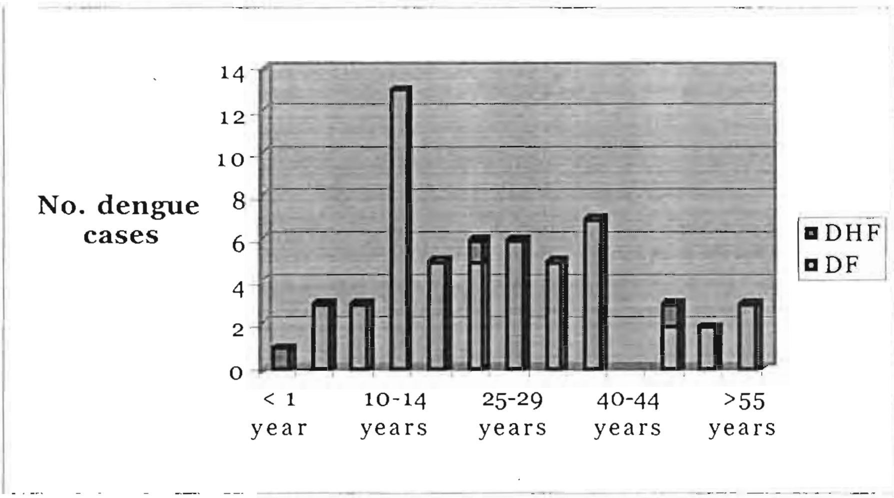


Fig. 1.7(a) : Number of DF/DHF cases by age (1999)



(source : Sarawak Health Department, Ministry of Health, 2000)

Fig. 1.7(b): Number of dengue cases by gender (1999)

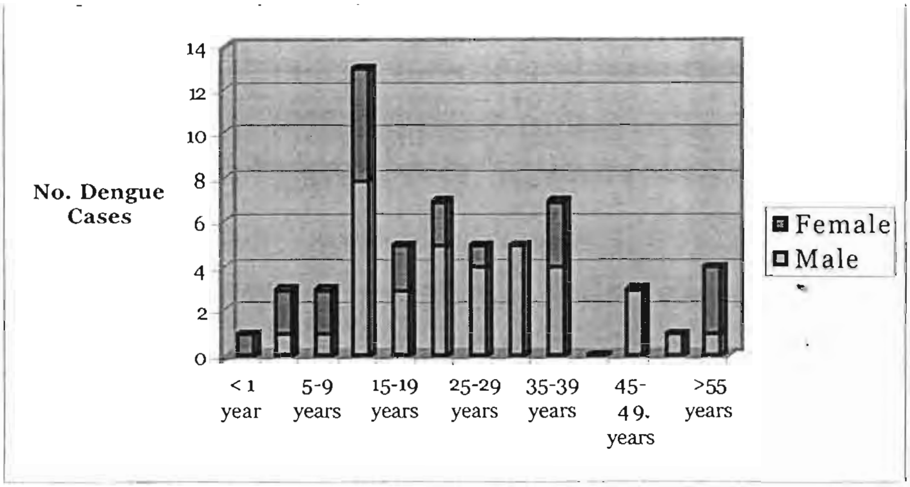
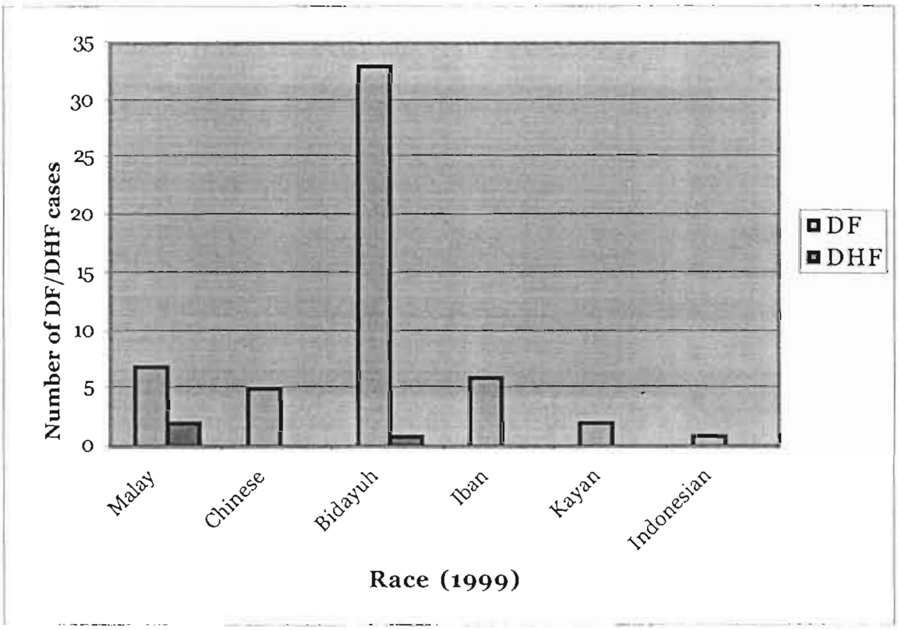


Fig. 1.7(c): Number of DF/DHF cases in each race (1999)



1.7 Objectives

The main objectives of this study are:

a) To explore the association of various risk factors with dengue cases reported in Lundu Hospital in 1999.
b) To design and develop a dengue surveillance system using GIS technology to monitor the potential *Ae. albopictus* breeding sites outdoors.

Within the above objectives, the project aims:

a) To describe the socio-demographic background of the households affected by dengue and the basic facilities available in their villages
b) To study the spatial and non-spatial distribution of the following categories (based on villages)
    - Village position
    - House position, case house position with relation to geographic features
    - Human Population
    - Containers density
    - Shading tree position
    - Dumping sites position
    - Egg density count per positive ovitrap (indoor, outdoor and dumping sites)
    - Serology result.

c) To describe the types of outdoor potential containers found in the villages
d) To determine whether there is any significant difference among the two clusters of villages (Kalimantan/Sarawak border villages, roadside villages) in term of dengue cases reported in 1999

If there is evidence of significant differences, are there any statistical differences among the two clusters of villages in terms of :
- *Aedes* breeding container density
- Human population density
- House density
- Distance of the dumping site to the house
- Distance of the house to the main road
- Shading tree density
- Dengue specific IgG and IgM positivity rate
- Egg density count per positive ovitrap (indoor, outdoor and dumping sites).

e) To determine the relationships between dengue cases reported in 1999 and possible risk factors as follows:
    - Shading trees density
    - Distance of dumping site from the house

- o Distance of the house from the main road
- o Human Population density
- o House density
- o *Aedes* breeding container density
- o Egg density count per positive ovitrap (indoor, outdoor and dumping sites)
- o Dengue specific IgG positivity rate.

1.8 Research Hypotheses

In relation to the objectives of this study, the following hypotheses were formulated:

H_1 There is significant difference between the two clusters of villages (border villages, roadside villages) in terms of :

- o dengue cases reported in 1999
- o *Aedes* breeding container density
- o House density
- o Human population density
- o Distance of the dumping site to the house
- o Distance of the house to the main road
- o Egg density count per positive ovitrap (indoors, outdoors and dumping sites)
- o Dengue specific IgG positivity rate.

H_2 There is relationship between dengue cases and following possible risk factors:

- o Shading trees density
- o Human population density
- o Distance of dumping site from the house
- o Distance of the house from the main road
- o House density
- o *Aedes* breeding container density
- o Dengue specific IgG positivity rate
- o Egg density count per positive ovitrap (indoors, outdoors and dumping sites).

1.9 Significance of the study

The principle contributions of this study are as follows:

- To give a new dimension to the existing dengue surveillance system within the context of the *Ae. albopictus* study by exploring, the use of GIS as a tool, in a rural area like Lundu, Sarawak.
- To provide research-based evidence to seek confirmation of the involvement of geographical factors in dengue transmission based on the 1999 dengue outbreak in Lundu as a case study

- To produce a dengue surveillance system specially for *Ae. albopictus*. This will consist of Dengue Database Management System, a Dengue Prediction System, and an Dengue Output and Report system.

1.10 Scope of the study

It has been recognised, from the beginning of this study, that there are significant limitations. This study was conducted in Lundu District within only one epidemiological year. Therefore, the findings may not reflect all other dengue outbreaks in Sarawak. It should be mentioned here that this proposed study does not take into consideration of the immune status of the human population, the changing of dengue serotypes and the number of virus strains circulating, which have been regarded as one of the most important factors in causing the epidemic of DHF. Thus for this study, "risk factors" denotes only the entomological and environmental factors.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the relevant literature on the factors influencing the transmission of dengue virus, with emphasis on the vector, human and geographical factors. It also reviews some issues on the existing dengue control and surveillance methods practised generally, and the potential of GIS in public health, specifically for dengue control. The aims of this review are to understand how these factors are related to the planning of a dengue surveillance system.

2.2 Factors influencing the transmission of dengue viruses

Over the years, despite the importance of factors influencing the transmission of dengue fever and its prevention and control, systematic analysis of these factors has not been given adequate attention. The reasons include lack of research, problems in information retrieval and difficulties designing investigative strategies (Kuno, 1997).

A study done by Foo et al (1985) in Selangor showed that there was a strong association between rainfall and dengue incidence. Peak transmission often happens during the rainy season. Rainfall, flooding, trash disposal and general sanitation such as water retention in roof gutters and drains may contribute to dengue epidemics. This is similar to Rudnick's study in Penang (1975) which emphasised that water storage and type of water supply are the important factors in dengue transmission. The principal larval breeding site for *Ae. aegypti* is water storage containers, which were one of the common breeding sites found in the Americas (Gubler, 1998). These findings were further confirmed by a study done in India by Lall & Dhanda (1996), where dengue outbreaks occur mostly during or after the rainy season. Chadee's (1990) study also found a similar pattern where fluctuation of mosquitoes due to the increase of container exposed to the rain water in Tobago, West Indies during the rainy season. However, a study performed in Singapore failed to find a positive correlation between rainfall and vector population (Goh, 1987). Therefore this correlation needs further confirmation.

Ambient temperature is of importance in dengue transmission because it influences vector distribution, blood feeding activity of the vector, the extrinsic incubation period (EIP) and adult longevity (Kuno, 1997). However, it is likely to affect countries in subtropical or temperate regions.

Another factor influencing transmission of dengue is transportation of the vector. Before the advent of air travel, ships were the main means of intercontinental travel for the spread of vectors and viruses. For example, *Ae. aegypti* was introduced to Malaysia during the 19^{th} century, coastal cities being the first recipients of vectors brought over from foreign countries via ships (Smith, 1956).

Ground transportation also provides an efficient mechanism of dissemination of mosquito vectors and viruses. This can be confirmed by studies done by Wellmer (1983) and Soper (1967). When the number of automobile used for transportation increases in dengue endemic urban areas, the more rapid and greater opportunities contact among human and virally infected vectors. Is it possible that those who stay near the main road are being subjected more to dengue transmission? Or will a better road communication system also be one of the contributing factors? Further research is needed to substantiate these assumptions.

Other factors responsible for the reinfestation of epidemic dengue and DHF, which can cause a public health problem may be closely associated with demographic and societal changes (Gubler & Kuno, 1997). The two major factors are, (1) global population growth and (2) unplanned, uncontrolled urbanisation in tropical developing countries. These two factors involve to the unplanned housing developments, overcrowding, and deterioration in water, sewer and waste management system and have created ideal conditions for increased transmission of mosquito borne disease in both urban and rural areas.

Because disease spread is a function of the probability of contact between human, virus and mosquito, transmission is facilitated in any *Ae. aegypti*-infested location where people congregate, resulting in either transmission from infective mosquitoes to humans or from viaremic humans to uninfected mosquitoes (Kuno, 1997). Wherever people congregate, the probability of contact among virus, female mosquito and virus increases.

Although dengue epidemics occur more frequently in urban than in rural environments, outbreak in the latter areas are not infrequent. Shekhar & Ong (1992) documented that in Malaysia between 1975 and 1987, DHF cases in urban areas decreased by 67% compared to rural areas, which by contrast, showed an increase by 25%. This indicates an increase in human traffic in rural areas, or urbanisation of rural areas. Chang & Nagum's (1986) study in Lawas, Sarawak found a similar pattern. The movement of rural people to urban areas to buy their domestic provision, and the exodus of students from urban schools to rural villages for festive holidays contributes to dengue transmission in rural areas.

Besides the human factor, the practice of using or storing water in living quarters can influence vector density and hence mosquito biting activities. In parts of Malaysia, residents still store water in or near the house. When piped water is available but with unreliable supply, residents tend to keep water storage tanks or other containers, which often cause higher vector densities (Barrera et al., 1993)

2.3 Principles of Dengue Control

The effort to eradicate *Ae. aegypti* started more than 40 years ago. In the recent years, there has been a shift in focus from eradication to control of the mosquitoes. Operational constraints, the labour-intensive nature of some of the methods used, and changing public attitudes, together with the increasing development of insecticide resistance, have prompted the search for more appropriate, effective and affordable approaches to mosquito control. To vector control personnel, community based programs hold considerable appeal because they are less costly, especially in terms of demand for manpower. With participation from the community, there is a tendency to shift towards the adoption of integrated strategies including source reduction, and sometimes biological control methods. Rosenbaum et al (1995) in their study emphasised the importance of community participation in designing interventions which will be easy to sustain in later stages. When planning community-based vector control initiatives for the prevention and control of dengue, effort should be concentrated on the need for broad-based environmental sanitation strategies. Two examples to be considered in such circumstances are repair and mosquito proofing of septic tanks and the application of expanded polystyrene beads to wet pit latrines to provide a barrier against egg laying by mosquitoes. Public health education using various mass media approaches is also effective. Prevention can be adapted once the community knows the importance of vector control. The content of the public health education syllabus is an important consideration, as some studies (Nathan, 1993) showed that the community may have a high level of awareness about dengue and its aetiology, but poor understanding of the symptom and little concern about the health risks associated with it.

In Malaysia, the dengue control program was set up in 1975 following the national epidemics of dengue 1973-1974 (Cheong, 1986). The dengue control program was amalgamated with the vector-borne Disease Control Program in 1983. The objectives are to reduce morbidity and mortality due to dengue; to promote public support and community participation in the prevention and control of dengue; and to obtain the full participation of the local authorities in dengue control activities. The strategies employed in vector control are directed both at the larval and adult stages of the *Aedes* mosquitoes. For larval control, the activities carried out are environmental management and source reduction measures, use of the larvicide Abate, regular house inspection and the enforcement of the Destruction of Disease-Bearing Insects Act, 1975. For adult control, fogging activities are instituted as soon as a case of dengue is notified in order to prevent the spread of the dengue virus. In outbreak situations, ULV fogging is carried out. The use of household pesticides in the house, mosquito nets, aerosol repellents and screening of windows and doors are widely practised by the local community.

Although there have been many efforts and approaches to sustaining a good dengue control program, the dengue situation as a whole has not improved very much. This is because effective control depends on many factors which are interconnected. In spite of these constraints, health authorities are still continuing to use the present approach. Human behavioural change, a promising potential approach, is not fully exploited yet. As long as a vaccine is not available for public use, chemical insecticides will continue to be an important intervention methodology.

2.4 Dengue Surveillance

Dengue surveillance is an important component of the dengue control program. In addition to monitoring secular trends, the goal of such surveillance is that it should provide an early warning or have predictive capability for epidemic outbreak. The rationale is that if epidemics can be predicted, they can be prevented by initiating emergency mosquito control. Most surveillance systems detect only a small proportion of all occurring cases because of the existence of asymptomatic, atypical, undiagnosed or unreported cases (Rigau-Perez and Gubler, 1997). However, surveillance still remains important if it is done efficiently, cost effectively, and can serve as an early warning measure.

There are two main systems available, namely disease surveillance and vector surveillance.

Disease surveillance is usually established by legal mandate, in order for health care personnel to report specific diseases or diagnostic categories to public health authorities. A surveillance system based on reports is said to be "passive". Active surveillance for a disease relies primary on information collected by personnel assigned to retrieve data on the disease or condition of interest. Disease surveillance is normally laboratory based. Laboratory based surveillance for dengue must be proactive, and have at least three components that place the emphasis on the inter- or pre-epidemic period. These three components are sentinel clinic and physician network, fever alert system, and sentinel hospital system. Individually, the three components are not sensitive enough to provide effective early warning, but when used collectively, they can often accurately predict epidemic activity (Gubler and Casta-Velez, 1991).

Prevention and control of DF and DHF currently depends on controlling the mosquito vector, thus vector surveillance is an essential part of a dengue surveillance program. In mosquito control, feedback is obtained by surveillance of adult mosquitoes or their larval sites. Initial surveys normally will identify the species of vector present and provide information on locations, densities, disease potential and larval habitats. This information will facilitate the planning of a control program.

A basic inspection program usually addresses adult and larval population densities and species composition, rainfall and tide monitoring, and breeding site locations (University of Florida & the American Mosquito Control

Association, 2001). Sometimes if additional information is needed, specialized surveillance may be carried out to detect arboviral presence in the mosquito population, operation of ovitrap (especially for *Ae. aegypti* and *Ae. albopictus* species), or sampling of mosquito eggs to locate breeding sites. This information provides justification for source reduction and insecticide applications, and also serves as an ongoing indicator of the effectiveness of the control program carried out in the area. Of course, such inspection might not be able to determine the absolute population of mosquitoes, but it can show fluctuations in relative mosquito abundance and diversity over time in the various habitats visited.

Ovitraps has been used by many workers in North America as a routine surveillance method. Fay & Eliason (1966) found that one mosquito inspector could cover a three to five times larger area and if oviposition surveys were made instead of larval surveys, and the costs were halved, or even quartered. Fay and Eliason (1966) considered that ovitrap surveys were more sensitive than larval surveys in detecting the presence of *Ae. aegypti*. Although primarily developed for *Ae. aegypti* surveillance, ovitraps when used in America has attracted ovipositing adults of other *Aedes* species, including *Ae. triseriatus, Ae. atropalpus, Ae. mediovittatus, Ae. zoosophus* and *Ae. albopictus* (Pratt & Kidwell, 1969). The most effective attractant for *Ae. albopictus* was hay infusion (Holck et al., 1988).

The importance of ovitrap in predicting population size has been stressed by Cuellar (1969). Field evaluation showed that the ovitrap was potentially a sensitive and efficient technique for detecting populations of *Ae. aegypti* (Chadee & Corbet, 1990b; Ritchie, 1984)

A good, reasonably accurate and comprehensive map is important in conducting a mosquito control operation. Maps provide information for field survey, program evaluation, reporting and budgeting purposes. Information like elevations, streets, roads, railways, ponds, lakes, streams, sewage lagoons, flooded areas and other potential breeding sites are essential for locating and plotting larval breeding places and adult sampling stations. When large areas are involved, the maps will be a necessity for better viewing and planning of control activities.

Surveys of larval-infested containers are widely used in mosquito control. Results are presented as "larval indices", a misleading term because they are based on counts of containers, not larvae. Three other indices are commonly cited: House index, Breteau index and Container Index.

Sheppard and co-worker (1973) in their finding have suggested the use of single larval collection for *Ae. aegypti* index instead of large numbers of larvae required. This method is less time consuming and untrained staff can be employed for the job with limited supervision. However, this method fails to record if there are other species that share the same habitat.

The most serious limitation of *Aedes* indices is that they do not address productivity, that is the number of adult *Ae. aegypti* produced over time (Tun Lin et al., 1995). Container size, degree of larval crowding, availability of nutrients and other factors can influence this productivity. Thus, the relationship between container indices and vector density is highly variable. It is hard to define the relationship between *Aedes* indices and epidemic risks.

2.4.1 Current Methods used for Dengue Vector Surveillance in Study Area

In the study area, Lundu, dengue vector surveillance has been carried out based on the guidelines from the Ministry of Health, Malaysia (Panduan Pencegahan dan Kawalan Penyakit Deman Denggi/Deman Denggi Berdarah, 1986). Generally, vector surveillance activities consist of :

a) Collecting and computing entomological data
b) Analyzing and collating entomological data
c) Reporting data to the Vector-borne disease Headquarter
d) Providing feedback to the Vector-borne disease district level

The objectives of carrying out these activities are:

a) To assess regularly the *Aedes* situation and density in terms of time and space
b) To correlate the distribution of dengue cases with *Aedes* vector density
c) To pin-point high risk areas (areas with high vector density) through plotting vector distribution and dengue cases on a map, so that these areas could serve as priority areas for control activities during normal conditions and especially during dengue epidemics.
d) To monitor periodically the insecticide susceptibility status of the *Aedes* mosquitoes.

The strategies used by the local health personnel emphasise more on larval surveys and will be supplemented with adult surveys if they have the necessary skill and experience to do so. In normal circumstances, the surveys are carried out once in every three months except in high risk areas where they are carried out at least once a month. All larvae found are collected for identification by the health personnel. A weekly report is generated based on the results of the larval survey.

Separate *Aedes* indices for *Ae. aegypti* and *Ae. albopictus* are computed based on two indices-*Aedes* Index and Breteau Index. The Breteau Index is the best single index for estimating density, especially when it is used in defining high risk areas.

Processing of the dengue field data is normally done using database and simple statistical analysis to provide descriptive results such as frequencies and means.

The output is normally prepared in the form of a report presented in a spreadsheet. The health personnel use this information to help them in taking necessary approaches like taking any immediate control activities.

Data collected during the surveys are mostly kept in a database that does not reflect any geographic information, especially the actual distance or the exact location. Most of the dengue survey teams only map the case houses based on a sketch map with no exact locations and distances. Since *Ae.albopictus* is an outdoor species, the abundance of larvae breeding sites is readily affected by factors such as : the presence of dumping sites and their distance from the village, the presence of shading trees in the house compound and the distance of outdoor containers from the case houses. These aspects usually are not taken into consideration in the conventional larval survey methods.

2.4.2 Discussion

The present dengue surveillance system has a few limitations, as described below:

a) does not address the presence of *Ae. Albopictus* (an outdoor species) especially during the house-to-house survey where House Index and Breteau Index do not acknowledge the outdoor species
b) lacks proper and accurate mapping system
c) absence of proper data information management system
d) does not address some of the risk factors which are related to geographical parameters, example : distance, shading tree density, etc

The growing prevalence of dengue worldwide has led many agencies and institutions, including the World Health Organisation to call for the development of new and innovative approaches to dengue surveillance and control. An important issue in this development is the recognition of the variability of environmental and epidemiologic parameters that influence the pattern of dengue vector distribution and disease transmission risks (Washino & Wood, 1994). Unfortunately, current techniques/methods in dengue surveillance and control are labour-intensive and time-consuming.

Data collected in the field are not managed in a systematic way and thus the reporting process is longer than necessary. The information transmitted to headquarters is only a summary format and detailed results need to be traced back to the raw data collected by the field health worker. Sometimes the summary results can be misleading or some hidden important information can be easily missed.

The sketch maps produced by the field health workers are not to scale as there is no incentive to do this so. As a result, some of the important geographical parameters which can be risk factors in dengue transmission are overlooked.

The GIS has been recommended in solving some of the issues above.

2.5 Geographic Information System (GIS)

Over the years, information technology has become critical to public health practice and management. By linking public health workers by means of electronic networks, information can be disseminated and exchanged rapidly and public health threats can be detected earlier, to enable rapid responses and actions.

To be successful in the management of a dengue vector control program, it is important that all the basic information (the surveillance of species, dispersal and dynamics of vectors, detection of breeding sources, and the recording of dengue cases and epidemic periods) should be manipulated properly and efficiently in order to control disease transmission. To access all these data from different sources at all levels of the health care system is generally very challenging. Although a large quantity of data are collected routinely or under special projects, the information is synthesized at the level where it was collected, then transmitted to the next level where it is aggregated and further transmitted until it is difficult to isolate the basic information. Data are often reported in the form of tables or isolated figures. To read and understand these reports is labour-intensive and time consuming. The GIS promises to change this.

New computer-based sensor technology and geographic methods have led to emerging interest in the use of satellite environmental assessment tools for design of disease control programs, especially for those that are vector borne (Focks et al, 1999). Use of statistical and image analysis methods such as GIS allow computer-based analysis of multiple layers of mapped data in digital form. Output produced inclusive of earth-observation satellite data, maps of host populations, vector distribution and disease prevalence. Once created, GIS provides a dynamic, easily updated mapping system that can be very useful to health personnel to plan and monitor disease-control programs (Malone et al., 1997).

A GIS can be defined as a system of hardware, software, data, people, organisations and institutional arrangements for collecting, storing, analysing and disseminating information about areas of the earth (Dueker &

Kjerne, 1989). The system can integrate the acquisition, storage, analysis, and display of geographic data. Generally, the objectives of a GIS are the management (acquisition, storage, maintenance), analysis (statistical, spatial modelling), and display (graphic, mapping) of geographic data.

Scholten and Lepper (1991) indicated that GIS is a very useful tool for health researchers and planners because health and ill-health are affected by a variety of life style and environmental factors, including locations where people live. Characteristics of these locations (including socio-demographic and environmental exposure) offer a valuable source for epidemiological research studies on health and the environment. By helping researchers to understand the distribution and diffusion of disease and its relationship to environmental factors, it is valuable to etiology, epidemiology and medical science.

Modern GIS systems provide the quick response needed for public health decision making. Mapping without computers is a tedious job. With GIS, detailed maps can be generated and revised (with added data layers) over and over again, especially suited to the cost-effective or focused allocation of scarce resources. GIS also facilitates policy development as it provides the basis for data sharing partnership between the local health department and other entities of local and state government and the community (Yasnoff & Sondik, 1999).

Compared with tables and charts, maps developed using GIS can be an extremely effective tool to help health personnel visualize and understand a public health problem. GIS technology enables detailed maps to be generated with relative speed and ease. Several advantages of GIS technology for public health practice, planning and research are as follows (Richard et al., 1999):

a) GIS technology improves the ability of practitioners, planners and researchers to organise and link datasets which will contribute to a better cost-effective intervention planning;
b) GIS technology provides public health practitioners and researchers with new types of data ranging from satellites images, aerial photographs, global positioning systems, demographic data and other relevant data;
c) GIS technology encourages the formation of data partnership and data sharing at the community level; and
d) As new GIS methods are developed, they can be added to the "toolkits" of epidemiology and health services research

There have been many studies using techniques such as remote sensing technology for vegetation and terrain classification in mosquito vector control (Hay et al., 1998). The majority suggests that the use of remote sensing will be particularly appealing to agencies responsible for broad area disease control in developing countries having minimal public health facilities.

Literature reports on remote sensing refer to studies on *Psoraphora columbiae* (Welch et al., 1989), *Ae. solicitans* (Barnes and Cibula, 1979), *Ae. aegypti* (Moloney et al., 1998), *Ae. taeniorhynchus* (Ritchie, 1993). Many of these studies focused on radar, aerial photography and satellite generated images to study environmental indicators such as vegetation indices, and temperature difference. However, Barnes and Cibula (1979) in their report have cited a few problems currently recognized as hindering the rapid development and dissemination of remote sensing technology. Some of these problems are the issues of the multidisciplinary natures of remote sensing which might be too costly to start in terms of building up human resources and equipment. Nonetheless, Welch et al (1989) emphasised that this technique is not expensive, the initial investment to start a laboratory with computers is not inexpensive. However, remote sensing is not the ultimate technique. There are many things that new technology cannot achieve in an effective way, for example a satisfactory doctor-patient interaction. Nevertheless, this technique is generally considered to be quicker, more accurate than ground survey technique. If the data grows, it may become more difficult for the program to monitor all of them. Moloney et al (1998) also commented that the ability of low-level aerial photography to enhance *Ae. aegypti* breeding site surveillance is at present limited, therefore ground surveillance still remains the most reliable tool until new improved techniques can be found.

There have been a good number of studies done on malaria using GIS but little has been done on dengue. This is partly because malaria prevalence is well known to be determined by the following factors: changes in land-use pattern, topography, temperature, rainfall, population movement and degree of deforestation (Hay et al., 1998). In most of the dengue studies, GIS is used to monitor dengue vectors and to map the distribution of the disease (Su & Chang, 1994; Ratana and Kenneth, 1997). Monitoring of the larval indices, adult spread, or breeding source of dengue vectors requires extensive and repeated surveillance while very large sample units (houses or containers) may still be impractical to study. Therefore, there are potential applications of geo-statistical methods for analysis of variability of epidemic observation.

Ratana and Kenneth (1997) used GIS as an analytical tool to map the distribution of DHF by creating overlays of epidemiological and digitised province data in Thailand. The countrywide GIS database demonstrated DHF incidence was not correlated with the area of forest cover in the provinces of Thailand. Global positioning system (GPS) instruments were used to map villages involved in dengue epidemiological studies in Tak province. Differentially processed GPS data with a spatial resolution of approximately 1 meter were incorporated into GIS for mapping and spatial analysis. Approximately 70,000 reported DHF cases in 1996 were mapped to determine the lowest to the highest incidence transmission in the whole of Thailand. An attribute database was also built and it included village name, house number, demographic data on house occupants, adult and immature *Ae. aegypti* populations, *Ae. aegypti* immature breeding sites and seroepidemiological data on house occupants. These databases are used as powerful tools to monitor the status of efforts to control *Ae. aegypti* breeding sites and to evaluate the impact of this control effort on dengue and DHF transmission. However, this study did not look into the relationship of other possible risk factors such as socio-demographic and geographical factors which might have contributed to the dengue cases reported. Furthermore, the emphasis of this study was on *Ae. Aegypti*.

A study done by Su & Chang (1994) in the Sanmin area of Kaoshiung City of Taiwan used GIS to manipulate spatially correlated data and to support decision making in the control of dengue disease. Because most data of dengue vector occurrence are closely related to geographic distribution of mosquitoes, the concepts and software of GIS were used to build the framework of a monitoring system for:

- monitoring the breakout of vectors
- understanding the distribution of breeding sites
- handling the control of dengue
- supervising the dengues cases
- supporting the investigation and decision making of the government

Attributes data like roads, vacant land layer, adjacent roads, ownership, area, density figures of vectors, breeding containers, inundated basements, and disease cases were used in spatial analysis.

Other dengue studies using GIS involved temporal data such as that of Morrison et al. (1998). This case study was based on an outbreak in Florida, Puerto Rico 1991-1992. K-function analysis was used to characterize the spatial clustering patterns for all reported cases and laboratory-positive cases alone, while the Barton/David & Knox tests were used to characterize spatio-temporal attributes of dengue cases reported during the outbreak. The findings suggested that adding the geographic component to the current system practised by the Puerto Rico Health Department would be useful for identifying hot spots of dengue transmission. Furthermore, GIS allows for exploratory spatial analysis to be conducted at regular intervals. However, a dengue surveillance database managed within a GIS would only be practical if a reliable address georeferencing system were to be instituted for the case area.

2.5.1 The Fundamentals of GIS

The information generated from GIS is useful in the decision support process for many activities such as planning, forecasting, etc. Its geographic database consists of spatial information of data, which is more useful compared to a traditional database.

The geographic database is the basis of GIS operation. The functions and efficiency of the GIS rely mostly on the detail and accuracy of the geographic database. Two major types of geographic database are: graphic (Map) and alpha-numeric (Attributes) (ESRI, 1990). The graphics part registers the coordinates and the spatial relation of map features while the alpha numeric part records their attributes.

In practice, GIS uses a database management system (DBMS) for storage and management of attribute information. Several database structures are available for this purpose: network, relational and hierarchical. The relational database is preferred because it resembles the traditional file management used (Su & Chang, 1994).

Conventional maps are commonly used in handling spatially distributed data but they are difficult to maintain, inconvenient for storage and retrieval, and impossible to overlay. With GIS, the paper maps can be digitized into computer readable formats. These formats are suitable for representation of geographic characteristics with continuous change, e.g land use, topology, etc. There are a few methods in transfering paper maps to digital forms before they are processed by GIS: digitising using a digitizing tablet and scanning into raster image then converted into vector form by Raster Vector conversion program.

Topology is a mathematical technique to record the spatial relationships of geographic elements. Generally, there are three categories of geographic elements: point, line, and area (ESRI, 1990). The advantages of using topology are that it saves storage space and hence any analysis process can be carried out more efficiently . With topology, GIS is able to do the following:

a) Spatial manipulation : calculation of length, area or perimeter, coordinate conversion and transformation, and proximal analysis
b) Spatial analysis : polygon overlay and construction of buffer or corridor
c) Digital terrain analysis : such as slope calculation, aspect analysis and construction of contour or cross-sectional maps
d) Network analysis : optimal route selection, and time-distance analysis

2.5.1.1 Spatial Information

The intensity of the dengue virus transmission depends on the density of vectors, serotype of the virus, the herd immunity and environmental factors. At present, control activities focus mainly on vector elimination whether it is done at the community or public health personnel level. These activities have limited impact on DHF transmission, as epidemics are still occurring in most of the countries in South-East Asia. To be more efficient, control strategies should take in account the diversity factors, such as environmental and geographic factors, which are defined as spatial information.

Barbazan and et al. (2000) highlighted the importance of using spatial information such as the density and size of human settlements, the distance between the communities and the type of land use in prediction of the occurrence of epidemics.

Similarly in the study of Roper et al. (1998), population density was used as a determinant of malaria distribution. This variable is generated using buffer function under GIS.

House density is another GIS generated data, which is useful to determine overcrowding, another risk factor for dengue transmission. Njemanze et al (1999) incorporated variables like water source, human population in their study of diarrhoeal diseases in Nigeria using risk analysis methods and GIS to evaluate the health impact of water source. To find a relationship among spatial information like geology, hydrology, towns and villages, these factors were overlayed. In another study done by Tanser and Wilkinson (1999) on the spatial implication of tuberculosis using GIS and Global Positioning System (GPS) technology in rural South Africa where distance has been used to measure the accessibility of health facilities to the homestead in the study district. Emch's study (2000) on the spatial and environmental risk factors for diarrheal disease in Matlab, Bangladesh also used household area and distance, population density as part of its spatial information.

Using GIS tools like *near analysis* and *buffering*, spatial information like distance from house to house, distance of dumping sites and distance of the house to the main road can be generated. This information may play a role in dengue transmission surveillance but is not given much attention. Current dengue surveillance system methods cannot generate such information.

2.6 Risk Factor Modelling

Focks et al. (1999) also used spatial analysis in the control and risk assessment of dengue where the main focus was on monitoring methodologies, risk assessment and mitigation. Two of his case studies, one from Hawaii involving mosquitoes population and one from Trinidad looking at dengue demonstrated the utility of combining spatial analysis with computer models in vector-borne disease systems. The computer model involved is a life-table simulation model that produces mean value estimates of various parameters for all cohorts of a single species of *Aedes* mosquito within a representative 1 ha area. The container-in-habiting mosquito simulation model (CIMSiM) basically is an accounting program for each cohort. Depending on the life stage, it maintains information on abundance, age, development with respect to the temperature and size, weight, fecundity and gonotrophic status.

Besides that, Focks et al. (1995) also developed dengue simulation model (DENSiM) which is essentially the corresponding account of the dynamics of a human population driven by country and age-specific birth and death rates. An accounting of individual serologies is maintained by type of dengue virus, reflecting infection and birth, to seropositive mothers. Daily estimates of adult mosquito survival, gonotrophic development, and the weight and number of emerging females from the CIMSiM are used to create the biting mosquito population in the DENSiM. The survival and emergence values determine the size of the population while the rate of gonotrophic development and female weight estimates influence biting frequency. Temperature and titer of virus in humans influences the extrinsic incubation period; titer may influence the probability of transfer of virus from human to mosquito. The infection model within the DENSiM accounts for the development of virus within individuals and its passage between both populations.

2.7 Summary

The epidemiological importance of *Ae. albopictus* in dengue transmission is evident in recent outbreaks in Malaysia. Evidence from studies done by Chang (1999) and Chow et al. (1998) showed that this species is slowly replacing *Ae. aegypti* as a vector in dengue transmission. However, current dengue surveillance and control programs only emphasize the indoor species *Ae. aegypti*. Furthermore, to respond to epidemics in a timely manner is a challenge when the relevant information is not available in time for decision making. To overcome this, a proper data management system is needed. GIS is used in control of many communicable diseases, including vector-borne disease and shows some potential in understanding disease transmission.

This study aims to give a new dimension to the existing dengue surveillance system in Sarawak within the context of *Ae. albopictus* study by exploring GIS as a tool. Furthermore, there are risk factors related to geographical parameters such as distance and density, which can contribute to dengue transmission and which will be explored here. This study also aims to produce a dengue surveillance system based on *Ae. albopictus* surveillance.

CHAPTER 3

THE DESIGN AND PROTOTYPING OF A DENGUE SURVEILLANCE SYSTEM

3.1 Introduction

This chapter will discuss the system design and the implementation of the proposed dengue surveillance system with the integration of spatial data generated by GIS. The chapter is divided into three sections. The first section presents the definition used in this study. The second section explains the conceptual design for above system from input to process and finally output. The third section presents the prototyping of the dengue surveillance system. The prototype is presented in the form of a data flow diagram which shows how the system works and interacts with its entities.

3.2 Definition of terms being used

Breeding containers are defined as any form of containers which provide the environment for *Aedes* breeding regardless of the presence of water or larvae. Types of containers for *Aedes* breeding can vary from artificial containers to natural containers. *Ae. albopictus* is more widely found in outdoor sites like tree-holes, bamboo stumps, fallen leaves, leaf axils, fallen coconuts and cocoa husks. This species are more productive during the rainy season as compared to *Ae. aegypti* (Gubler & Kuno, 1977).

Container density is defined as number of such potential containers found within one hectare of the house.

Dumping site is defined as a place/àrea where rubbish is discarded. It is in this unsanitary condition that the abundance of discarded containers is found. This environment will continue to support the breeding of *Ae. albopictus* (Chang & Nagum, 1994). If the dumping site is not properly managed, the chances for the nearby household members to contract DF/DHF due to increase in vector density.

Dumping site density is defined as number of such dumping sites found within one hectare of the house.

Human population density is defined as the number of people staying within one hectare of the house. High density or crowding with poor sanitation resulting in the proliferation of inadequate water storage and garbage containers have been responsible for an enormous proliferation of the *Aedes* mosquitoes.

Distance of the house from the main road is defined as the shortest distance measured from the perimeter of the house to the main road. Main road here is defined as a tar road accessible by public transportation, especially public buses. When the number of automobiles used for transportation in dengue-endemic urban areas increases, there are more chances for contact between humans and virally infected vectors (Wellmer, 1983).

Shading tree is defined as trees which provide sufficient degree of shading to promote mosquitoes' activities specially in breeding within 5 m from the house. Trees included in this group are rambutan, durian, langsat, cocoa, and asam. Those trees with fewer leaves like papaya, banana are not included in this study.

Shading tree density is defined as number of such shading trees found within one hectare of the house.

Dengue cases reported is clinical suspected case diagnosed by doctors of the hospital and notified through telephone/written notification to the Health Department. All notified cases of dengue fever/dengue hemorrhagic fever must be registered in the Dengue Case Registration Book. (Ministry of Health, Malaysia, 1986). In Malaysia, any form of suspected DF/DHF cases are notified under the Infectious Diseases Act, 1988.

Ovitraps are used extensively as a tool to monitor and detect *Aedes* oviposition. They give an approximate gauge of the adult population in an area, and they act as an indicator of the abundance of *Ae. aegypti* and *Ae. albopictus*. Ovitraps will be set in the selected houses within the villages in two sites. The word "indoor" is taken to mean the interior of the house, while "outdoor" refers to the outside of the building but within the confines of the house perimeters (5 m approximately). One will be indoor and another one will be placed at 5 m away from the house perimeter. The third site will be the dumping sites identified earlier by GPS.

IgM and *IgG* are antibody molecules that belong to a family of plasma proteins called immunoglobulins and abbreviated *Ig*. IgM tends to rise to detectable levels in the blood during the acute phase of the illness. Levels of IgM to dengue virus peaks within 2 weeks, decay rapidly over the next two weeks and then more slowly, ultimately becoming undetectable 60 to 90 days after infection. On the other hand, IgG antibody begins to appear a few days later that IgM antibody, usually first appearing around the 5th day after the onset of symptoms and detectable for up to two years (Gubler & Sather, 1988).

3.3 The Conceptual Design of Dengue Surveillance System

The concept of spatial dependence in the mapping of insect pest population data and geostatistics (the statistics of spatially and temporally correlated data) have been widely used recently (Roper et al., 1998). Though it is widely used, GIS as a tool to analyze spatial patterns in dengue vector populations is still being developed (Focks et al., 1999). The spatial patterns of disease vector levels can provide important clues to understanding dengue.

To monitor Aedes density larval index, breeding sources require an extensive and repeated vector surveillance. To survey very large sample units such as houses and breeding containers is burdensome. Furthermore, important parameters such as spatial related risk factors cannot be incorporated into the vector surveillance and control activities, especially when big areas are involved. Therefore, by mapping the spatial pattern of occurrence and distribution of disease, vectors or breeding sources would be a better approach in managing an outbreak of DF.

The key objective of this study is to introduce the potential of GIS technology in building the dengue vector surveillance system based on entomological and environmental data collected in Lundu. The system consists of the following main components as shown in Figure 3.1.

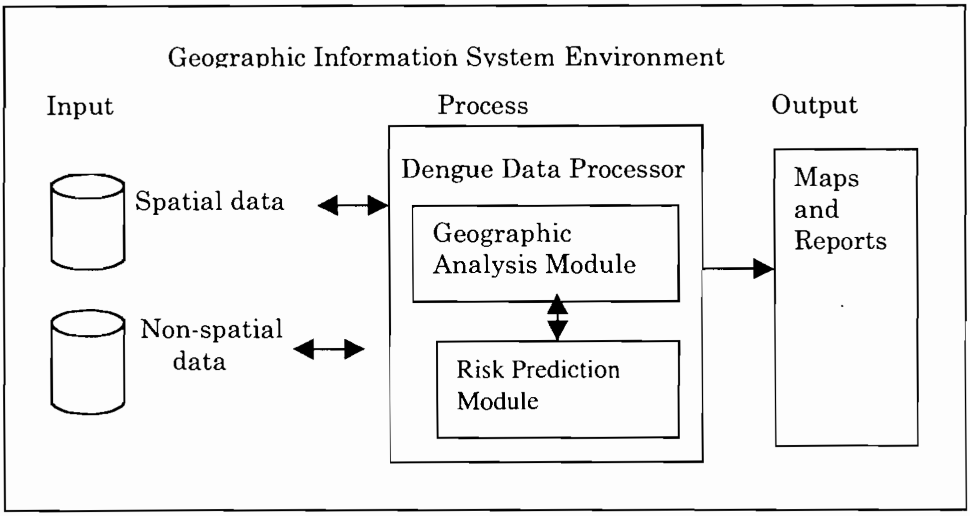


Fig. 3.1 The overview of Dengue Surveillance System

3.3.1 Data Requirement for Dengue Surveillance System

The database is the basic to GIS and contains two main type of data, namely spatial and non-spatial. These data are kept in the GIS database. Attribute data are collected and kept in database and transformed into the GIS database before any geographical analysis is done.

a) The Spatial Database

A good, accurate and comprehensive map is important in any vector control operation. Maps provide information for field survey, program evaluation, reporting and budgeting purposes. Information like road, river, household, dumping sites, other buildings are essential for locating and plotting larval breeding places and adult sampling stations. Furthermore, socio-demographic information which is stored under household profile facilitate the recognition of the variability of environmental and epidemiological parameters that influence the pattern of dengue vector distribution and disease transmission risks (Washino and Wood, 1994).

The spatial database is presented in Table 3.1. The features chosen are based on the literature review in Chapter 2.

Table 3.1 Feature representation in GIS

Feature	**Type**
House	Points (center of the house)
Other buildings	Points (center of the building)
Road	Line
Land use	Polygon
Dumping site	Points
River	Line
Border (country)	Line

House is important, as it is the basic of the entire mapping system. All houses are given an ID and carry entomological, demographic and geographical information under attributes database. Each *house* is stored as a point.

Other buildings are digitized as points to show the location and how it relates to *house*. For examples, the distance of the health clinic to the *house* can contribute to the accessibility of health care.

Road information is important as it facilitates the movement of the villagers. The bigger the road, the more movement, especially public transportation. *Road* is digitized as a line.

Land use is digitized as a polygon. It comprises information on the land use pattern, whether for agriculture, or other use. The type of land use in this study is primary forest, secondary jungle, grass, swamp, rubber, oil palm, pepper, coconut, sundry tree cultivation, sundry non-cultivation and wet paddy. This layer of spatial information will overlay with other attributes to find any significant relationship that influences the dengue cases reported.

Dumping sites were digitized as points. *Dumping sites* are one of the main breeding ground for *Aedes* mosquitoes. By measuring the distance of the dumping sites to the household, the risk of dengue transmission can be investigated and determined.

River was digitized as a line. Normally where a river is located, more human settlements are found. This is because the river provides source of water for villagers to do their washing, and cleaning.

Border is digitized as a line. *Border* is important in this study as *Ae. albopictus* is an outdoor species and originated from the forest located at the *border* of the study site (between Kalimantan and Sarawak)

The information contained in the spatial database is held in the form of digital coordinates and the description of the spatial features is explained in the form of attributes. For example, a point can be used to represent a dengue case house, lines represent roads and rivers, or a polygon represents a pond. In general, the different sets of data will be stored as separate layers. These separate layers can be overlaid for further analysis and manipulation to produce information needed in dengue surveillance.

With the use of GIS spatial analysis tools, spatial information such as distance and density within a range can be generated from the raw data. In dengue vector surveillance study, these spatial data are understudied mainly because the lack of technology assisted methodology (Su & Chang, 1994). Geographic factors like distance from the house to house, from dumping site to the house could provide indication whether these distances influence the transmission of dengue virus. Human population density is another indicator for overcrowding in the village. As more people stay together in an area, the possibility for human interaction is greater, the dissemination of dengue virus is more widespread.

b) The Attribute Database

The attribute database contains data describing characteristics or qualities of the spatial features.such as land use, distance of the house from the dumping sites, and number of household members. Thus, a dengue case house (point) in the spatial database can also display characteristics of this house in the attribute database, such as name and number of occupancy, occupation, highest education achievement and so forth. The whole structure of attribute database and its data is shown in the Figure 3.2.

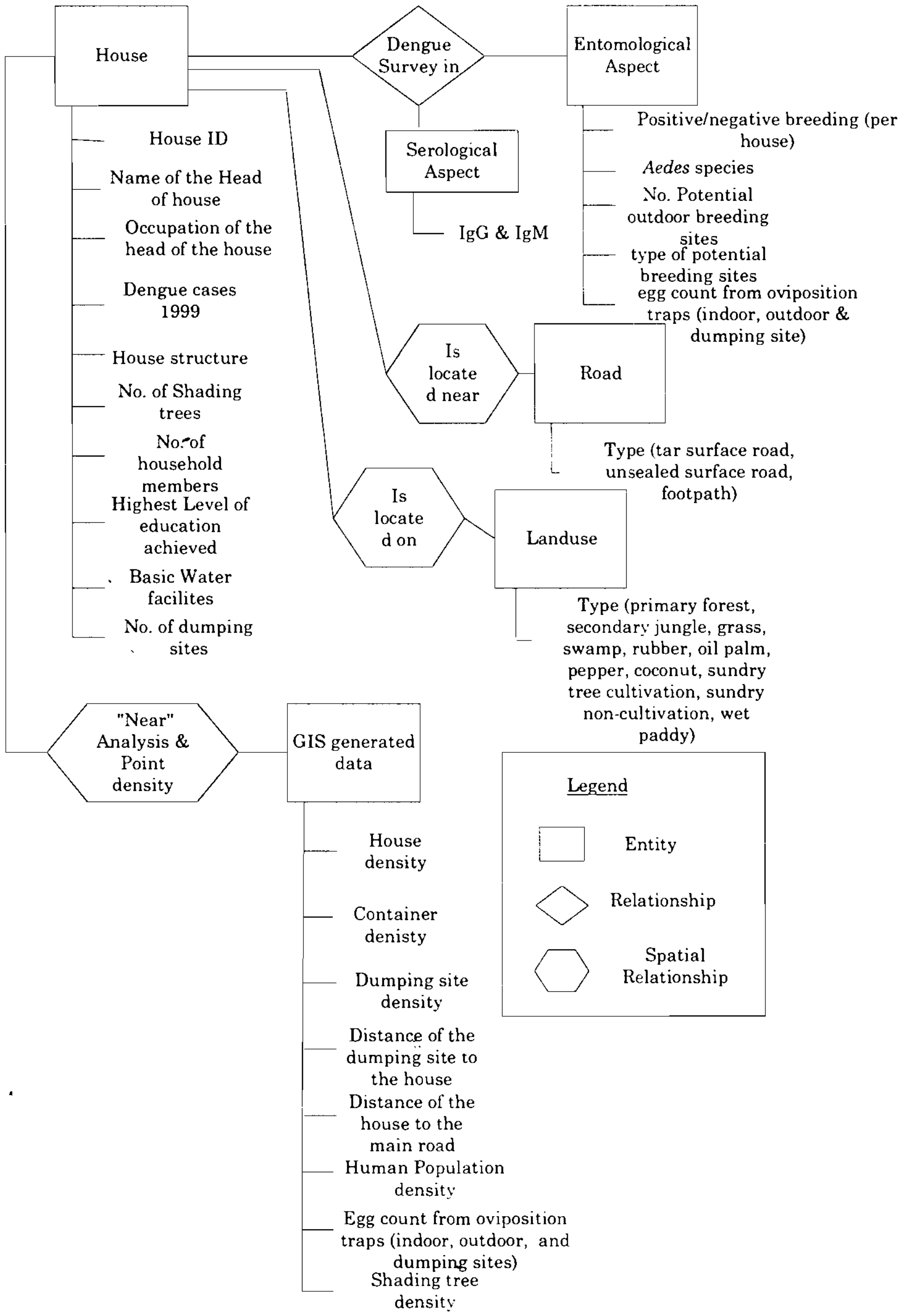


Fig. 3.2 ER diagram for Dengue Surveillance System

All houses were given an ID as an address. In each house, demographic information was collected through interviews. This information includes of the name of the head of the household and his/her occupation, number of household members, the highest level of education, number of dengue cases reported in 1999. Besides interview, there was observation to obtain information on the type of house structure (brick, semi-concrete, wooden wall with thatch roof, wooden wall with iron roof), number of shading trees and dumping sites within 5m from the house, type of water supplied (gravity feed, JKR piped water, water tank). House structure, especially wooden structure is shown associated with dengue infection during an epidemic. Shading trees and dumping sites provide ideal environment for mosquito breeding. The more shading trees and dumping sites, the more breeding ground are expected. The type of basic water facilities used by the villagers is important as this information will give an overview of the scope of dependability on gravity by the villagers. Gravity feed is not a reliable water resource, and a water tank is a potential breeding site for mosquitoes.

Serological information of the population such as IgG and IgM were also collected to screen the level of previous and current infection. Serological survey are normally conducted to define the true incidence of infection in the population. The result of these surveys provide unique opportunities to characterize the epidemics, define the populations at highest risk, and identify risk factors for infection (Rodriguez-Figueroa et al., 1995).

Entomological data were collected by conducting house to house survey. Data included larval survey to determine the *Aedes* species, Container Index (percentage of positive container), number and type of outdoor potential breeding sites. Ovitraps were set indoors, outdoors and at the dumping sites to get the total mosquitoes egg count. These factors play a very important role in contributing to the dengue transmission (Morrison et al., 1998; Focks et al., 1999).

Road information (tar surface road, unsealed surface road, footpath) was also collected during this stage. Information on type of land-use (primary forest, secondary jungle, grass swamp, rubber plantation, oil palm plantation, pepper planting, coconut, sundry tree cultivation, sundry non-cultivation, wet paddy field) were also collected to see if these information relates to dengue transmission.

The intensity of the dengue virus transmission depends on the density of vectors, serotype of the virus, the herd immunity and environmental factors. At present, control activities focus mainly on vector elimination. To be more effective, control strategies should take into account the diversity factors such as environmental and geographic factors which are defined as spatial information. Some of the spatial information like distances, density are generated by GIS tools. In some of the communicable diseases studies, spatial information has proved to be useful in risk prediction and analysis. Studies done by Tanser & Wilkinson(1999), Dearwent (1998), Melly et al. (1998), Roper et al. (1998), Barbazan et al. (2000) used some of this spatial information to help them to understand the epidemiological and ecological pattern of the disease. The present study aims to use a similar approach to investigate the relationship between dengue case occurrence,and distance from dumping site to the house, distance of the house to the main road, house density, human population density, dumping site density, and oviposition activity of gravid females of *Ae. albopictus* using oviposition traps. It also includes egg density counts from indoor, outdoor, and dumping sites.

3.3.2 Dengue Data Processor

Under the Dengue Surveillance System, two processes were used namely, the geographic analysis module and statistical analysis module.

a) The Geographic Analysis Module

GIS has a variety of analytical tools to analyse data based on their spatial characteristics. Three of the tools used in this study are the *overlay*, *near analysis*, and *point density.*

Overlay process compares different entities based on their common geographic occurrence.

Eastman (1992) gives an example of the ability of GIS to analyse data:

> Perhaps the simplest example of this is to consider what happens when we are concerned with the joint occurrence of features with different geographies. For example, find all areas of residential land on bedrock types associated with radon gas. This is a problem that a traditional DBMS simply cannot solve- for the reason that bedrock types and landuse divisions simply do not share the same geography. Traditional data base query is fine so long as we are thinking about attributes belonging to the same individuals. But when the entities are different it simply cannot cope. For this we need a GIS. In fact, it is the ability to compare different entities based on their common geographic occurrence that is the hallmark of GIS – a process called "overlay" since it is identical in character to overlaying

transparent maps of the two entity groups on top of one another.

Distance analysis is used to measure the distance of two destinations/targets. It is helpful if the study aims to know if distance of the dumping site to the house would have contributed to the transmission of dengue virus. Linear distance (Euclidean distance) of the house to the nearby house also will give information on the level of congestion of the villages and if this factor is another risk factor for dengue transmission.

Parts of the data like containers, shading tree, human population after being collected from the field were converted into density value using *point density* function. It is difficult to predict a high risk area by house as the surrounding can also play a role in disease transmission. For this, all attributes identified as risk factors (house density, human population density, potential container density, shading tree density, outdoor mosquito egg count, indoor mosquito egg count, dumping site mosquito egg count) were transformed into a density index, except two risk factors, that is distances (distance of the dumping site to the house and also distance of the house to the main road). This method helps to produce contours which show up in clustering. The get around the problem of plot density, and points can be weighted to reflect their importance.

With the above explanation, this study aims to overlay the spatial and non-spatial data to identify hotspots and high risk areas for dengue transmission. Hotspots/high risk areas can only be generated if there is a prediction model. For example if dengue cases are predicted based on number of potential containers and ovirtrap count, a thematic layer for each attribute will be built and overlayed. When the prediction formula is available, the system will automatically identify the hotspots/high risk areas for visualization.

b) The Risk Prediction Module

The model development involves regression analysis in attempting to find the optimal dengue risk prediction model. The function of this risk prediction module is to provide information as to when and where an outbreak might occur, based on the risk assessment. This module also will act as an early warning system for emergency preparedness. The stages of development are diagrammed as in Fig. 3.3.

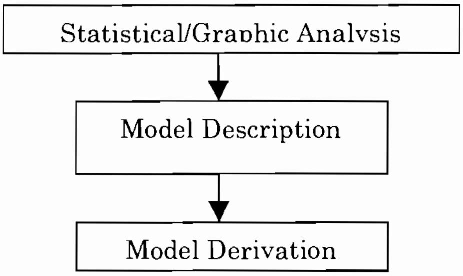


Fig. 3.3 The development of the Prediction Model

For further analysis, modeling and forecasting of the epidemics for dengue, an external program involving specialized statistical software may be needed. In this study, statistical analysis is recommended.

The function expected from this statistical analysis software is to determine whether the contributing factors from spatial and non-spatial data are inter-related. In this case, multiple regression is used to account for (predict) the variance in an interval dependent, based on linear combination of interval, dichotomous variables (Shott, 1990). The multiple regression equation takes the form of

$Y = b_1X_1 + b_2X_2 + b_nX_n + c + e \longrightarrow$ Equation 3.1

Y = the true dependent, that is dengue cases reported for the year
X_1, X_2, X_3 and X_n = parameters or risk factors
b's = regression coefficients for the corresponding X (independent) terms
c= constant or intercept
e= error term reflected in the residuals

Associated with multiple regression is R^2 , multiple correlation coefficient, which is the percent of variance in the dependent variable explained collectively by all the independent variables.

By physical mean, c = 0. For example, if the explanatory variables are container density and house density, the formula will be as follow:

$Y = b_1X_1 + b_2X_2 + b_nX_n + c + e \longrightarrow$ Equation 3.2

Where Y = Dengue cases reported
X_1 = Container density
X_2 = House density

If $X_1 \longrightarrow 0$

$X_1 \longrightarrow 0$

$Y \longrightarrow 0$

Then $c \longrightarrow 0$

3.3.2.1 Incorporation of the Risk Prediction Module into GIS

Once the model is derived, the formula can be transformed into ArcInfo to identify hot spot/high risk area for better visualization.

3.3.2.2 Information Requirement

Before any process can be done on the input, it is important to know the output expected from the Dengue Surveillance System.

Table 3.2 Information Requirement

Input	**Type**	**Process**	**Output**
Location of the house	Spatial	Point Density	House Density
House Road River Land use	Spatial	Mapping and overlay	Base map
Potential Container count	Non-spatial	Point density	Container Density
Location of the dumping site	Spatial	Point Density	Dumping site density
House Dumping site	Spatial	Near analysis	Distance of the dumping site to the house
House Road	Spatial	Near analysis	Distance of the house to the main road
No. of household members per house	Non-spatial	Point density	Human population density
Egg count from ovitrap (indoor, outdoor, dumping site)	Non-spatial	Point density	Egg count density (indoor, outdoor, dumping site)

House	Spatial		
House Dengue cases	Spatial Non-spatial	Mapping	Case House mapping
Shading tree House	Non-spatial Spatial	Point density	Shading tree density
House density, Container density, Dumping site density, Distance of the house to the main road, Distance of the dumping site to the house, Human population density, Egg count per oviposition, Shading tree density		Multiple Regression Correlation	Risk Prediction Model

3.3.3 The Dengue Output and Report

This component is for visualization and reporting such as producing maps, charts, reports, and so forth. It extracts necessary elements from the database, whether in the format of spatial features or attributes, and produce map outputs on the screen or other devices such as plotters, printers or graphics files. With this, different layers of maps can be displayed and overlaid, using different colours for each layer. Maps generated from different analyse can be overlapped onto different map layers to show new information on old data, one of the most powerful tool of GIS (Njemanze et al., 1999, McKee et al., 2000)

Based on the queries from the users (Research Team and Public Health Team), different types of maps can be produced. Some of the important features of the map, with its information and purpose are in Table 3.3.

Table 3.3 Type of map produced with its information and purposes

Type of map	**Information required**	**Purpose of using the information**
Entire Lundu map	Spatial data (topology), number of cases by villages	To investigate the distribution of dengue cases as a whole with relation to topology information
Village perimeter	Location of the houses, other buildings, case house,	To visualize the location of houses and distance from other buildings (clinic, health centers)
Density Map	Potential container density, house density, human population density	When different coverage is being overlayed, it is easier to view the map by having the attribute in the form of a density map

3.4 Architecture of The Dengue Surveillance System

The Dengue Surveillance System consists of four main providers/users from GIS system developer, mapping section, research team and public health team. Each has its own role, for example, GIS system developer will provide input like map layout and lookup table for the system. The mapping section will provide coverage information. The Research Team will provide attribute data and conduct analysis and data query. The public health team will conduct final result query and get their maps and reports from the system.

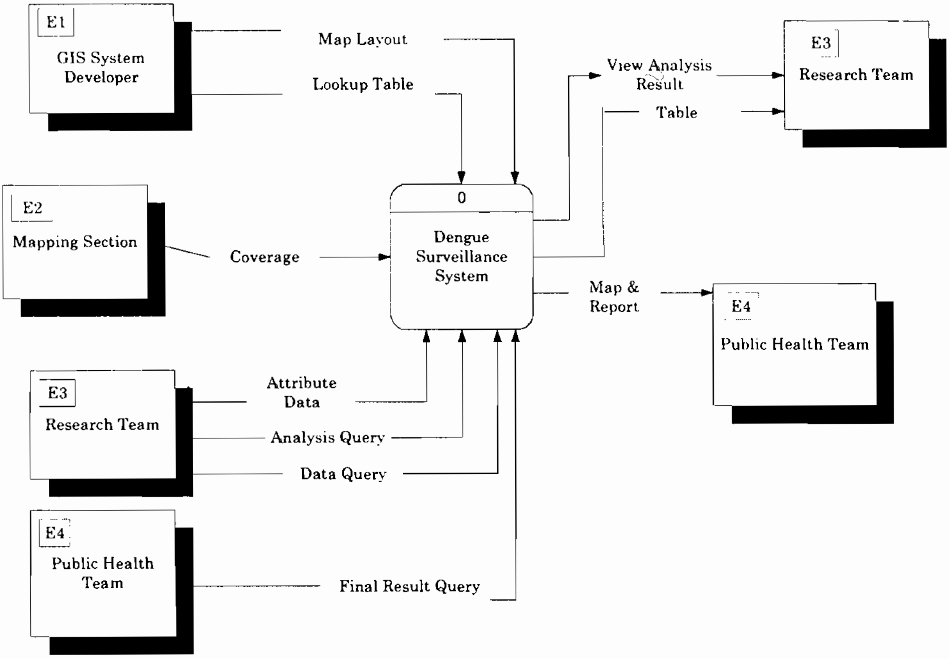


Fig. 3.4 Architecture of The Dengue Surveillance System

The Function of the new proposed Dengue Surveillance System

a) To provide a proper data management system for managing data on spatial data, attribute data for easy data input, updating, retrieving and report generating;
b) To produce output in the form of maps and reports for visualization, that can assist in dengue decision making;
c) To provide information as to when and where a dengue outbreak might occur, based on the risk prediction module.

This system is created to provide information to those involved in dengue activities planning and decision making, to assist efficient and effective monitoring of dengue surveillance programs, and to provide dengue-related information to public health communities. Spatial data and attributes data are maintained in a database where creation and maintenance can be done.

When planning a control campaign, health personnel can use the above system to prioritize the high risk areas for immediate attention and implementation of control activities.

3.5 The Prototyping

3.5.1 The Prototyping Design of Dengue Surveillance System

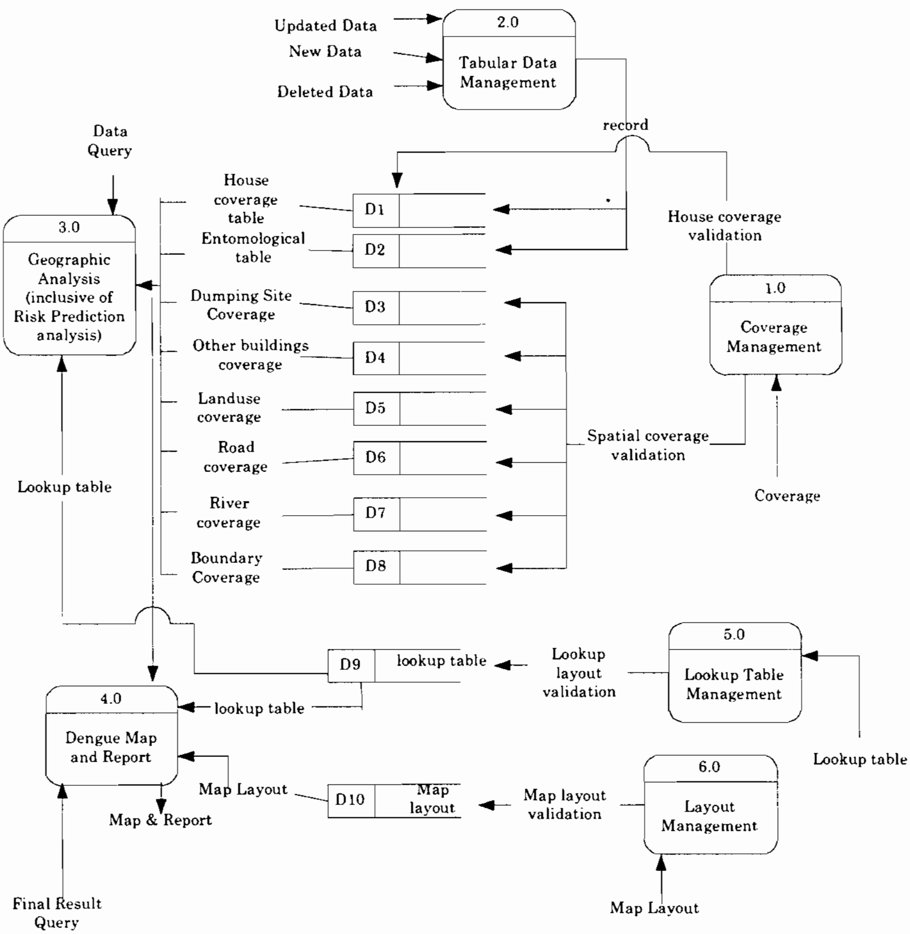


Fig. 3.5 The Dengue Surveillance System-Prototyping Design

3.5.2 Description of the system

Generally, the whole system consists of the following components:

a) Coverage Management

When paper maps or any form of digital maps are being transferred into ArcInfo, the system will validate the coverage with the correct attribute table before it imports the coverage into its spatial database and information table. Once the layers of maps are being converted into ArcInfo format, all the layers are combined to produce a complete map of Lundu area. Then, map projection and transformation are performed onto the full map of Lundu to produce map in Rectified Skewed Orthomorphic (RSO) format. This component is managed and maintained by the Mapping Section.

b) Tabular Data management

Tabular Data management is designed mainly for data input and updating. No new features are allowed into the database but update information within the features itself is allowed. The data input and collection is done by the Research Team based on their research objectives and project requirement.

c) Geography Analysis Module (with Risk Prediction Analysis)

This component is important as it allows one to study real-world processes by developing and applying models. These models illuminate underlying trends in the geographic data and thus produce new information or new relationships within and between data sets (ESRI, 1995). In this case, different data set from tabular data and coverage data will be combined and analysed, so that an understanding of dengue transmission can be easily achieved. Before starting any analysis, the Research Team needs to access the problem and establish objectives. Data needs to be prepared either for spatial operations or tabular analysis. It requires the input from Coverage Management and Tabular Data Management. Results of geographic analysis can be communicated with maps, reports or both. When the results are generated, the dengue surveillance system will send the information to the Dengue Survey Report for reporting and presentation purposes.

d) The Dengue Map and Report

A map is best used to display geographic relationships and a report is most suitable for summarizing tabular data and documenting any calculated value. Therefore, this component is used to produce maps and reports in any size, which must be determined from the beginning by the user. The requirement and request is normally from the Public Health Team. These reports will be used in decision making for surveillance and control.

e) Lookup Table Management

This is also known as a relate table, external attribute table, or expansion table. A special tabular data file associated with a particular feature attribute table and contains additional information about the feature beyond those stored in the feature attribute table. For example, types of house structure such as brick, semi-concrete, wooden wall with thatch roof, wooden wall with iron roof are the additional feature about the house surveyed.

f) Layout Management

Layout management enables the users to arrange the types of map presentation they need. These include the map itself, north arrow, scale, legend, and title of the presentation. Users can arrange the layout, the color and the text of presentation. This component is designed by the GIS System developer based on the request or requirement of the Public Health Team to produce the required dengue survey report.

3.5.3 Data acquisition

There are many methods of data acquisition, especially in capturing spatial data. Some of the spatial data can be captured using the standard digitizing method. However, in this study, where accurate maps are not available and the distances between features (house) are small, , GPS is used for adequate discrimination among sampling units.

a) Data Collection

Four types of data were collected based on three different methods. The first type was socio-demographic background of the study area, collected by interview, using a set of questionnaires (Appendix D). Information collected is number of household members, occupation, and level of education. The second type of data was information on basic facilities like type of water supply, house structure. This information was collected by observation. The third was entomological data. Information like the prevalence of *Ae. albopictus* and *Ae. aegypti*, and larval habitat was collected through observation. Ovitraps also were set indoors, outdoors and at the dumping sites to find out the vector density. The fourth type of data was serological, to identify the true incidence of infection in the study area using IgM and IgG titres.

b) Data Conversion

The topography maps obtained from the Land and Survey department are in the scale of 1:50,000. This is the biggest scale obtainable and it is available for public purchase.

These maps provide the basic information of the geographical features in the area of study. The topographic maps that were used were Lundu, Gunong Undan, Kampung Pueh and Kampong Biawak map. The creation of the spatial database involved three process, which were:

i) Scanning and digitizing
ii) Data projection and transformation
iii) Features attributes editing

Before any conversion, it is important to identify the data sources. This information is shown in Table 3.4.

Table 3.4 Data sources

Data	Source
House	GPS
Other buildings	GPS
Road	Digitizing
Land use	Digitizing
Dumping site	GPS
River	Digitizing
Border (Country)	Digitizing

Table 3.5 Topographic Maps used with specification

Name	Scale	Projection
Lundu	1:50,000	Lambert Orthomorphic
Gunong Undan	1:50,000	Lambert Orthomorphic
Kampong Pueh	1:50,000	Borneo Rectified Skew Orthomorphic (RSO)
Kampong Biawak	1:50,000	Borneo Rectified Skew Orthomorphic (RSO)

i) Scanning and digitizing

There are several ways to digitize maps. The easiest and fastest way is to scan the maps into raster images and convert them into vector form using Raster-to-Vector conversion program (Su & Chang, 1994). Raster and vector are the two basic data structures for storing and manipulating images and graphics data on a computer. A raster image comes in the form of individual pixels, and each spatial location or resolution element has a pixel associated where the pixel value indicates attributes such as color, elevation, or an ID number. Vector data come in the form of points and lines, that are geometrically and mathematically associated. Points are stored using the coordinates, for example, a two-dimensional point is stored as (x,y). Lines are stored as a series of point pairs, where each pair represents a straight line segment, for example, (x_1, y_1) and (x_2, y_2) indicating a line from (x_1, y_1) to (x_2, y_2). In general, vector data structure produces smaller file size than raster image because a raster image needs space for all pixels while only point coordinates are stored in vector representation. Besides the size issue, vector data is easier than raster data to handle on a computer because it has fewer data and it is more flexible to be adjusted for different scale.

Heads-up digitizing is similar to manual digitizing in the way the lines have to be traced by hand, but it works directly on the computer screen using the scanned raster image as backdrop. While lines are still manually traced, the accuracy level is higher than using a digitizing tablet because the raster images are scanned at high resolution, normally from 200 DPI to 1600 DPI. With the help of the display tools, such as zoom in and out, the operator can work with the resolution of the raster data, and digitizing at a higher accuracy level.

The latest maps of Lundu were digitized using the heads-up digitizing method, where emphasis is on *roads*, *land use*, *boundaries* and *rivers*. These geographic features were the ones used in most of the dengue and GIS related studies (Morrison et al., 1998; Su & Chang, 1994; Ratana & Kenneth, 1997).

The digitizing process was done using the AutoCAD 2000 software. Each feature is digitized on a different layer. The digitized maps are saved in Drawing exchange Format (.DXF). AutoCAD drawing files can be exported into AutoCAD' s drawing exchange format (DXF) which can be imported into many other programs including ArcInfo.

Integrating map data from different data sources is a common task in producing a single comprehensive map and database. During this integration process, errors can occur. To minimize these errors, calibration is required. All calibration methods allow for scale, offset, rotation, skew and mirroring. Two common methods are point calibration and line calibration. In this study, point calibration was used. Before the digitizing starts, the first step is to key in the geodetic coordinates for a number of points on the map. A minimum of two points are needed to calibrate, however three or four points will allow the program to adjust for shrinkage of a paper map. By selecting four points that enclose the features to be digitized, the geodetic easting and northing in meters can be determined. The program also generates a statistic for the calibration. If the residuals (error) are "small", residuals of below 10 m are reasonable for 1:25,000 map to 1:50,000 map.

ii) Data Projection and transformation

The understanding of uses of map projections is very important as any representation of the earth's surface in two dimensions usually involves distortion from parameter such as shape, area, distance, or direction. Furthermore, different projections produce different distortions. In the case of this study, the base maps which consist of seven paper maps found three pieces in different projections compared to the other four pieces. Therefore it is important to determine the projection of all the base maps before automating the map sheets. There are a few commonly used map projections such as Mercator, Universal Transverse Mercator (UTM), Transverse Mercator, Albers Equal-Area Conic, Lambert Equal-Area Conic. Rectified Skewed Orthomorphic has been chosen because this is the only projection format recommended for this part of study area (Borneo island).

Once the map is digitized, the x- and y- coordinates are held initially in digitizer measurement. In order to make this information meaningful and also to impose a scale factor, these measurement need to be converted into the real-world coordinate system as the same projection in the original map. This process is called *transformation.*

iii) Features Attributes Editing

ArcInfo stores the descriptive information for a feature in a tabular data file in which a record stores all the information about one occurrence of a feature (example, a polygon in the land use coverage) and an item stores one type of information (example, attribute information like primary forest or secondary forest, rubber or oil palm plantation) for all features in the database. These data files are known as *features attribute tables.*

To start with, an empty data file is created. Attributes are added to the data file, and soon the data file is joined with the feature attribute table (PAT or AAT) for the coverage. Attributes can be joined to a feature attribute table by way of one-to-one relate or a one-to-one relate.

c) Global Positioning System

The use of GPS to map study sites is essential for GIS investigations of spatial relationships between risk factors and disease occurrence in areas for which accurate or up-to-date maps are not available and require the use of GPS. This study involves variables of distances between house units, so differential GPS is necessary for adequate discrimination among sampling units. In the study of Ratana et al. (1997), 1 m accuracy was used because the distribution of village houses were close to each other. However, the accuracy of data to the geographic analysis was the main concern in determining the accuracy of GPS.

The position of houses and dumping sites in the seven villages in this study were mapped using a Trimble GeoSurveyor Asset GPS instrument as a rover unit. A Trimble Pathfinder GPS instrument was used as a base station supported by a desktop PC at the Mechanical Engineering Laboratory in the UNIMAS campus (Latitude 1°27'45.87952"N, Longitude 110 °5.55886"E). It was decided to set it up in an open area with a 10 degree elevation above the base itself for better signals. Both rover and base station units were run simultaneously for differential correction to achieve 1-3 m accuracy. To obtain a known coordinate for the base unit, the base station needs to be switched on for at least three days before the commencement of the field work.

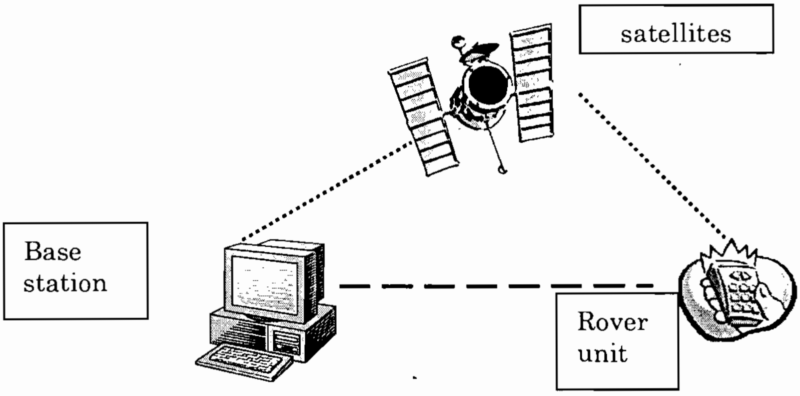


Fig. 3.6 The Main Components in the GPS

Before collecting data in the field, it is important to build the data dictionary to enable descriptive data input into Handheld rover unit (TDC 1). After completing the data collection, the data need to be transferred into a computer as the memory capacity of the rover unit is limited (720 KB). The design of the data dictionary is as below :

Table 3.6 Data Dictionary for GPS

No.	Feature	Attribute	Data type	Remark
1.	House (point)	House ID	Numeric (6 digit)	First 3 digits of village ID and last 3 digits of house number.
		Head of house	Text (50 char)	For checking purposes
		House structure	Menu (5 choices)	Brick, semi-concrete, wooden wall with thatch roof, wooden wall with iron roof, others
		Number of shading tree	Numeric (2 digit)	Within 5 m from the house
2.	Road (line)	Tar	Menu (2 choices)	Yes, no.
3.	Other building (point)	Type	Menu (10 choices)	Clinic, church, mosque, hospital, community hall, school, kindergarden, government office, police station, other.
4.	Dumping site (point)	Scattered	Menu (2 choices)	Yes, No

Each of the seven villages was given a code number for identification purposes as shown in Table 4.5. Since the size of the house are small, a point was taken instead of polygon. When taken as a point, a compass and measuring tape was used for achieve consistency throughout the whole data collection. The details regarding the features used and its type is shown in Table 4.6. It was observed that the reception of the signal under the cloudy weather condition was often disturbed. In this case, the antenna of the rover unit has to be as high as possible for good reception. Otherwise, the reception of satellite signals is distorted and the reading will not be accurate. During the data collection phase, sketch maps provided by the Dengue Survey team of Lundu Hospital were used to trace the location of the house and its owner.

Table 3.7 Name of villages with their designated codes

Name of Village	Code Number
Kampong Biawak	101
Kampong Pasir Ulu	108
Kampong Jangkar	111
Kampong Semunin	112
Kampong Stommuda	113
Kampong Bokah	114
Kampong Stungkor Lama	115

Error in GPS position determination arises from several uncontrollable sources, including atmospheric and topographic conditions, orbital and clock error, receiver noise, and selective availability, the intentional error component built into the signal of each satellite (French, 1996). To circumvent these sources of errors, post-processing differential correction of locational data, or differential GPS was used. Pathfinder office software, version 1.10 (Trimble Navigation, Sunnyvale, CA) was used to perform differential correction of all features locations and to create a locational database for use in GIS analysis. ArcInfo software, version 1.0 was used for GIS analysis. The Pathfinder locational database was exported as ArcInfo shape fiels, entered into ArcInfo and then merged with non-spatial data exported from Access Database.

Once the map is completely digitized, the digital maps are printed and overlaid with the original paper map for final checking. This is to check if the original paper map contains some elements not digitized, or if it contains ancillary information external to the map face. Also if an error is suspected, it can be rectified.

3.5.4 Dengue Data Processor

The dengue data processor consists of two main modules namely the Geographic Analysis module and the risk prediction module. The Geographic analysis module produces information for the use of risk prediction analysis. It gets its input from dengue data collected in the field. With the input from Geographic Analysis Module, the risk prediction module will identify high risk area for dengue outbreak and an early a warning signal can be transmitted to the dengue health personnel for immediate action.

There are other modules, which are not highlighted in Fig. 3.2, but equally play an important role in the system, such as The Dengue Data Management Module, The Dengue Map and Report Module.

The Dengue Data Management System is used for the creation, maintenance and accessing of the GIS database. The system incorporates the traditional relational database management system functions, as well as a variety of other utilities to manage the geographic data. This database management system makes it possible to pose complex queries, produce statistical summaries and tabular reports of attribute data. It also makes the map analysis possible with its ability to combine elements from many layers.

The Dengue Map and Report Module is the map and report producer tool. It allows necessary elements to be extracted from the database, such as spatial features and attributes, and produce map and report on the screen or other devices.

a) Geographic Analysis Module

Spatial analysis (ESRI, 1995) is the process of extracting or creating new information about a set of geographic (spatial) features. In this study, there are two main spatial analyse which can be performed onto the database, namely Near Analysis and Point Density.

Near Analysis provides the information on its distance from one destination/target to another one. From each grid point distances are measured to the nearest features of interest for each primary data layer using the ArcInfo "NEAR" command. The concept behind "NEAR" analysis is Euclidean distance. There are many ways to measure distance. There are distances that are Euclidean (measured with a 'ruler') and there are other distances based on similarity. The formula for the measure of the distance between two coordinates $a(x_1, y_1)$ and $b(x_2, y_2)$ is

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad \rightarrow \quad \text{Equation 3.3}$$

Point density calculates the density of point features around each output grid cell. Units of density are points per unit of area. There are two methods in generating point density: Simple and Kernel. Point density using the simple function calculates using the number of points that fall within the neighborhood of each output grid cell, divided by the area of neighborhood. A Kernel function was used to fit a smoothly tapered surface to each point, and the density is calculated from these surfaces where they overlay the center of the output grid cell. This gives a smoother output grid, while maintaining the same general values for density. A circular neighborhood is always used with the Kernel function. The Kernel function is based on the quadratic Kernel function described in Silverman (1986). The general form of a Kernel estimator is

$$f_\lambda(y) = \frac{1}{n^\lambda} \sum_{i=1}^{n} K_0\left(\frac{y-y_i}{\lambda}\right) \longrightarrow \text{Equation 3.4}$$

where K_0 is a Kernel function and λ is the bandwidth. One of the symmetric probability density functions commonly used as Kernel functions are quadratic

$$K_0(t) = \begin{cases} 3/4\,(1-t^2) & \text{for } |t| \le 1 \\ 0 & \text{otherwise} \end{cases} \longrightarrow \text{Equation 3.5}$$

The new coverage is dependent on the input coverage. If the input coverage is point, then the output coverage is also a point. An example of the output from this function is shown in Fig. 3.7.

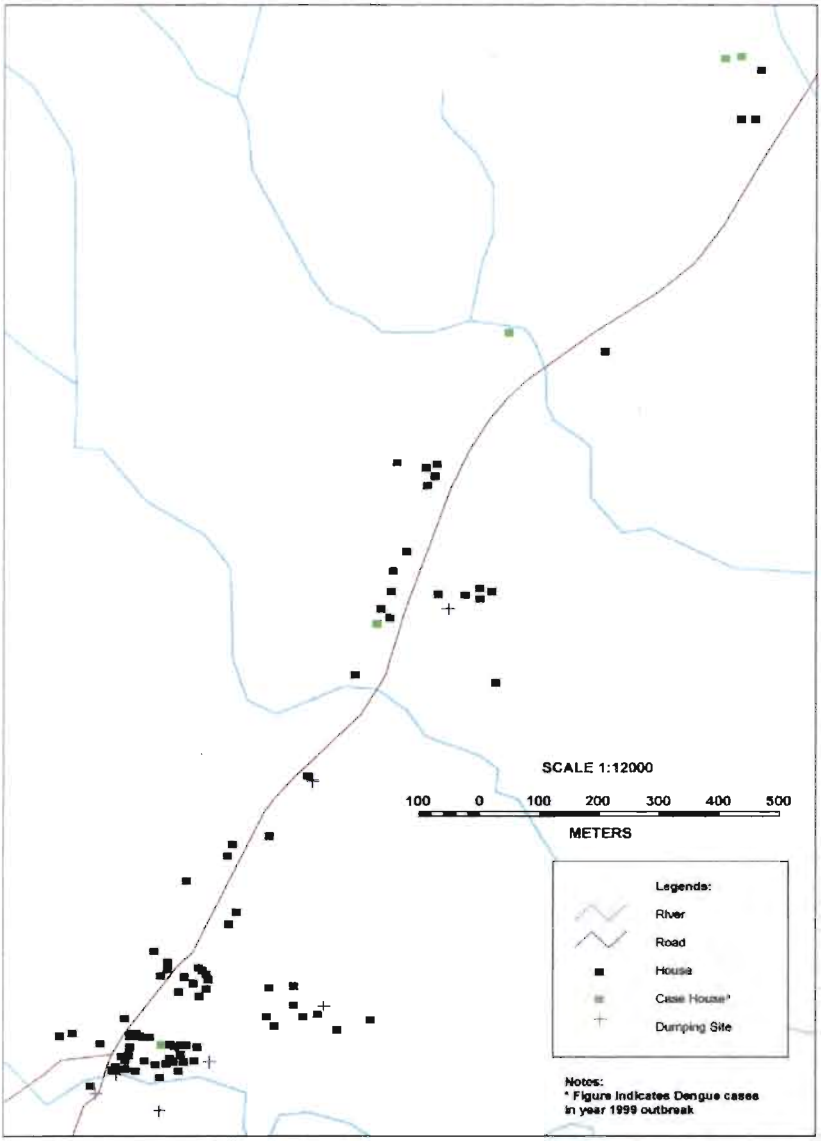


Fig. 3.7(a) Kampong Biawak : House Density

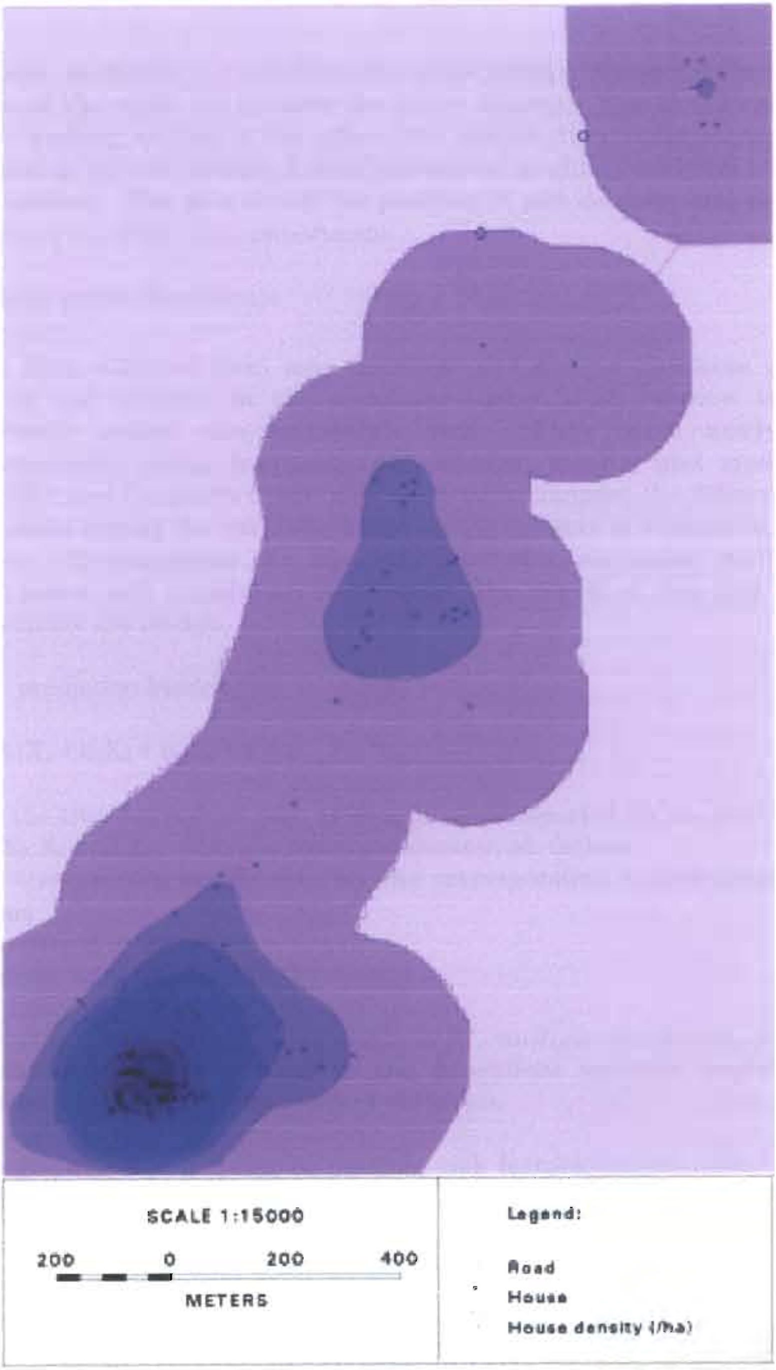


Fig. 3.7(b) Kampong Biawak : House Density

The two maps in Figure 3.7 are from the same village, Kampong Biawak. The purpose of the maps are to show the house density. This is difficult to visualize by looking at Fig. 3.7(a) where the distribution looks scattered. However, in map (b), the density Kernel estimation produces contours which indicate clustering. The gets round the problem of plot density, and points can be weighted to reflect their importance.

b) Risk prediction module

The data collected from map database and dengue database were coded and entered in the computer using SPSS version 10.01 software under non-parametric test. They were analyzed descriptively using frequency distribution, means, and median. ANOVA and Student's t test also are used to compare the differences in means among the variables based on the clusters of villages in this study. To determine the association between variables, multiple regression and correlation was used. The result of this test will determine the model.

The prediction Model:

$Y = b_1X_1 + b_2X_2 + b_nX_n + c + e$

Y = the true dependent such as dengue cases reported for the year
X_1, X_2, X_3 and X_n = dengue cases parameter/risk factors
b's = regression coefficients for the corresponding x (independent) terms
c= constant or intercept
e= error term reflected in the residuals

Associated with multiple regression is R^2, *multiple correlation*, which is the percent of variance in the dependent variable explained collectively by all the independent variables.

Dengue cases parameter or possible risk factors chosen under this analysis are :

Table 3.8 Specification of the risk factors

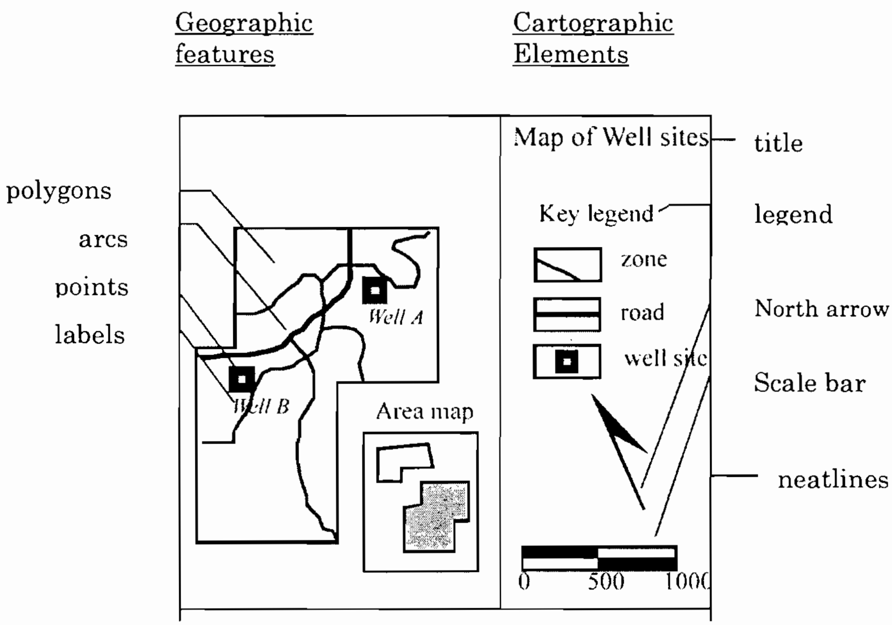
Risk factors	**GIS generated**	
	Near analysis	**Point density using Kernel function (per hectare)**
Container density		√
Human Density		√
Shading tree		√

density		
Distance of the house from the main road	√	
Distance of the dumping site to the house	√	
Indoor mosquito egg count		√
Outdoor mosquito egg count		√
Dumping site mosquito egg count		√

3.5.5 The Dengue Map and Report

The expected output of this component is a digital map and report. A map is a graphic representation of a part of the earth's surface. It also includes descriptive information, which helps in interpreting the information on the map. The main component of a map is shown in Fig. 3.8. These maps will be presented in a later chapter and in the appendix. This will also incorporate the prediction model in the form of a map for visualization.

Fig. 3.8 : Main Components of a map



(Source : ESRI, 1995)

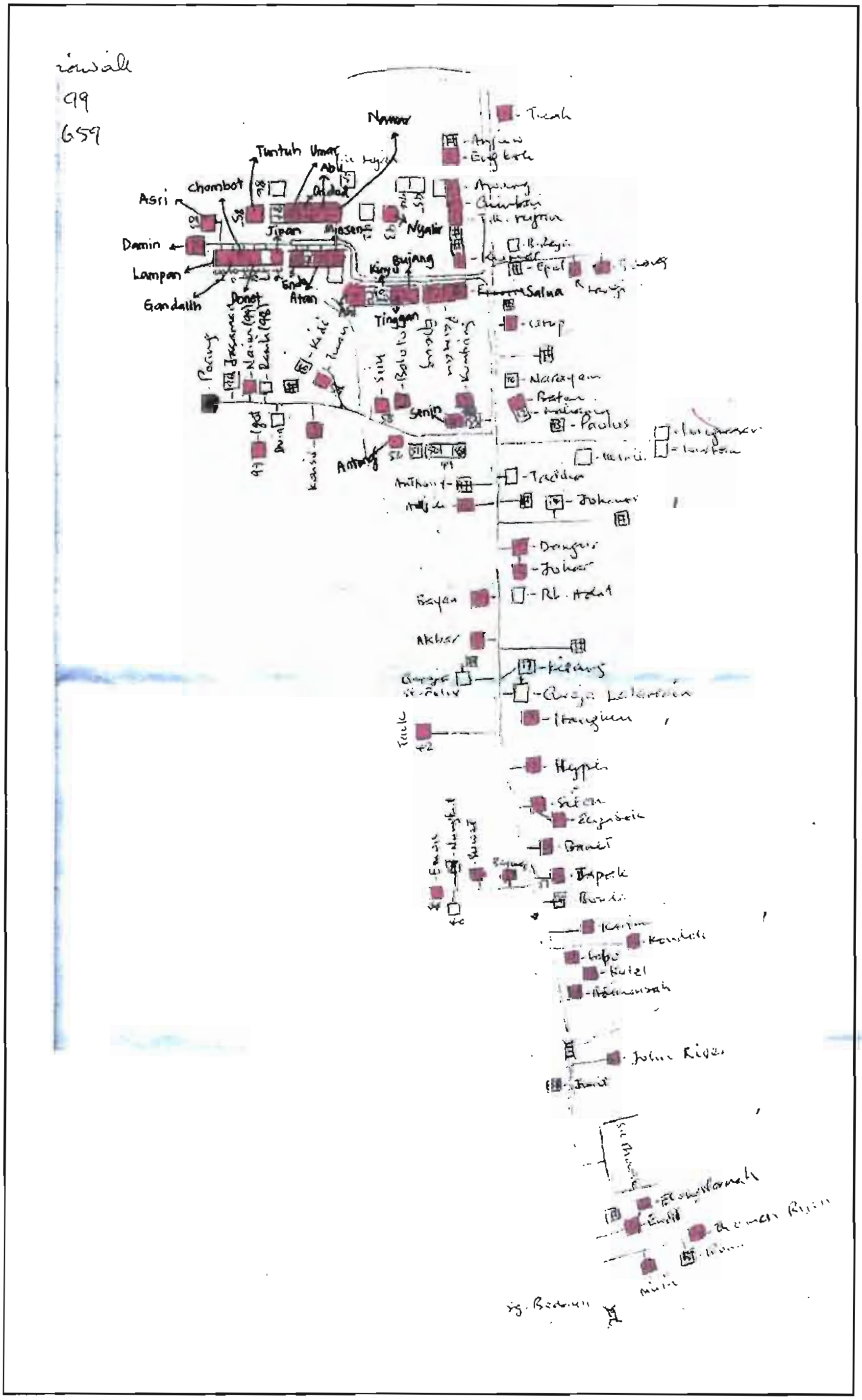


Fig 3.9(a) Kampong Biawak : Distribution of houses, dumping sites, case house and other geographical features.

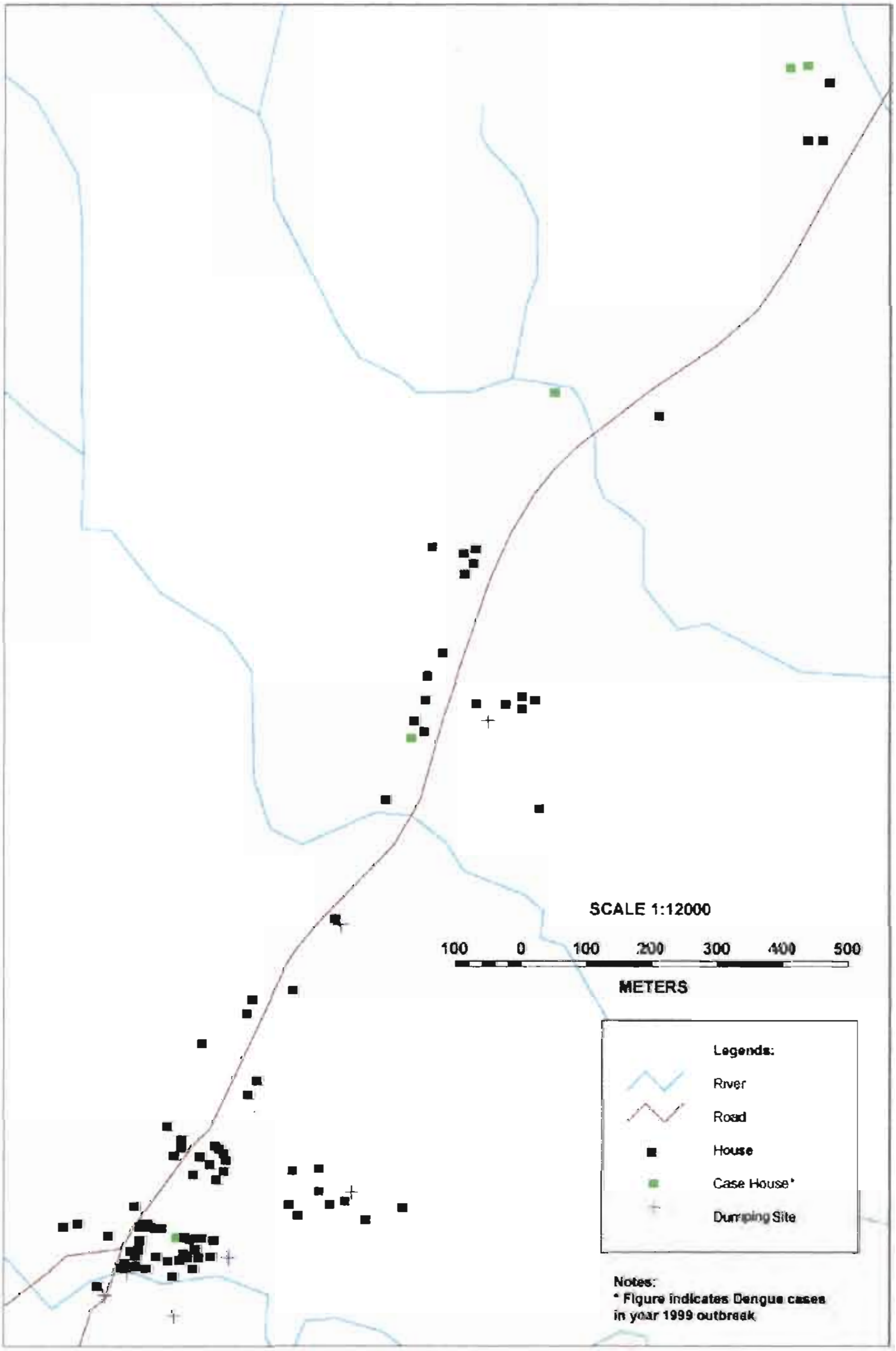


Figure 3.93(b) Kampong Biawak : Distribution of houses, dumping sites, case house and other geographical features.

The map (b) was produced using GPS and GIS, map (a) was produced by the Vector-borne Assistant Health Inspector using a hand-drawn map. The differences between these two maps are:

a) accuracy – Map (a) was produced in actual scale compared to Map (b), in which no proper measurement was used. Therefore, it is difficult to estimate distance from one house to another, or distance of the house to main road.
b) other crucial topology features were not available in Map (b) compared to Map (a). With topology information, the relationship between risk factors and geographical factors can be determined.

3.6 Summary

The use of GIS in the investigation of the relationship between spatial and non-spatial risk factors with disease occurrence is not a new approach in understanding the transmission of vector borne disease. However, the prerequisite of understanding how disease can be transmitted needs to start with a strong and powerful surveillance system. This research integrates GIS as a tool to improve the current dengue surveillance system. It provides guidelines on how to build a data management system, which is the fundamental basis for active disease surveillance. This system is not poised to fully replace the entire dengue surveillance system, especially involving entomological ground and serological survey, but it provides a systematic and efficient way of storing and managing the data collected. When the data are properly kept and managed, through mathematic modeling, a prediction model can be produced for predicting potential dengue outbreak. This chapter provides an accurate map with overlay and density function, which facilitates the map visualization and report generating phases. This chapter also highlights the use of differential Global Positioning System in mapping sites, when the distance between features are small.

CHAPTER 4

ENTOMOLOGICAL ASPECTS OF DENGUE AND RISK FACTORS ANALYSIS

4.1 Introduction

The risk factors for the emergence of DF and DHF are becoming more complex and are not well studied. However, continuous efforts have been made to link between various risk factors and the resurgence of DF and DHF. A better understanding of these factors are crucial in combating dengue outbreaks.

Many of the current efforts are looking into new potential risk factors, like socio-demographic and environmental elements. Spatial factors like distance, house and vector density, may play an important role in dengue transmission, but they have not been given much attention. Some of the possible reasons are that this information is not available for review, and current dengue surveillance system methods cannot generate it.

This chapter discusses the collection and statistical analysis of entomological data, with incorporation of ecological and serological data. This information is important as it is the raw data for the dengue surveillance system using GIS. This chapter will also give an overview of the basics of dengue surveillance. It compares geographical location with entomological, ecological and serological factors. These findings will be discussed in the following chapter together with the application of the Dengue Surveillance System presented in Chapter 5.

4.2 Materials and Methods

4.2.1 Sampling Method

Cross-sectional study approach was used in this study. Three sampling techniques were used in this study. The first approach was based on dengue reported cases in 1999, where all the 23 villages identified in the sample were chosen as the total population (N). Seven villages were chosen based on the high number of dengue cases reported. The purpose of this approach was to give an overall description of the socio-demographic background and basic facilities available in the sampled villages. Entomological and geographical profiles are described.

For serological and ovitrap studies, systematic random sampling was used. This was due to the constraints in obtaining enough blood samples and the time constraints of setting up the ovitraps.

The third sampling technique involved the use of the cluster sampling technique where the villages were divided into two clusters. The clusters were identified on the basic of location and human ecology. The first cluster was remote and far away from the main road and situated near to the Kalimantan border with a forest fringe. It has been reported that *Ae. albopictus* is more commonly found near to the forest fringe (Macdonald, 1956; Rudnick, 1965b) and in the interior of secondary forest (Macdonald & Traub, 1960). This setting was chosen as the study aims to know if there are more dengue cases found at the border villages. If so, what are the risk factors which contribute to these differences. These findings will be interesting as *Ae. albopictus* is an outdoor species, originating in the forest.

The second cluster was chosen on the basis of studies done by Wellmer (1983) and Soper (1967). Areas that are located at the roadside facilitate the movement of human population, especially using public/individual transportation. As they are more accessible to the main road, chances for dengue transmission are more likely. It is assumed that the transmission intensity of dengue fever would be different in these two ecological settings. With this, the following villages were selected.

Table 4.1 Sampling population for clusters of villages

Sampling unit	**Villages**	**Confirmed Cases**	**Numbers of houses**	**Rational**
Border Villages	Kg. Biawak	6	102	Remote and far away from the main road
	Kg. Pasir Ulu	6	76	
	Kg. Jangkar	5	65	
Roadside Villages	Kg. Semunin	2	35	At the side of the main road
	Kg. Stommuda	3	135	
	Kg. Stungkor Lama	4	81	
	Kg. Bokah	3	86	
Total		29	580	

4.2.2 Data Collection

This section is divided into three types of data input:

a) Interview – information on socio-demographic background was collected based on a set of questionnaires. Information collected includes number of household members, occupation, and level of education.

b) Basic facilities – information on type of water supply used (whether it is municipal authority pipes, gravity feed or water tank), house structure(brick, semi concrete, wooden and thatched roof, or wooden and iron roof). This information was collected by observation.

c) Entomological data collection consisting of:
   - o The prevalence of *Ae. albopictus* and *Ae. aegypti* or any other species in the area was done through house-to-house *Aedes* survey using the single larval survey method. Samples of larvae were collected and identified at the laboratory by a trained public health assistant
   - o Larval habitat – quantity and type of potential breeding containers were ascertained through observation
   - o Shading trees – number of shading trees found within 5 m radius of the house
   - o Dumping site – number of dumping sites and the distance of the house to the nearest dumping site. Location of the dumping sites were recorded by GPS.

d) Ovitrap

Systematic random sampling was used to determine the number of houses to be recruited for the ovitrap survey.

Table 4.2 Systematic Random Sampling for Ovitraps

Village	**Number of household member**	**No. of Households chosen (10% confidence level)**
Semunin	35	21
Biawak	99	34
Jangkar	66	29
Pasir Ulu	70	30
Bokah	89	33
Stungkor Lama	82	32
Stommuda	122	36
Total	563	215

The type of ovitrap used were black plastic containers, a standard method widely adopted for *Ae. aegypti* work by the U.S. Centers for Disease Control (Fay and Eliason, 1966). The size of the container was 8.5 cm in diameter and 7.0 cm in height. The plastic container was lined with rough, absorbent paper (#76 seed germination paper, Extra Heavy Weight, Anchor Paper Co., Box 65648, St Paul, MN 55165, USA). Traps were set in the morning (9-11 am), the period of minimum oviposition activity and recovered or exchanged for fresh traps at 7 days intervals, as recommended by Ritchie (1984). They were placed in open, visible places inside the house, within the house compound and at the dumping sites identified. During the inspection, the ovipositional substrate (paper) was periodically collected and returned to the laboratory in plastic bags. Samples were kept cool and moist during transportation, since too much moisture can cause eggs to hatch. Eggs or the resulting larvae were then identified.

e) Serological survey

Serological surveys are normally conducted to define the true incidence of infection in the population. The result of these surveys provide unique opportunities to characterize epidemics, define the populations at highest risk, and identify risk factors for infection. For example, Rodriguez-Figueroa et al (1995) in a study in Puerto Rico, used epidemiological and serological surveys to determine risk factors resulting in the definition of a quantitative relationship between risk of dengue infection and mosquito population density. Effective dengue surveillance should include serological survey, which involves routine laboratory testing and activities to identify active infection, as early as possible, without relying on clinical recognition and passive reporting.

Blood samples were collected by venepuncture instead of finger prick. Even though collection by filter paper is more convenient and economical, not all serological tests can be performed using such samples. Furthermore, no serum is available for future use.

Since the duration of IgM-antibody is short (60-90 days) in relation to the duration of dengue epidemics, and this study is conducted within nine months after the epidemic, IgG test is preferred.

To choose a suitable diagnostic test, factors to be taken into consideration are specificity, sensitivity and predictive value. Most public health laboratories rely on the IgM capture enzyme-linked immunabosorbent assay (MAC-ELISA) for dengue diagnosis; some perform the hemagglutination-inhibition test; and a few do neutralization tests, virus isolation and identification.

In this study, IgM and IgG capture ELISA (Cardosa et al., 1992) was used to screen for the presence of antibodies against dengue virus.

4.2.3 Statistical Analysis

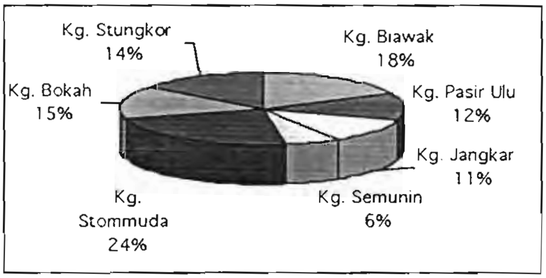
The data collected under this section were analyzed using SPSS version 10.01. Descriptive analysis using frequency, means, and median were used. To determine the association between variables and dengue cases reported, and to describe the differences between the two clusters of villages, two sample *t*-test, and Pearson's Chi-Square were used.

4.3 Results

4.3.1 Household Profile

A total of 551 households were surveyed in this study. The highest number of households was from Kg. Stommuda with 24% of the whole population surveyed. Kg. Semunin had the lowest number of households with 6% of the population only. The breakdown of the number of households by villages is shown in Fig. 4.1

Figure 4.1 Number of households by village



The mean number of persons per household was 5.9. There were 31 houses with more than 10 household members.

Table 4.3 Number of household members by villages

Villages	Total no. of household surveyed	Mean no. of household members per house	Minimum no. of household members per house	Maximum no. of household members per house
Kg. Biawak	84	6.18	1	17
Kg. Pasir Ulu	59	5.81	2	10
Kg. Jangkar	55	5.89	1	15
Kg. Semunin	29	5.76	1	12
Kg. Stommuda	74	5.85	1	14
Kg. Bokah	46	5.72	1	14
Kg. Stungkor Lama	38	5.90	2	10
Total	385	5.90		

Majority of the house owners were farmers (54.8%), which suggests agricultural landuse. Most of these farmers were involved in pepper, palm oil, paddy and small-scale vegetable plantations. There were a small number of households (6.4%) from the border villages which conducting small to medium size businesses.

About one third (32.4%) of the total population had more than 9 years of formal education.

Table 4.4 Occupation of the house owners by village

Villages	**Occupation**					
	Farmers	**Government**	**Business**	**Laborers**	**Others**	**Jobless**
Kg. Biawak	64	6	7	3	2	2
Kg. Pasir Ulu	46	5	5	0	3	1
Kg. Jangkar	45	3	1	2	1	1
Kg. Semunin	11	8	4	3	0	1
Kg.Stommuda	56	9	1	3	7	1
Kg. Bokah	28	2	0	9	6	1
Kg. Stungkor Lama	30	2	2	3	6	0
Total	280 (54.8%)	35 (6.8%)	20 (3.9%)	23 (4.5%)	26 (5.1%)	7 (1.4%)

Table 4.5 : Highest level of education achieved by villages

Villages	**No formal education**	**1-6 years**	**6-9 years**	**9+ years**
Kg.Biawak	0	5	17	59
Kg.Pasir Ulu	2	3	8	42
Kg. Jangkar	2	6	6	37
Kg.Semunin	0	4	4	19
Kg. Stommuda	14	13	13	17
Kg.Bokah	8	10	6	5
Kg.Stungkor Lama	12	15	4	3
Total	38 (11.4%)	56 (16.8%)	58 9(17%)	182 (54%)

As most of these villages still lack a modern water supply, it is not surprising the most frequent source of water was from gravity feed pipes (86%). There were two villages, Kampong Stungkor and Kampong Jangkar which did not have electricity. The source of electricity was from generators supplied by the local council. However, even though there were no proper water pipes, a majority of the villagers did not store their water in the water tanks, a potential breeding site for both *Ae. albopictus* and *Ae. aegypti*. The main water supply is from gravity feed (86% of the total population).

The majority of the villagers built their own houses which were wooden structures with iron roofing (50.1%). For those villages situated near to the border of Sarawak/Kalimantan, such as Kampong Biawak, Kampong Pasir Ulu and Kampong Jangkar, the timber logs used for building houses were more accessible and cheaper. However, most of these houses did not have a proper sanitation system. Most of the villagers depended on dug toilets, without proper water supply. The toilets were not properly maintained and mostly were located near to the kitchen. These conditions were widely found in Kampong Jangkar and Kampong Pasir Ulu.

In most of the villages, except Kampong Semunin, there were no proper dumping facilities for solid waste. Most of the villagers either discarded their rubbish in the house compound or nearby river, or carried it to their farms to be buried. In some of the dumping sites, all kinds of mosquito breeding containers were found. In Kampong Semunin, the villagers normally brought their rubbish to the nearest dumping site provided by the local council.

Table 4.6 : Water supply Facilities by villages

Villages	Municipal authority Piped Water	Gravity Feed	Water Tank
Kg.Biawak	1	83	2
Kg.Pasir Ulu	0	60	18
Kg.Jangkar	0	54	1
Kg.Semunin	29	2	1
Kg.Stommuda	0	92	7
Kg.Bokah	0	47	0
Kg.Stungkor Lama	0	45	0
Total	30 (6%)	383 (86%)	29 (6%)

Fig. 4.2 Basic facilities at the villages

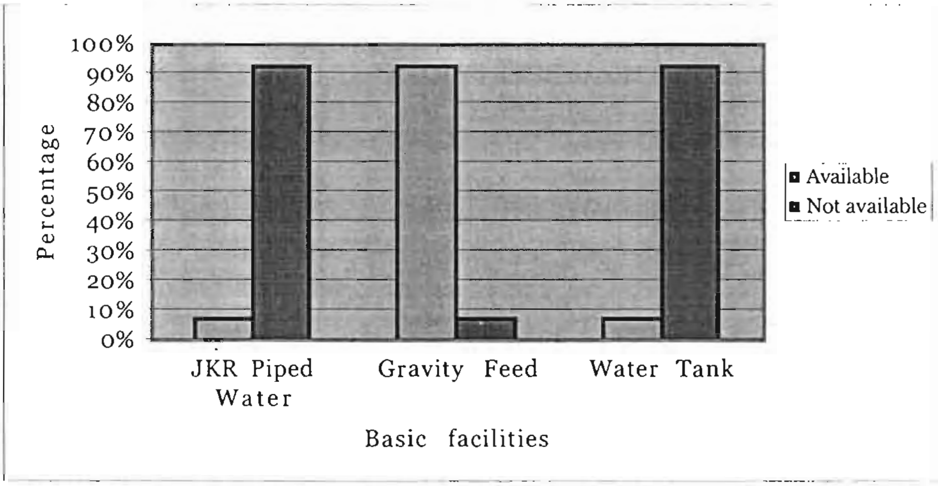


Table 4.7 : Type of house structure by villages

Villages	**House Structure**			
	Brick	**Semi Concrete**	**Wooden & thatched roof**	**Wooden & iron roof**
Kg.Biawak	6	10	4	78
Kg.Pasir Ulu	15	16	4	32
Kg.Jangkar	7	13	4	39
Kg.Semunin	17	4	3	9
Kg.Stommuda	45	18	12	53
Kg.Bokah	21	21	4	39
Kg.Stungkor Lama	26	8	16	31
Total	137 (24.7%)	90 (16.2%)	47 (8%)	281 (50%)

4.3.2 *Aedes* Larval Survey

4.3.2.1 House Survey

A random *Aedes* larval survey was carried out and confirmed that *Ae. Albopictus* was the only available species in the area as predicted, as indicated by Chang & Nagum (1982). Out of the 415 houses surveyed, 38 houses were found to have *Ae. albopictus* larval. Of all the villages surveyed, Kg. Semunin had the highest number of houses with *Ae. albopictus* larvae (House index=18.8%). This is interesting in view of what was discussed earlier (in section 4.2), as Kampong Semunin has more facilities than other villages in this study. One practice of the villagers is to store water in big earthenware jars, seldom changing the water or using any form of larvicide or cover to prevent breeding. The

Breteau index (number of positive containers per 100 houses) ranged from 6.52 in Kampong Bokah to 262.5 in Kampong Semunin.

Table 4.8 Breteau and House index by villages

Village	**No. of house surveyed**	**House Index (%)**	**Breteau Index (%)**
Kampong Biawak	83	6.0	16.9
Kampong Pasir Ulu	63	1.6	9.5
Kampong Jangkar	55	14.6	50.9
Kampong Semunin	32	18.8	263
Kampong Stommuda	92	15.2	181
Kampong Bokah	46	6.5	6.5
Kampong Stungkor Lama	44	2.3	6.8

4.3.2.2 Larval Habitat

4.3.2.2.1 Potential Breeding Containers

In addition to house surveys, inspection for potential outdoor breeding sites was also carried out. All containers in respective of positive or negative were inclusive in this study. As *Ae. albopictus* is an outdoor species, the study was confined to larval habitats outdoors (5 m from the house). Of all the households surveyed, the total number of potential breeding sites was 1521 with a mean of 3.63. The lowest number of containers found was one and the highest was 48.

Table 4.9 Total number of potential breeding containers and the mean by villages

Villages	**Total No. of Potential Breeding Container**	**Mean no. of container per house**
Kampong Biawak	184	2.19
Kampong Pasir Ulu	223	3.43
Kampong Jangkar	142	2.58
Kampong Semunin	358	11.2
Kampong Stommuda	425	4.62
Kampong Bokah	145	3.09
Kampong Stungkor Lama	44	1.00
Total	1521	3.63

Table 4.10 Type of container found in the village

Type of container	Number	Percentage
Tin can	613	43.1
Plastic cup/pan/bowl	210	14.8
Coconut husk	126	8.9
Drum	144	10.1
Jar	85	6.0
Cocoa husk	67	4.7
Metal pots	75	5.3
Clay ware	59	4.2
Tyre	42	3.0
Total	1421	100

The study also found that the type of potential breeding container for *Ae. albopictus* was not confined to natural containers like cocoa or coconut husk. The survey showed that tin cans were the most popular breeding containers for all villages (43.1%). This was followed by plastic cups, pans or bowls (14.8%). Most of the tin cans found were not disposed properly and they were exposed in a upright position to collect rain water or any other source of water. Chang and Nagum (1994) found that the most common out-of-door habitat of *Ae. albopictus* in Sibu was discarded tin cans.

Table 4.11 The most frequent potential breeding container by village

Name of the village	First (%)	Second (%)	Third (%)
Kampong Biawak	Tin can (25.5%)	Plastic Cup/pan/bowl (24.5%)	Coconut husk (19.6%)
Kampong Pasir Ulu	Tin can (37.2%)	Plastic Cup/pan/bowl (20.2%)	Coconut husk (11.7%)
Kampong Jangkar	Tin can (24.6%)	Plastic Cup/pan/bowl (23.9%)	Drum (18.3%)
Kampong Semunin	Tin can (26.3%)	Cocoa husk (15.9%)	Plastic Cup/pan/bowl (14.8%)
Kampong Stommuda	Tin can (62.1%)	Others (bottle, pile) (22.1%)	Drum (4.9%)
Kampong Bokah	Tin can (37.9%)	Clay ware (25.5%)	Drum (13.1%)
Kampong Stungkor	Tin can (72.7%)	Drum (2.3%)	Tyre (2.3%)

4.3.2.2.2 Shading Trees

Of all the villages surveyed, Kampong Jangkar had the highest count of shading trees as it is surrounded by sundry tree cultivation.

Table 4.12 Number of shading trees per house by village

Villages	Total no. of shading trees	No. of shading trees per house
Kampong Biawak	50	0.5
Kampong Pasir Ulu	50	0.76
Kampong Jangkar	85	1.42
Kampong Semunin	27	0.82
Kampong Stommuda	65	0.5
Kampong Bokah	87	1.06
Kampong Stungkor Lama	69	0.9

4.3.2.2.3 Village Dumping Site

Kampong Biawak had the most dumping sites within the village perimeter (98) and Kampong Stungkor Lama had the least (4).

Table 4.13 Number of dumping site by villages

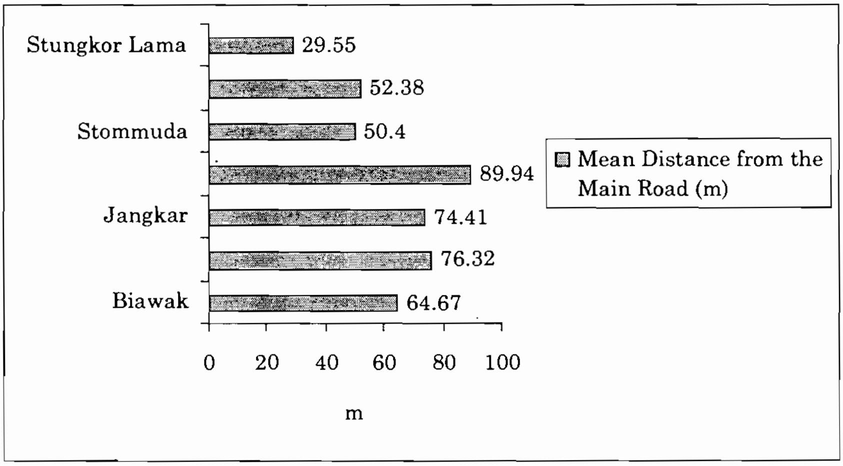
Villages	Number of dumping sites	Mean number of dumping site per house
Kampong Biawak	98	0.93
Kampong Pasir Ulu	54	0.90
Kampong Jangkar	54	1.00
Kampong Semunin	29	0.91
Kampong Stommuda	66	0.72
Kampong Bokah	15	0.32
Kampong Stungkor Lama	4	0.091

4.3.3 Geographic Information System Generated Data

a) Distance (m) of the house from the main road

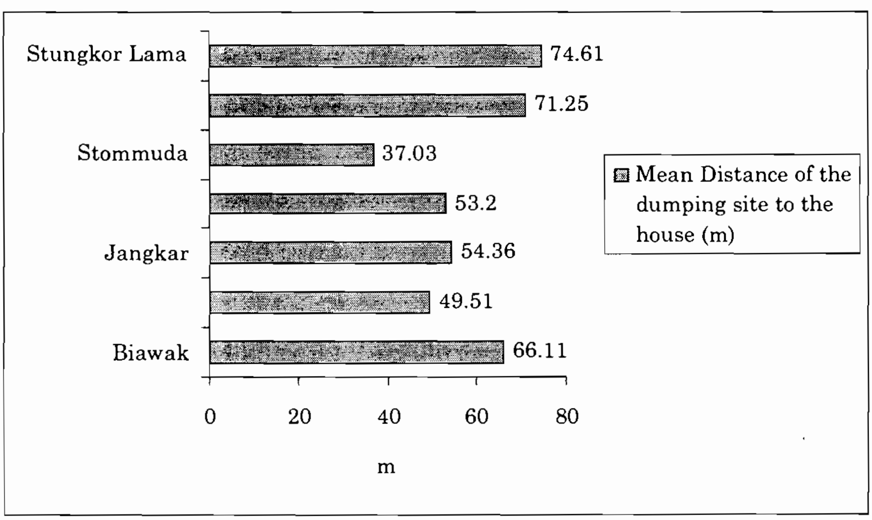
The data were generated using the function of "Near" analysis under the ArcInfo tool to find the distance of the house from the main road which could contribute to dengue transmission. This was done on the assumption that human beings are the host of dengue virus transmission. Figure 4.5 shows the mean distance of the houses from the main road, by village.

Fig. 4.3 Mean distance (m) of the house from the main road by village.



b) Distance (m) of the dumping site to the house

Fig. 4.4 Mean distance (m) of the dumping site to the house by village



The result shows that longest mean distance of the dumping site to the house is in Kampong Stungkor Lama (74.61m) and the lowest is in Kampong Stommuda.

4.3.4 Ovitrap

A total of 32,838 *Aedes* eggs were collected in 56 days of trapping. Yields per positive seed paper ranged from 40 to 230. All eggs were collected based on eight weeks of uninterrupted field work. The details are as follows:

Among all the villages, Kampong Semunin had the highest mean eggs per week for all sites (Indoor = 253.5, Outdoor=455.4, Dumping Sites=359.3), followed by Kampong Jangkar for outdoor and dumping sites (Outdoor=429.6, Dumping site=137.1). However, for indoor ovitrap results, the second highest mean count per week (109.1) was from Kampong Bokah.

Among the three sites studied, outdoor ovitrap had the highest mean count at 455.4 per week, followed by dumping sites at 359.3 eggs per week. This further proved that *Ae. albopictus* was abundant in this study area, outdoors.

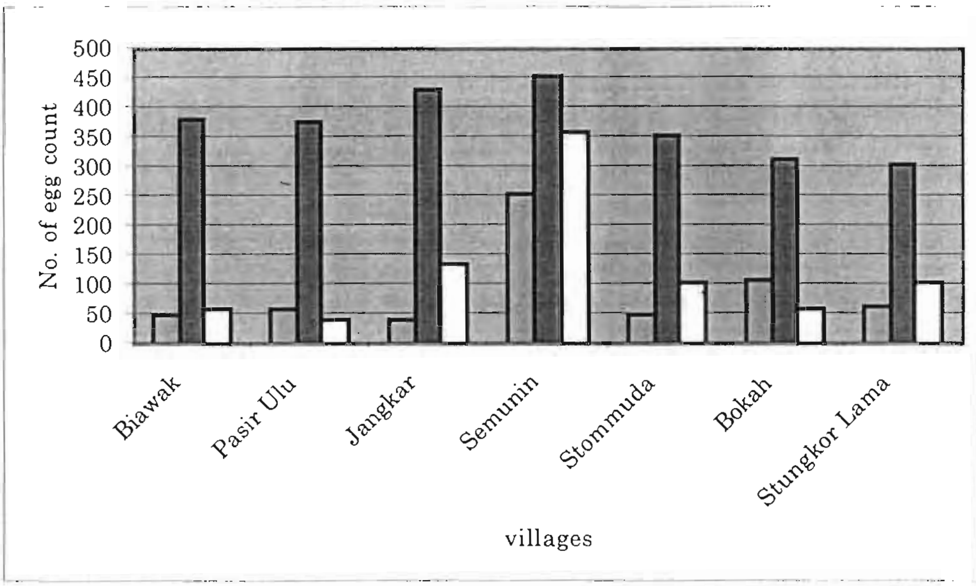
Mosquitoe eggs collected from the ovitrap were randomly picked and allow to hatch in the laboratory for species identification. The results showed that all the eggs were from *Ae. albopictus*.

Table 4.14 Ovitrap result by weeks by villages

Village	Habitat	Week 1	2	3	4	5	6	7	8	Total no. of eggs	Mean eggs per week
Biawak	I	5	0	10	0	72	115	15	179	396	49.5
	O	48	131	207	390	629	746	459	441	3051	381.4
	DS	2	5	50	47	110	25	115	100	486	60.8
Pasir Ulu	I	2	10	10	0	40	70	160	167	459	57.4
	O	52	93	527	106	601	699	492	446	3016	377
	DS	20	18	34	0	50	90	80	20	312	39
Jangkar	I	0	0	10	36	50	59	77	80	312	39
	O	8	310	409	349	899	574	441	447	3437	429.6
	DS	23	45	110	65	242	232	120	260	1097	137.1
Semunin	I	201	258	52	169	175	491	355	327	2028	253.5
	O	37	91	293	516	597	787	812	510	3643	455.4
	DS	55	79	178	386	488	490	758	440	2874	359.3
Stommu da	I	21	3	40	60	83	78	41	89	415	51.9
	O	2	290	409	643	259	563	364	314	2844	355.5
	DS	141	108	111	228	0	83	45	110	826	103.25
Bokah	I	33	22	64	74	146	181	179	174	873	109.1
	O	2	120	539	291	467	428	150	506	2503	312.9
	DS	19	10	102	80	100	88	40	50	489	61.1
Stungkor Lama	I	8	12	7	59	203	55	78	99	521	65.1
	O	108	60	473	295	641	88	473	289	2429	303.4
	DS	36	41	138	45	360	57	82	68	827	103.4

I=Indoor, O=Outdoor, DS=Dumping Site

Fig. 4.5 Distribution of mean eggs count by village (indoor, outdoor and dumping site)



4.3.5 Serological Results

Serological tests indicated that 23.7% of the total samples had experienced asymptomatic dengue infection. Two samples (0.9%) were confirmed by IgM positivity and 49 samples (22.8%) had IgG responses. The highest number of samples indicated with recent dengue infection was from Kampong Biawak with 19, followed by Kampong Jangkar (8). As for IgM result, only two positive samples were detected, one from Kampong Pasir Ulu and another one from Kampong Semunin. This indicates no current transmission of dengue in the study villages during the survey period.

Table 4.15 IgG and IgM result by villages

	Serological result	
Name of the Village	**IgG Positive**	**IgM Positive**
Biawak	19 (44.1%)	0
Pasir Ulu	6 (20%)	1 (3.3%)
Jangkar	8 (27.6%)	0
Semunin	6 (28.6%)	1 (4.8%)
Stommuda	4 (11.1%)	0
Bokah	3 (9.1%)	0
Stungkor Lama	3 (9.4%)	0
Total	49 (22.8%)	2 (0.9%)

The results in Table 4.14 show that Kampong Biawak has the highest count of villagers with previous dengue infection. Among the IgG positive samples, 28 (57.1%) are farmers.

4.3.6 Risk Factors Analysis by Cluster of Villages

As indicated in Chapter 3, two clusters of villages were identified to investigate whether any of the risk factors (entomological or geographical) were influenced by geographical location. These clusters were defined as border villages and roadside villages.

The aim of this aspect of the study was to find out if any significant differences existed between the dengue cases reported 1999 and clusters of villages. The comparison of two means was done by way of two sample *t*-test.

Table 4.16 Number of dengue cases by cluster of villages

Clusters	**No dengue case**	**With dengue cases**	**Total**
Border villages	82 (88.2%)	11 (11.8%)	93 (100%)
Roadside Villages	120 (96.8%)	4 (3.2%)	124 (100%)
Total	202 (93.1%)	15 (6.9%)	217 (100%)

Border=Kg. Biawak, Kg. Pasir Ulu and Kg. Jangkar
Roadside=Kg.Stommuda, Kg.Bokah, Kg. Stungkor Lama, and Kg.Semunin
Pearson's Chi-Square=6.111, df=1, p=0.013

H_0: The dengue cases for two clusters of villages are identical

We reject H_0 that dengue cases in two clusters of villages are identical at any reasonable significance level.

11.8% of households in border villages were found to have at least one dengue case, but only 3.2% of household in roadside villages were found to have at least one case. In another words, there were 4.032 times more cases found in border villages than roadside villages.

Table 4.17 IgG results by clusters of villages

Clusters of villages	**IgG Negative**	**IgG Positive**
Border	60 (35.7%)	33 (67.3%)
Roadside	108 (64.3%)	16 (32.7%)
Total	168 (100%)	49 (100%)

Border=Kg. Biawak, Kg. Pasir Ulu and Kg. Jangkar
Roadside=Kg.Stommuda, Kg.Bokah, Kg. Stungkor Lama, and Kg.Semunin
Pearson's Chi-Square=15.5, df=1, p=0.000
Odd's Ratio=0.269, 95% Confidence Interval=0.137, 0.529

H_0: The IgG result for two clusters of villages are identical

We reject H_0 that IgG result in all two clusters of villages are identical at any reasonable significance level.

67.3% of households in border villages were found to have IgG positive cases, but only 32.7% of in roadside villages. In another words, there were 3.717 times more IgG positive cases found in border villages as compared to roadside villages.

Table 4.18 Comparison of risk factors by clusters of villages

Risk factors	Mean	SD	t	df	p
Container density					
- Border	3.5963	3.0955	-4.320	206.624	0.001*
- Roadside	6.0167				
Human Population density					
- Border	11.1338	11.0802	0.146	157.327	0.884
- Roadside	10.9367				
House density					
- Border	1.8038	1.6283	-5.992	204.359	0.001*
- Roadside	3.6065				
Shading tree density					
- Border	2.6335	2.3311	-1.058	214.956	0.291
- Roadside	3.0214				
Distance of the house to the main road					
- Border	71.4171	79.0114	20114	136.338	0.036
- Roadside	51.9249				
Distance of the dumping site to the house					
- Border	57.178	62.229	-0.244	184.085	0.808
- Roadside	59.178				
Egg Count per positive ovitrap (Indoor)					
- Border	0.9350	0.6654	-10.89	137.497	0.001*

- Roadside	4.0976				
Egg Count per positive ovitrap (outdoor) - Border - Roadside	9.9185 14.0166	7.2523	-3.777	212.608	0.001*
Egg Count per positive ovitrap (dumping sites) - Border - Roadside	2.1448 3.8738	2.9316	-3.879	213.783	0.001*

*Significant at 0.01 level (2-tailed)

H_0: The risk factors for two clusters of villages are identical

There were five risk factors [Container density, house density, Egg Count per positive ovitrap (Indoor), Egg Count per positive ovitrap (outdoor), Egg Count per positive ovitrap (dumping sites)]. For all these five factors, we reject H_0 that these risk factors in all two clusters of villages are identical at any reasonable significance level.

4.3.7 Relationships between dengue cases and risk factors

Table 4.19 Relationships between dengue cases and risk factors

Number of dengue cases	**σ**	**p**
Container density	0.127*	0.003

*Significant at 0.05 level (2-tailed)

Table 4.20 Relationships between risk factors

Variable	**Variable**	**σ**	**p**
Number of breeding site outdoor	House Density	0.264**	0.001
	Egg count per positive ovitrap (outdoor)	0.213**	0.006
Distance of dumping site to the house	Container density	0.318**	0.001
	Human density	0.303**	0.001
	House density	0.432**	0.001
	Shading tree density	0.271**	0.001

	Egg count per positive ovitrap (Indoor)	0.214**	0.001
	Egg count per positive ovitrap (Dumping site)	0.191**	0.001
Container Density	Shading tree density	0.291**	0.001
	House Density	0.624**	0.001
Distance of the house to the Main Road	Human Density	0.201**	0.001
	Shading tree density	0.226**	0.001
House density	Distance of the house to the Main road	0.280**	0.001
	Egg count per positive ovitrap (Indoor)	0.616**	0.001
	Human density	0.929**	0.001
	Shading tree density	0.747**	0.001
	Egg count per positive ovitrap (Dumping site)	0.256	0.001
Human Density	Shading tree density	0.724**	0.001
	Container Density	0.648**	0.001
	Egg count per positive ovitrap (Indoor)	0.478**	0.001
	Egg count per positive ovitrap (Outdoor)	0.536**	0.001
	Egg count per positive ovitrap (Dumping site)	0.239**	0.001
Shading tree density	Egg count per positive ovitrap (Indoor)	0.514**	0.001
	Egg count per positive ovitrap (Outdoor)	0.741**	0.001
	Egg count per positive ovitrap	0.209**	0.001

	(Dumping site)		
Container Density	Egg count per positive ovitrap (Indoor)	0.415**	0.001
	Egg count per positive ovitrap (Outdoor)	0.185**	0.001
Egg count per positive ovitrap (Indoor)	Egg count per positive ovitrap (Outdoor)	0.685**	0.001
	Egg count per positive ovitrap (Dumping site)	0.368**	0.001
Egg count per positive ovitrap (Outdoor)	Egg count per positive ovitrap (Dumping site)	0.375**	0.001

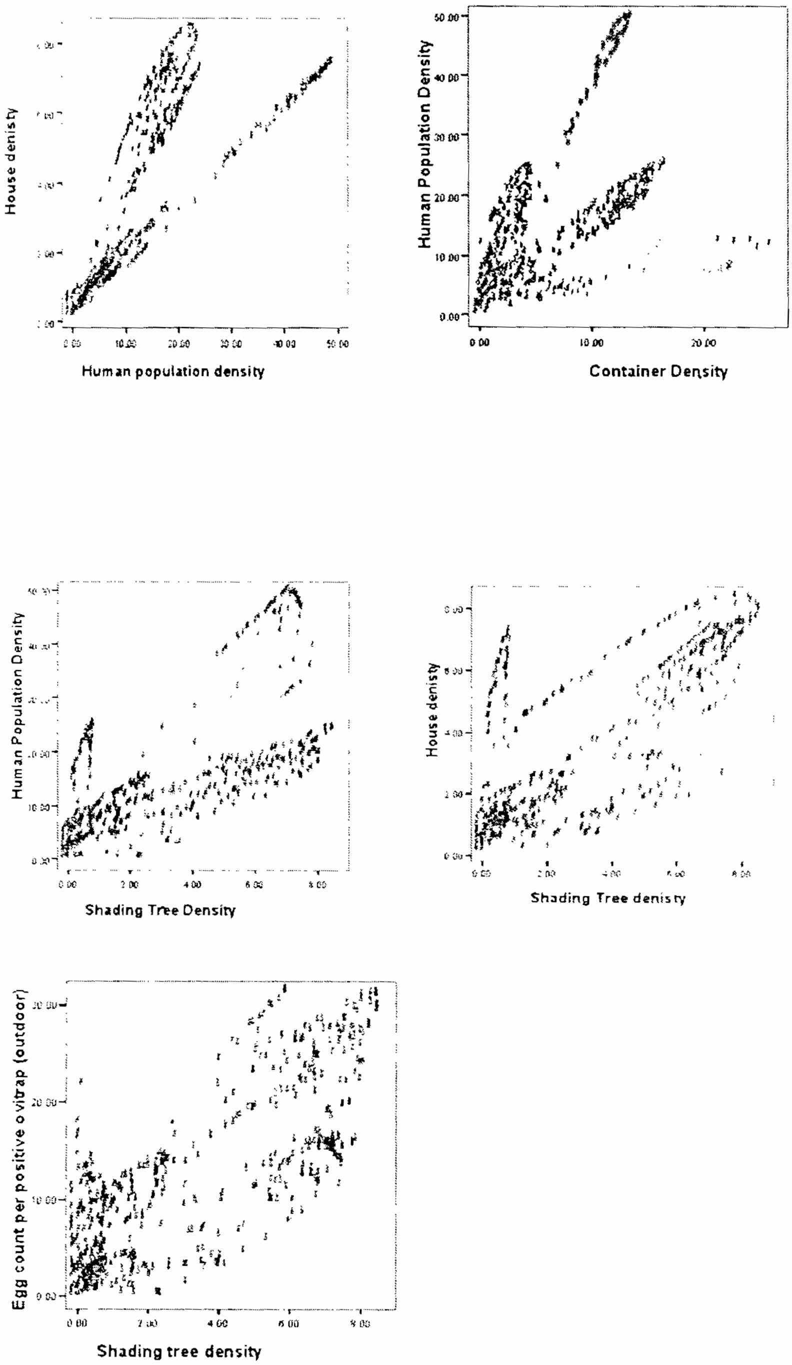
**Significant at 0.01 level (2-tailed)

Table 4.19, Spearman's correlation=0.127, at $p<0.01$ reveals that, only container density has weak relationship with dengue cases reported 1999. Thus, the null hypothesis , which stated there is no relationship between dengue cases and container density is rejected.

Further analysis was done to investigate the relationship between risk factors and the findings showed (Table 4.20) that the variables which showed strong relationship are house density and human population density (Spearman's correlation=0.929, p=0.000), house density and shading tree density (Spearman's correlation=0.747, p=0.000), human population density and shading tree density (Spearman's correlation=0.724, p=0.000), human population density and potential container density (Spearman's correlation=0.648, p=0.000), Egg count per positive ovitrap (outdoor) and shading tree density (Spearman's correlation=0.741, p=0.000).

A positive and strong correlation between house density and human population density means that, as the house density becomes higher, the human population also increases. This is not uncommon, as the villagers in this study area consist of a Bidayuh majority, who believe in family extensions. Having more people gathered within an area encourages more social activities, which can cause the increase of potential containers being discarded in the area. This is why the container density also increases as the human population increases. The villagers also like to plant a lot of trees in their surroundings as they produce fruits. So, as the human population density grows, more trees are found in the surroundings. The more trees, the more shading areas for the breeding of mosquitoes. This is why the egg count per positive ovitrap (outdoor) increases with the shading tree density increases.

Figure 4.6 Scatterplot : Linear Correlation between risk factors



4.4 Summary

This chapter contains the entire findings on the entomological aspect of the study. The household profile and basic facilities are analysed and described to give an overall background of the study area. These are followed by descriptions of non-spatial to spatial risk factors based on the seven villages. A comparative study between two different locations of villages is also being done to investigate if location influences dengue occurrence. Finally, a risk factor analysis was done to determine whether dengue cases are significantly related to any of the risk factors studied.

The results also show that there is significant difference in terms of dengue cases in border villages and roadside villages. Of all the risk factors, container density, house density, egg count per positive ovitrap (indoor), egg count per positive ovitrap (outdoor), egg count per positive ovitrap (dumping sites) were found to be significantly higher in the roadside villages. A weak positive significant relationship was also found between dengue cases and container density.

The next chapter, summarizes and discusses the findings, limitation, conclusion and recommendation for future study.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 Overall Summary and Discussion of Results

This study had two main goals:

- To elucidate the association of various risk factors with dengue cases reported in Lundu district, 1999

- to design and develop a dengue surveillance system for monitoring the vector *Ae.albopictus* in potential outdoor breeding sites.

In order to achieve these goals, five specific objectives were identified:

- To describe the socio-demographic background of the households and their basic facilities in the villages affected by dengue
- To study the spatial and non-spatial distribution of geographical, entomological, and serological data based on villages
- To describe the types of outdoor potential containers found in the villages
- To determine whether there is any significant difference among the two clusters of villages (border and roadside) in term of dengue cases reported in 1999, their geographical, entomological, and serological profile
- To determine the relationships between dengue cases reported in 1999 and the potential risk factors.

The objectives of the study were realized by entomological, serological and socio-demographic surveys assisted by GIS and analysed using spatial and statistical analysis (SPSS version 10.01). Data from the above were analysed through the use of relevant tests such as *t*-test and Spearman's Correlation.

The first objective of the study was to describe the socio-demographic background of the households and their basic facilities available in the villages. In summary, it was found that of the 551 households surveyed in the sample, the majority of the households are from Kg. Stommuda (24%). Mean number of household member per house is 5.9. Majority of the house owners are farmers (49.9%) which explained why the main socio-economy activity is farming. Almost one third of the sample had more than 9 years of education from the school (32.4%). This finding is consistence with the General Report of the

Population Census Malaysia, 1991 where 34% of the population in Sarawak attended secondary schools.

In this case, low income and poor basic facilities are the main factors that caused the standard of living in this area low. To improve the standard of living, there are many inter-sectoral efforts must be taken. This is supported by the WHO report on infectious diseases where population increases, leading to overcrowding and poverty are causing dramatic increases in DF (WHO, 1999).

The most frequent source of water supply is by gravity feed (92.3%). This is due to the lack of a government piped water supply. Some villages like Kg. Stungkor Lama and Kg. Jangkar are without electricity. The majority of the villagers build their own houses with wood, and iron roofing (50.1%). Almost all the villages depend on dug (pour) toilet. In the absence of dumping facilities, lead to unsanitary condition around the village perimeter.

The second objective was to study the spatial and non-spatial distribution of geographical, entomological and serological data based on villages. It was stated by Chang & Nagum (1982) that *Ae. albopictus* is more widespread in rural towns and plantations and this further strengthens Parasmesvaran's (1965) conclusion that this species is more common in outer urban areas. As the main socio-economic activities of the villagers are outdoor farming, they are exposed to *Ae. albopictus* biting. Furthermore, with the unsanitary conditions due to the lack of basic facilities, the surrounding area of the house further promotes the breeding of *Ae. albopictus*.

A house built of wood also may aggravate the insanitary environment. A study done by Rudnick (1986) crowded, wooden structures can promote high density breeding of the *Aedes* vector. His study was done in Jinjang, a densely populated town eight miles northwest of Kuala Lumpur. However, more evidence is needed to clarify to what extent house structure contributes to dengue transmission. For sure, house structure is related to standard of living and income level of the occupants. In this context, a more income will enable the villagers to use concrete and better roofing. A better standard of living is better basic facilities.

Twenty years after Chang & Nagum studies(1982), the distribution of *Ae. albopictus* is still dominant and *Ae. aegypti* has not colonized the Lundu district. Kg. Semunin as situated in rural town has the highest Breteau index of 262.5 and house index of 18.75 compared to other villages. One is expect Kampong Semunin, the only village near to the town with all facilities available, should not have the highest House index. There may be a number of possible explanation for the fact that the findings of the current study are not consistent with those reported in the literature, no obvious explanation seems to present itself. The earthenware jars for water storage in this village could support the breeding of *Ae. albopictus*.

From the serological survey, the most IgG positive samples were from Kampong Biawak, with 22.79% positive out of 215 samples tested. This indicates that dengue virus probably circulates in the village without being noticed. However, there has been no recent dengue infection as indicated from the results of serological analysis. Other villages such as Kampong Pasir Ulu, Kampong Jangkar and Kampong Semunin had a similar percentage of IgG positivity rate ranging from 20% to 28.57%. Out of the three villages, two had one positive IgM sample each. This indicates that there is a possibility of current dengue virus transmission in the villages. Based on the entomological results, Kampong Semunin has high Breteau (262.5) and House (18.75) index. The same findings also appeared in the mean count of potential breeding containers (11.19). For outdoor ovitrap result, all the three villages reported to have high result were 455.4, 377, and 429.6 eggs per ovitrap respectively. On the other hand, the last three villages (Stommuda, Bokah and Stungkor Lama) had fewer IgG positive samples, compared to others. This is consistent with some of the studies that showed entomological results have no relationship to serological results. In this case, Kampong Stommuda is the example.

The third objective was to study the types of outdoor potential containers found in the villages. The most popular breeding containers were tin cans, followed by plastic cups/pans and bowls for all villages. As there is lack of scavenging services provided by the local council, many of these potential breeding containers were found not to be disposed properly and exposed upright to rain water. In this study tin cans were found to be the most favorable breeding place for *Ae. albopictus*.

The fourth objective was to determine whether there is any significant difference among the two clusters of villages (border, and roadside) in terms of geographical, entomological, serological data. Analysis of the data only revealed there are significant difference in clusters of villages attributable to container density, house density, distance of the house from the main road, and number of *Ae. albopictus* eggs from ovitraps set indoor, outdoor, and in dumping sites. Based on cross tabulation test and t-test (95% confidence level), these are the findings:

Chi-Square result revealed that there is significant difference in terms of dengue cases in border villages and roadside villages. The odds ratio further testifies to the above finding by showing there are four times more cases reported in border villages compared to roadside villages. Where there is difference, further analysis using two sample *t*-test would determine which of the risk factors contributed to the difference. The *t*-test result showed that house density, container density, indoor mosquitoes egg count, outdoor mosquitoes egg count, and dumping sites mosquitoes egg count gave significant result at $p<0.05$. The mean value for these factors showed higher values/counts at the roadside villages compared to border villages. There are many possible explanations for these results. This apparent paradox can be explained by the fact that *Ae. albopictus* is an outdoor species, and originates from the forest, many of them could have bred at the forest fringe, situated next to the border villages (Hawley, 1988). In the roadside villages, man-made containers are the only breeding source. That is why the container density is higher in the roadside villages. Furthermore, a study by Rodriguez-Figueroa et al. (1995) showed that in areas of high dengue prevalence, the affected household members take more precautions to clean up their houses and compound, compared to those in villages with lower dengue cases.

The use of GIS in investigation of the relationship between spatial and non-spatial risk factors with disease occurrence is not a new approach in understanding the transmission of vector borne disease. The pre-requisite of any communicable disease control is a strong and effective surveillance system. All data derived from surveillance must be managed and stored in a systematic way. This study has achieved its objective by introducing a new dengue surveillance system with spatial and non-spatial risk factors, using GIS as a tool. It also highlights the use of differential Global Positioning System in mapping study sites when the distance between features is small and cannot be done by the conventional mapping method. However, it is impractical that this system need to further verify in a larger geographical area with sufficient dengue data.

A number of potential risk factors for the dengue cases reported in Lundu was investigated. None of the factors (house density, container density, human population density, shading tree density, indoor mosquito egg count, outdoor mosquito egg count, and dumping sites mosquito egg, distance of the dumping site to the house, distance of the house to the main road were associated with the dengue cases. Our analysis of the above relationship is limited by the preliminary nature of dengue cases in Lundu. Furthermore, the study was done six months after the outbreak, when many of the important risk factors must have been reduced and eliminated due the intensive post-epidemic control measures. Dengue transmission occurrence is caused by a unique combination of virological, entomological and environmental factors.

The addition of GPS and GIS technologies to dengue studies affords the possibility of exploring spatial dimensions of disease transmission not easily examined in the absence of these capabilities. Further, the incorporation of these techniques in the long term will help to save the high cost of dengue surveillance. Su & Chang's study (1994) also recommended the use of GIS as long term management of *Aedes* mosquitoes and control of epidemic of dengue disease. By incorporating geostastics (such as Kriging) modeling and forecasting of possible dengue epidemics, there will be a proper and efficient use of a decision support system.

With respect to the ovitrap results, it was observed that *Aedes albopictus* preferred outdoor ovitraps with a mean count of 373.6 per week compared to indoor ovitraps with mean count of 89.35 per week. This is consistent with the study done by Mogi et al. (1988) in Chiang Mai, Thailand. At the same time, compared to dumping sites ovitraps, outdoor ovitraps still produced higher mean counts. One possible explanation is that this is part of the species survival mechanism (Rozeboom et al., 1973). In nature, it was observed that *Ae. albopictus* females seldom deposit all of their mature eggs in a single oviposition. Instead, they appeared to move from place to place, to deposit a few eggs at each site. The female probably lays all mature eggs during the course of several ovipositions, periodically interrupting her egg laying to fly to another container (Hawley, 1988). In this situation, dumping sites normally will have more discarded containers which have compete with the ovitrap set earlier. Therefore, it is not surprising that the dumping site ovitraps did not give a high egg count.

The use of seed germination paper has proved successful in collecting the mosquito eggs. For the first time, this type of paper has been used in setting up the ovitrap for *Ae. albopictus* study. However, the type of container used are standard, adopted for *Ae. aegypti* work by Centers for Disease Control (Fay and Eliason, 1966).

5.2 Limitation

It was recognized from the beginning that this study would have several significant limitations. First, the study was conducted in Lundu, one of the districts of Sarawak. Therefore the findings may not extend to other districts in Sarawak. However, it is reasonable to suggest that the findings of this study could provide a basis for future dengue related studies and work, especially, in the development of a dengue surveillance system. The experience of conducting the field work could provide a good reference for future work.

Second, the dengue surveillance system would have been more complete has the risk prediction module been in place. It was recognized from the beginning that to develop a risk prediction model needs a more complete and comprehensive approach involving many years of dengue data. Furthermore, a prediction model once developed needs to be tested before it can be used.

5.3 Conclusions and Recommendations

The findings of this study supported the concept of using GIS as a tool in understanding dengue transmission in a rural setting. This system has potential which should be explored further. Even though the GIS generated risk factors showed no relationship with dengue cases reported, this does not mean these are not important. After all, most other research has not taken this approach in investigating dengue transmission.

The dengue surveillance model built in this study will be able to serve as a basis for field operations to update their day to day data in an organized manner. These data once in place will be able to be useful for disease prediction. Ideally, this model should generate an understanding of the relationship between dengue cases and potential risk factors; however, due to the shortcomings of the data collected, it would be difficult to predict without a comprehensive mathematic modeling and testing.

The model built in this study will facilitate the field operations but it will not able to replace totally manual house surveys. GIS facilitates producing the base map with incorporation of spatial and non-spatial information like location, distance and density, which are the fundamental to disease epidemiology. Entomological, serological and socio-demographic information must be collected by manual surveys.

A good, active disease surveillance program depends on a strong health information system. For this, GIS system helps in inputting, storing, accessing, analyzing and presenting spatially referenced data from various sources in the form of maps and report. Therefore, it can put together all the dengue parameters and generate the necessary maps and reports for better dengue epidemiological surveillance.

Geographical epidemiology rests largely upon the assumption that spatial incidence of disease holds a key to its causes (Schaerstrom, 1996). However, high mobility, long latent periods and environmental change complicate matters, distorting what might otherwise be a direct relationship between cause and effect. In another words, the place or environment where a case is discovered and diagnosed is not necessary the same place or environment where the exposure occurred. Many studies examining associations between geographical patterns of disease and causal factors adopt the key underlying assumption that current residence in an area can be equated with exposure to conditions that currently (and historically) pertain there (Bentham, 1988). This information is important, especially if the disease has a long latency period, and it allows the mobility of the population. There are many types of analysis method dealing with time and space data, such as temporal cluster analysis, and spatio-temporal analysis.

Study done by Morrison et al (1998) using Kriging function, Barton/ David & Knox tests deals with the spread of dengue disease over a large area to estimate the underlying spatial process of dengue epidemics in Florida, Puerto Rico.

It is suggested that future research should includes different sites. Such studies would enable more reliable comparisons of findings.

This study was confined to *Ae. albopictus,* which is primary outdoors. A different approach need to used in studying *Ae. aegypti* or in an area where two species co-exist. Dengue transmission is complex because many risk factors are involved. These risk factors are not fully elucidated. In the WHO Global Strategy for Prevention and Control of Dengue Fever and Dengue Hemorrhagic Fever, one of the strategic areas for development (WHO, 1999) is integrated vector control with community and inter-sectoral participation, and active surveillance based on a strong health information system.

In *Ae. aegypti* areas, the approach of using GIS need to take consideration issues like whether the species existence has any relationship with geographical factors. If the purpose of using GIS is to map the disease and vector distribution, it is definitely the right tool to use.

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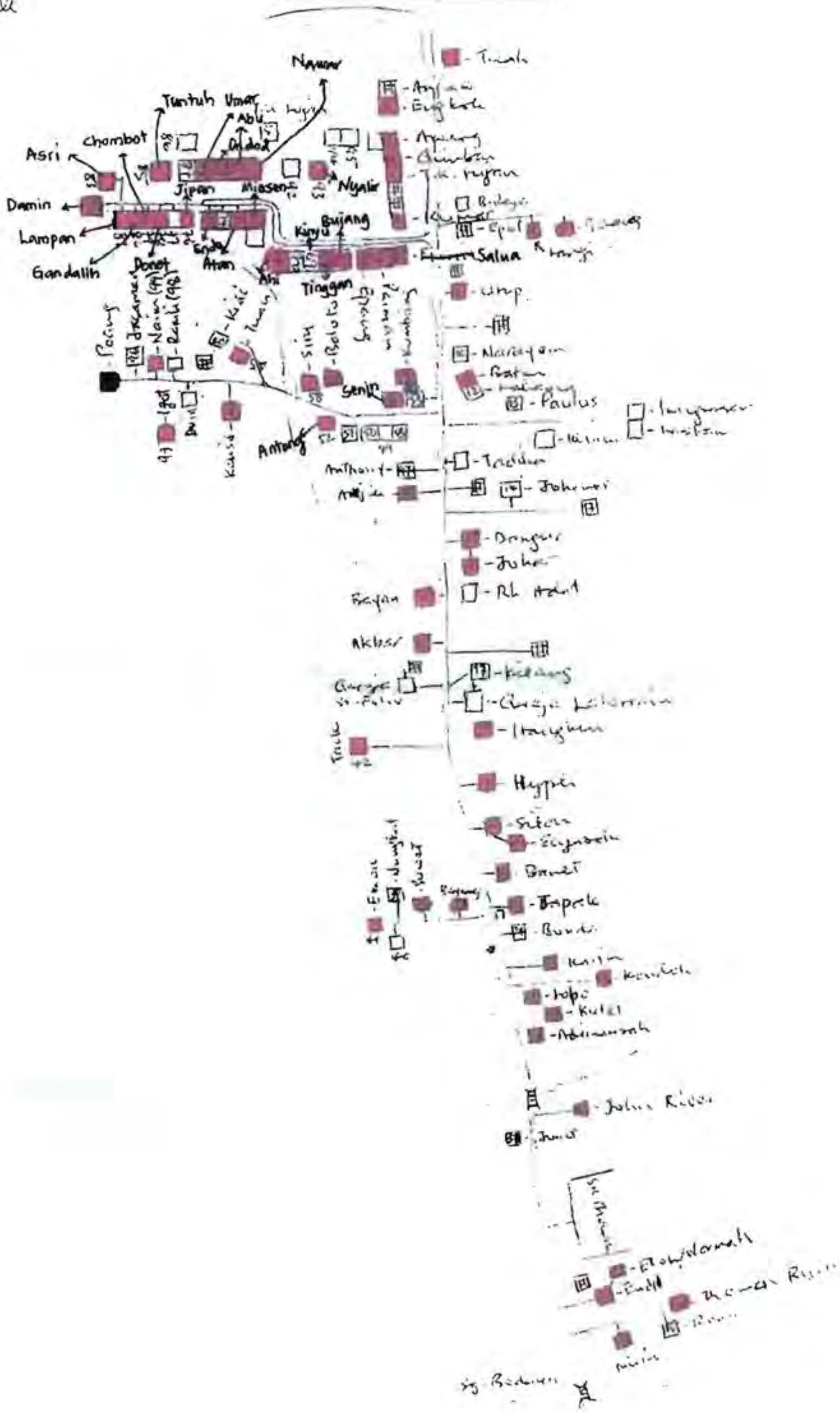
APPENDIX A
Sketch Maps of the villages

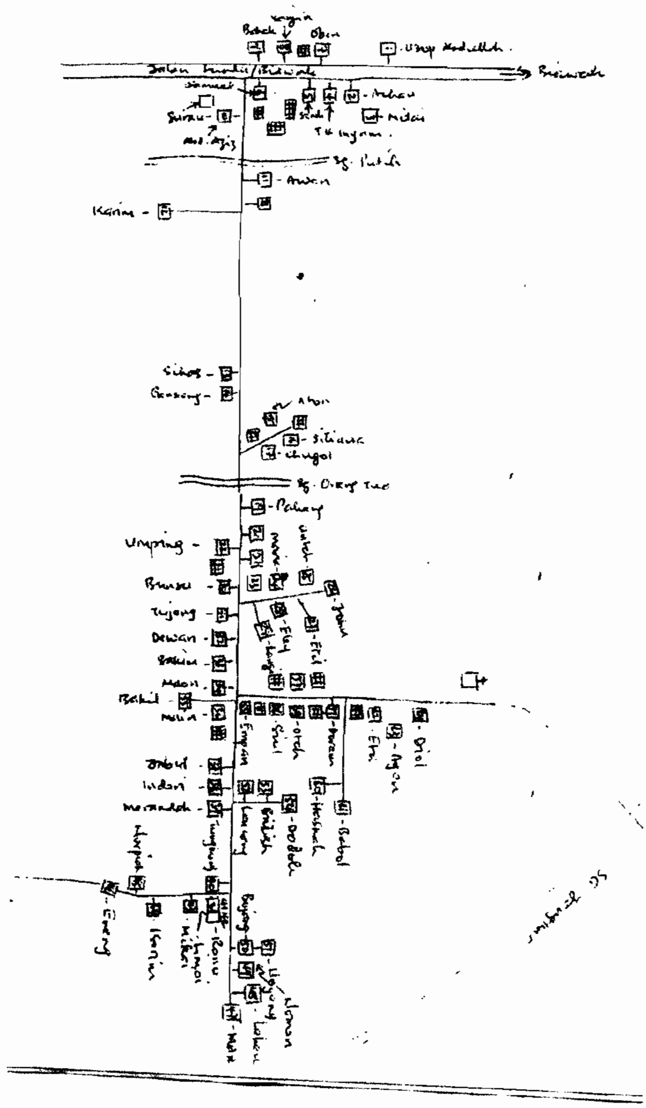
99
659

Kampong Biawak

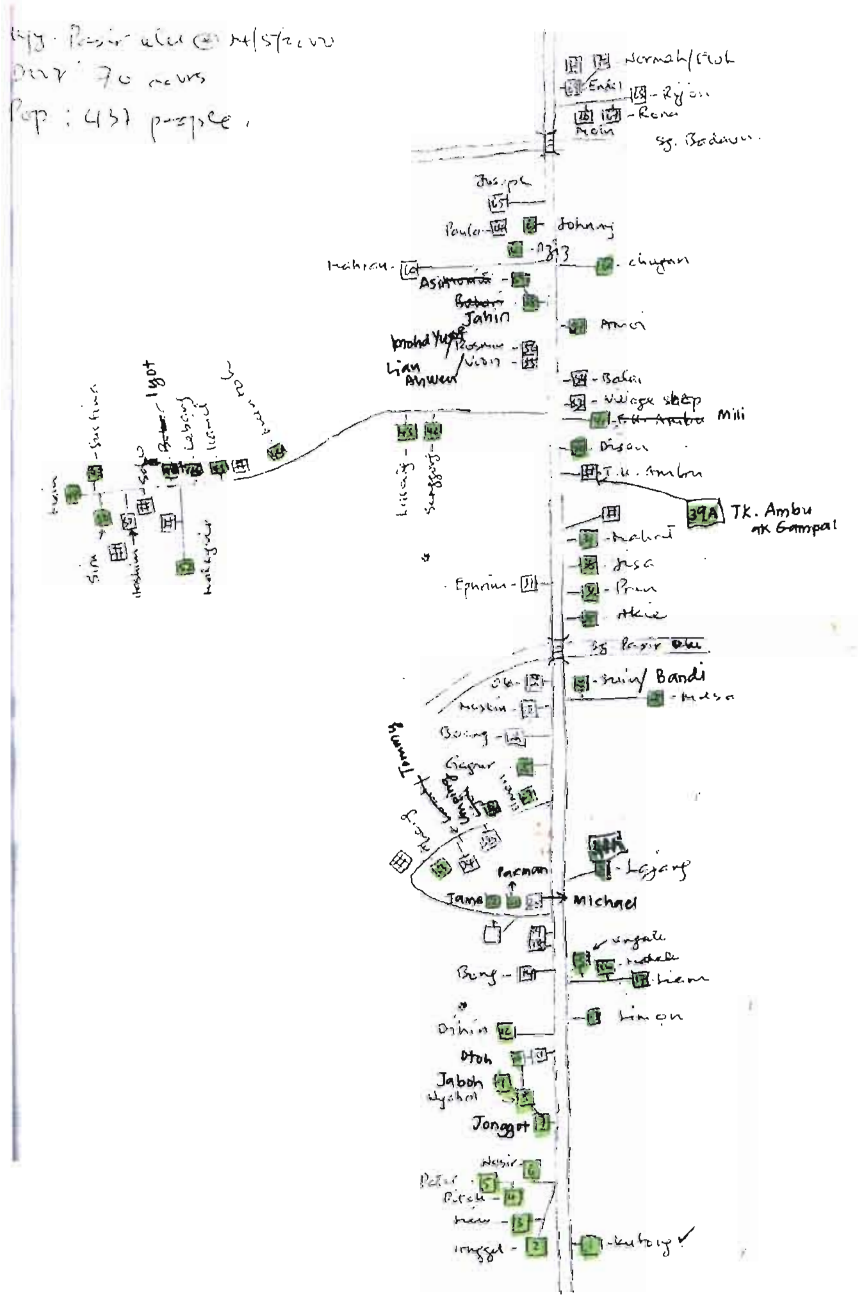


Kampong Jangkar

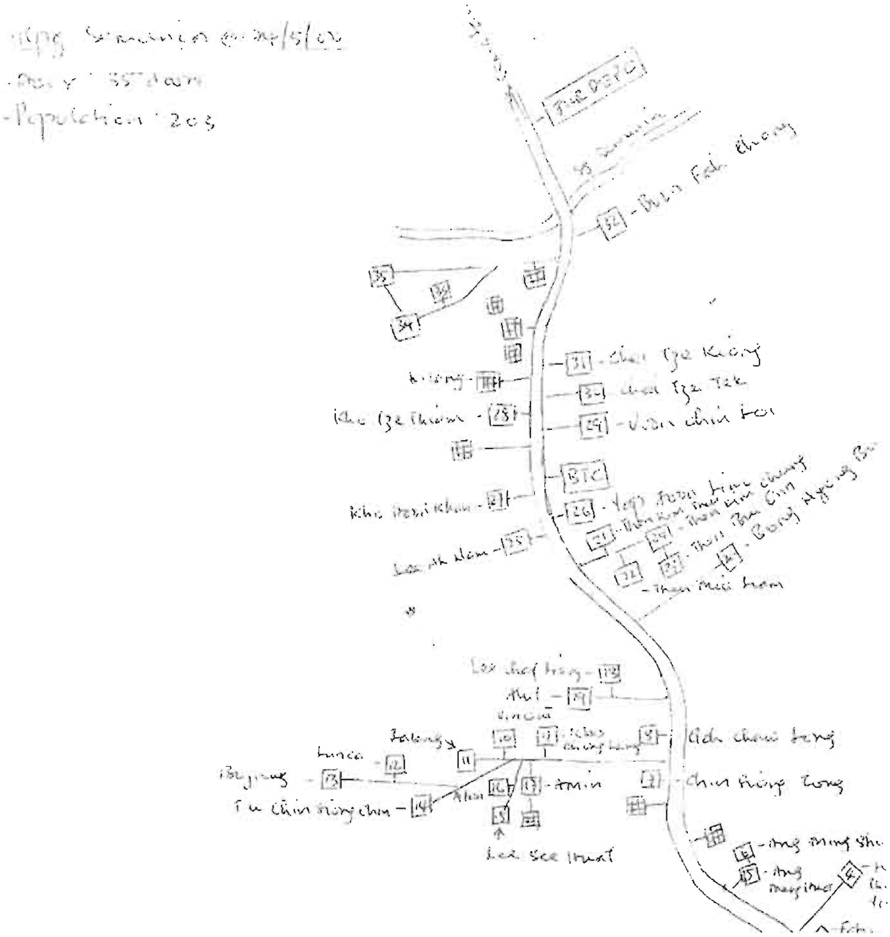
Kpg. Jangkar Proper @ 24/5/02
Door : 66 Doors
Pop : 283 people.



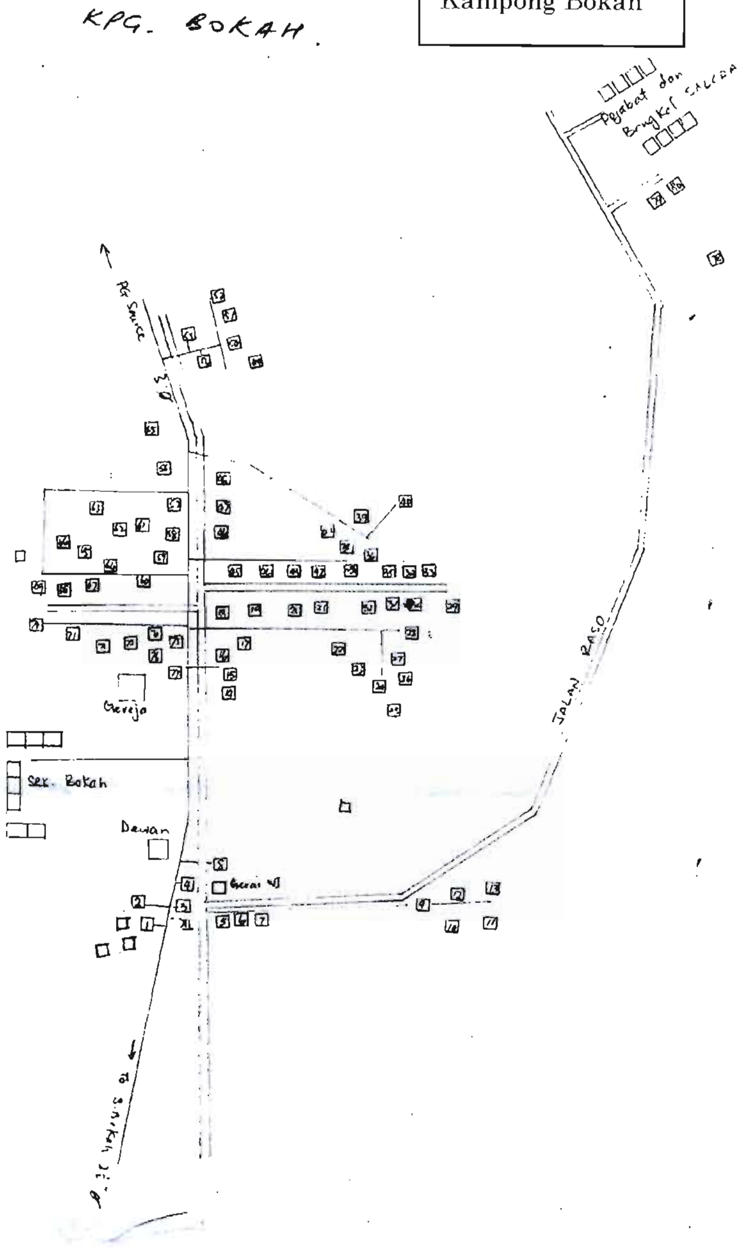
Kampong Pasir Ulu



Kampong Semunin



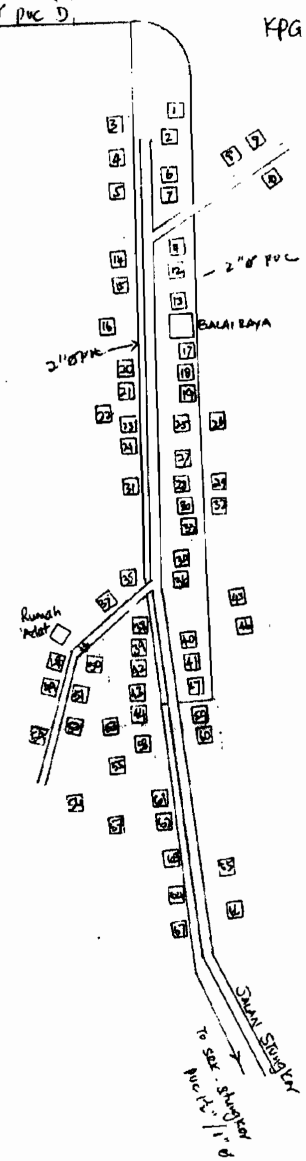
Kampong Bokah



Kampong Stungkor Lama

From 2½" ø pvc 'D'
PG. Source

KPG Stungkor Lama (1n

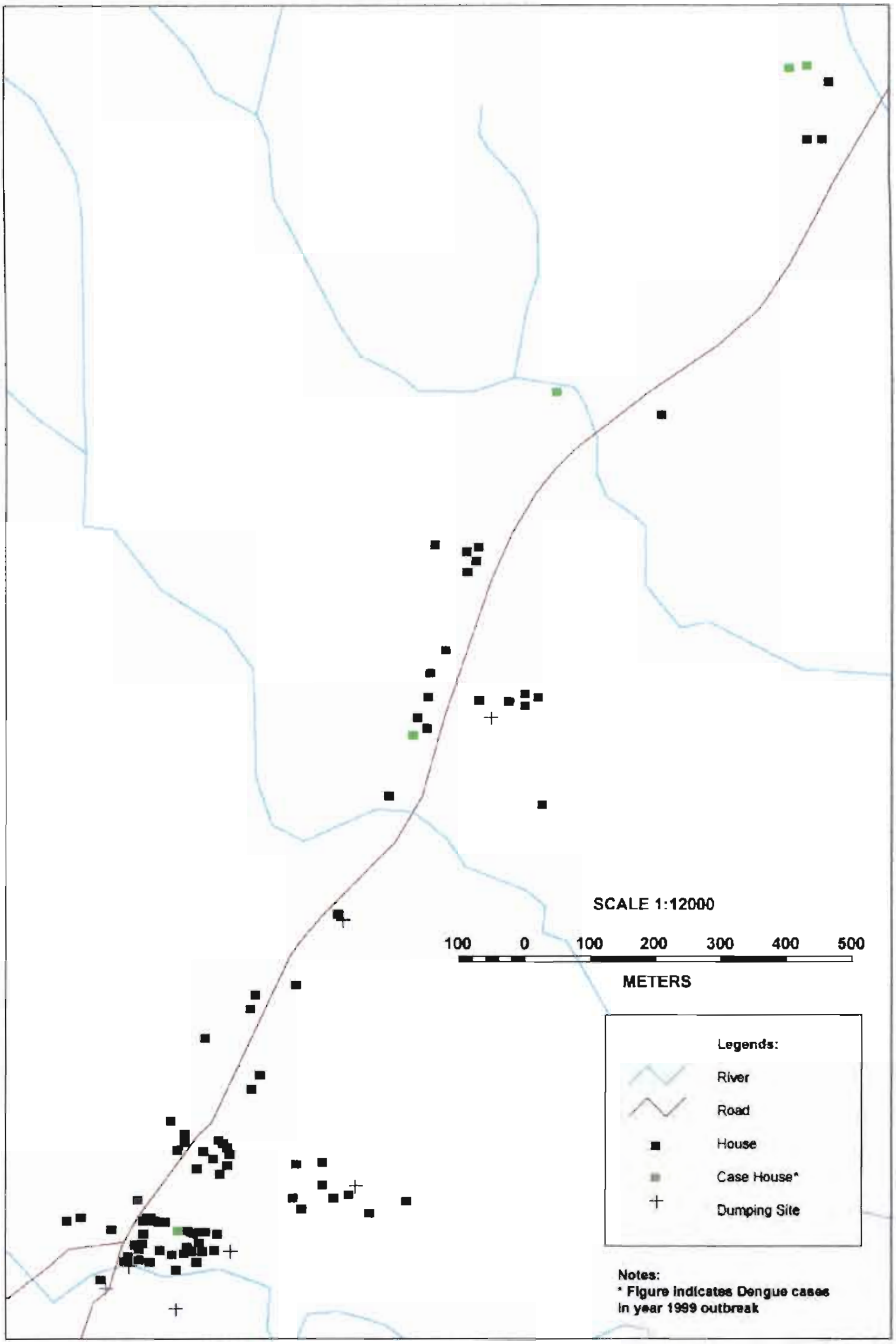


1. Gagok
2. Nyodiap
3. Jikem
4. Gusang
5. Mehek
6. Jowob
7. Jesu
8. Sihi
9. Alui
10. Jimeg
11. Jikeng
12. Suud
13. Noyes
14. Jines
15. Lindei
16. Dihik
17. Mitos
18. Saim
19. Ligim
20. Siki
21. Nyigon
22. Soli
23. Sugi
24. Jokek
25. Nojew
26. Noliaw
27. Noyaw
28. Ngaking
29. Jacie
30. Jihan
31. Nyudom
32. Misiem
33. Joe
34. Jinol
35. Marinor
36. Apen
37. Awang
38. Ketuk
39. TK. Tobaw
40. Jingop
41. Jiket
42. Sidel
43. Miges
44. Akew
45. Sapri
46. Kuek
47. Does
48. Juleng
49. Likud
50. Neom
51. Nasan
52. Jinang
53. Juliak
54. Nuen
55. Assan
56. Apin
57. Julian
58. Sijan
59. Jingep
60. Badak
61. Lindek
62. Satie
63. Jokien
64. Jatai
65. Dudog
66. Sipung
67. Doren

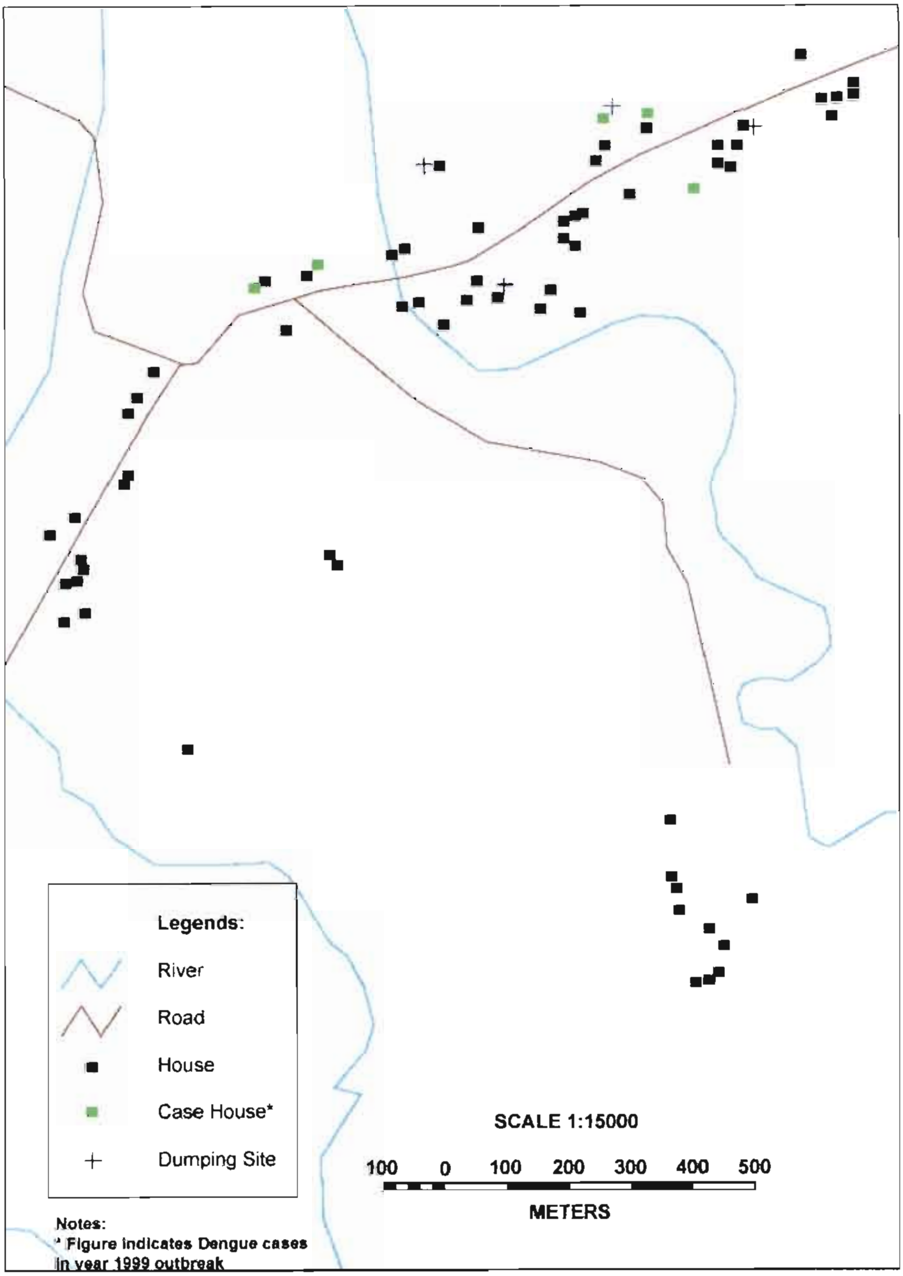
APPENDIX B

GIS generated maps for the villages

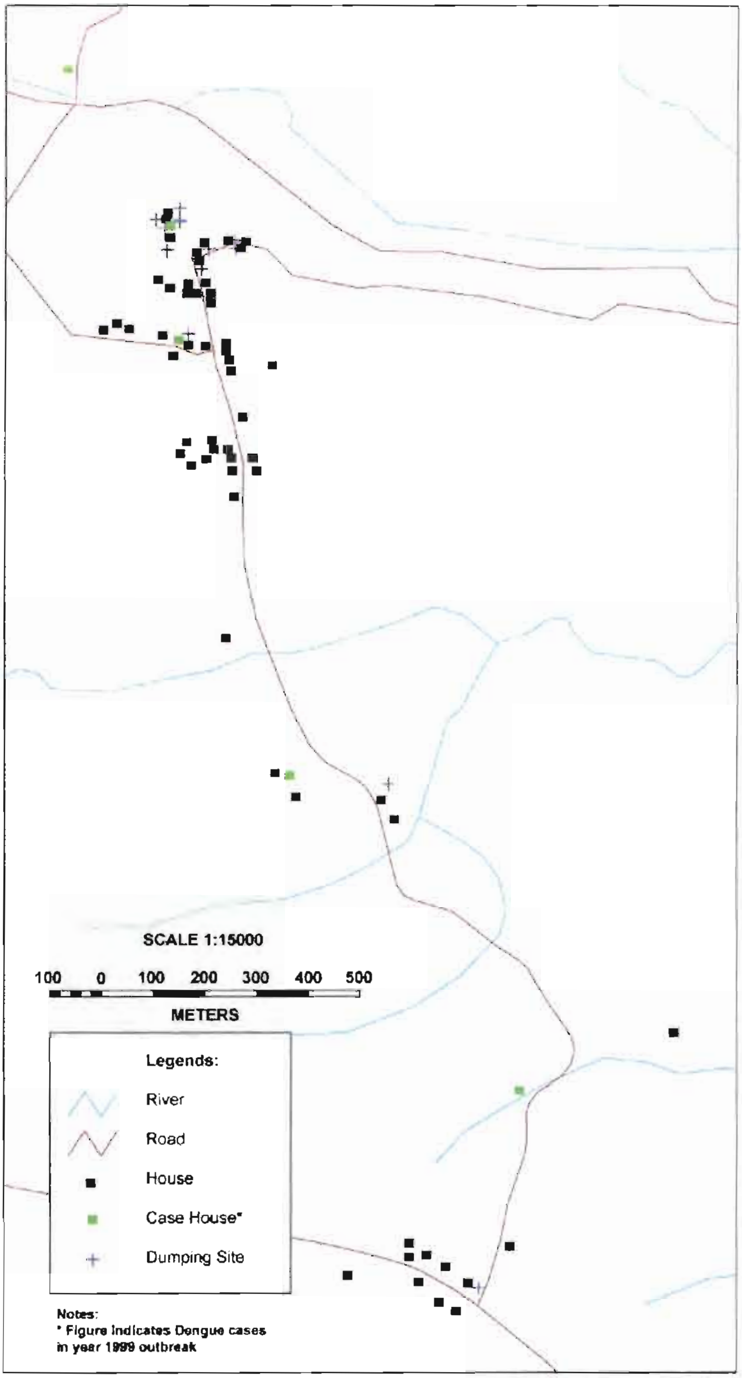
Kampong Biawak



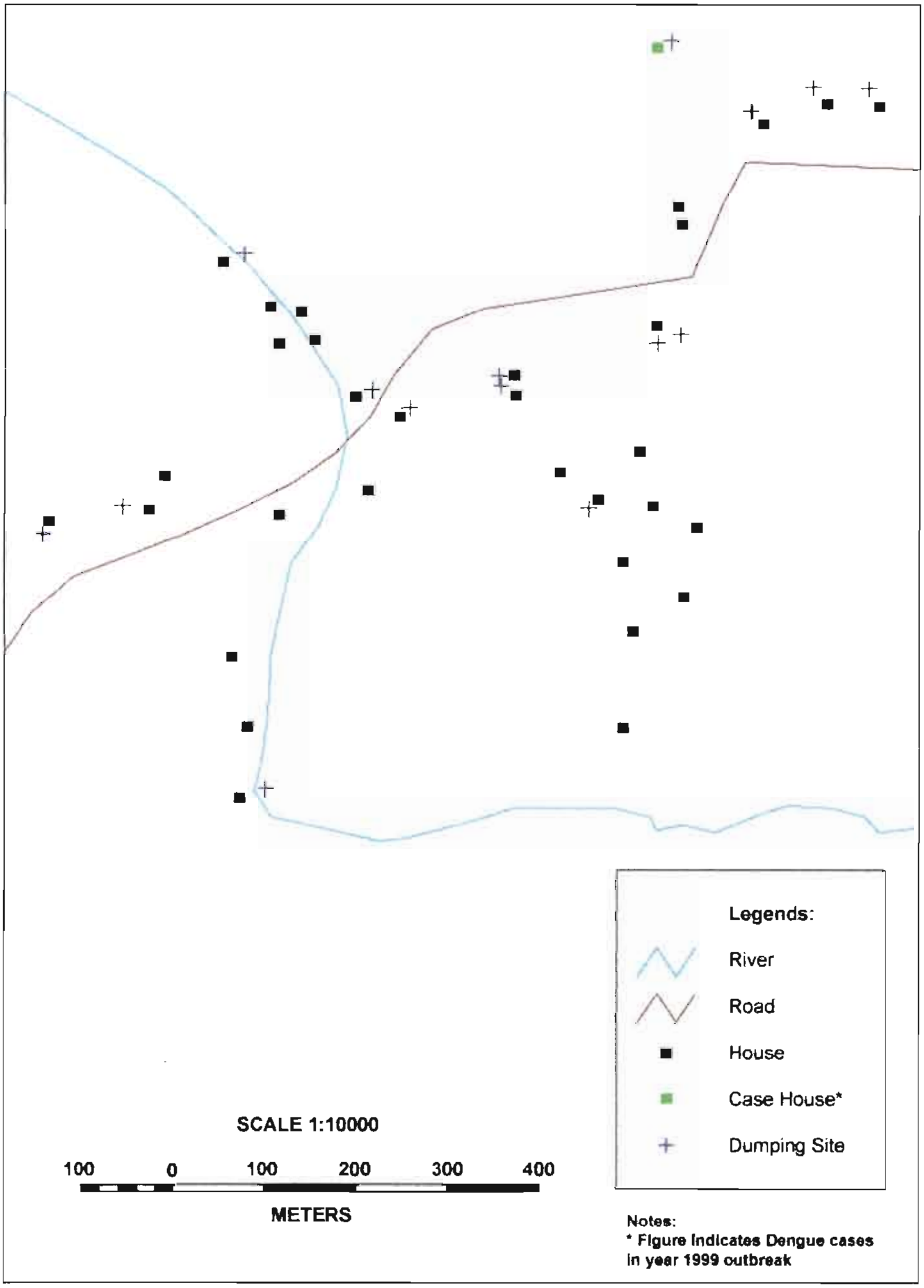
Kampong Pasir Ulu



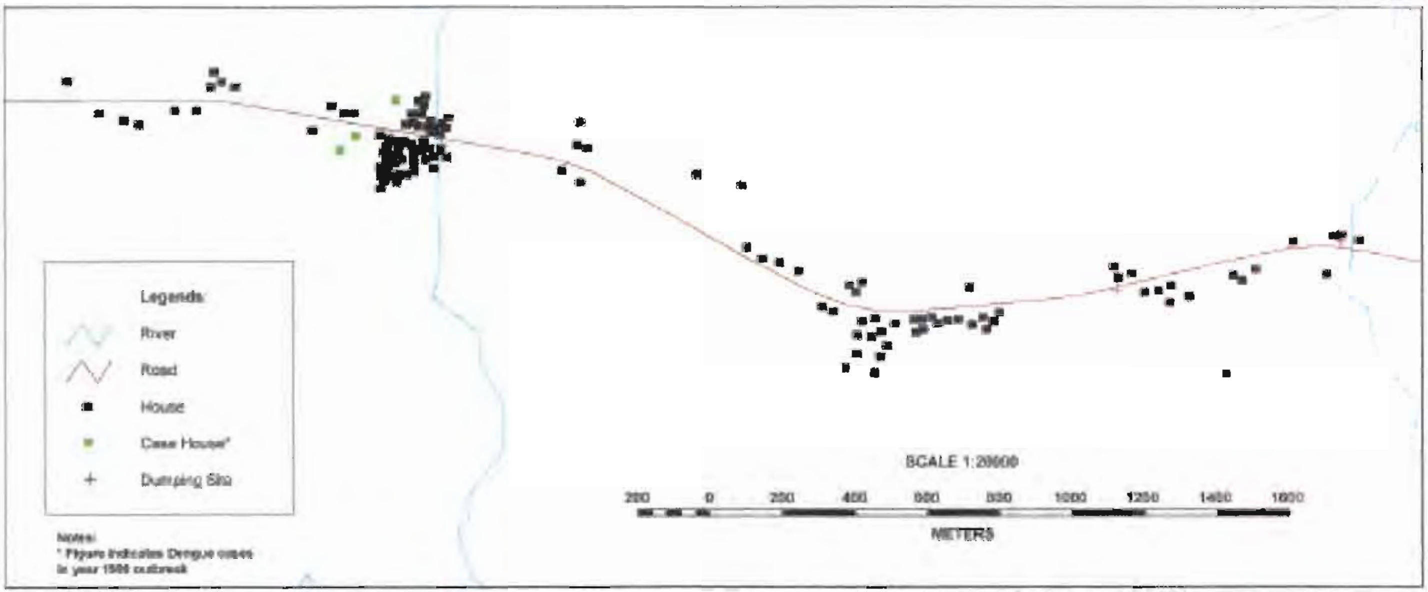
Kampong Jangkar



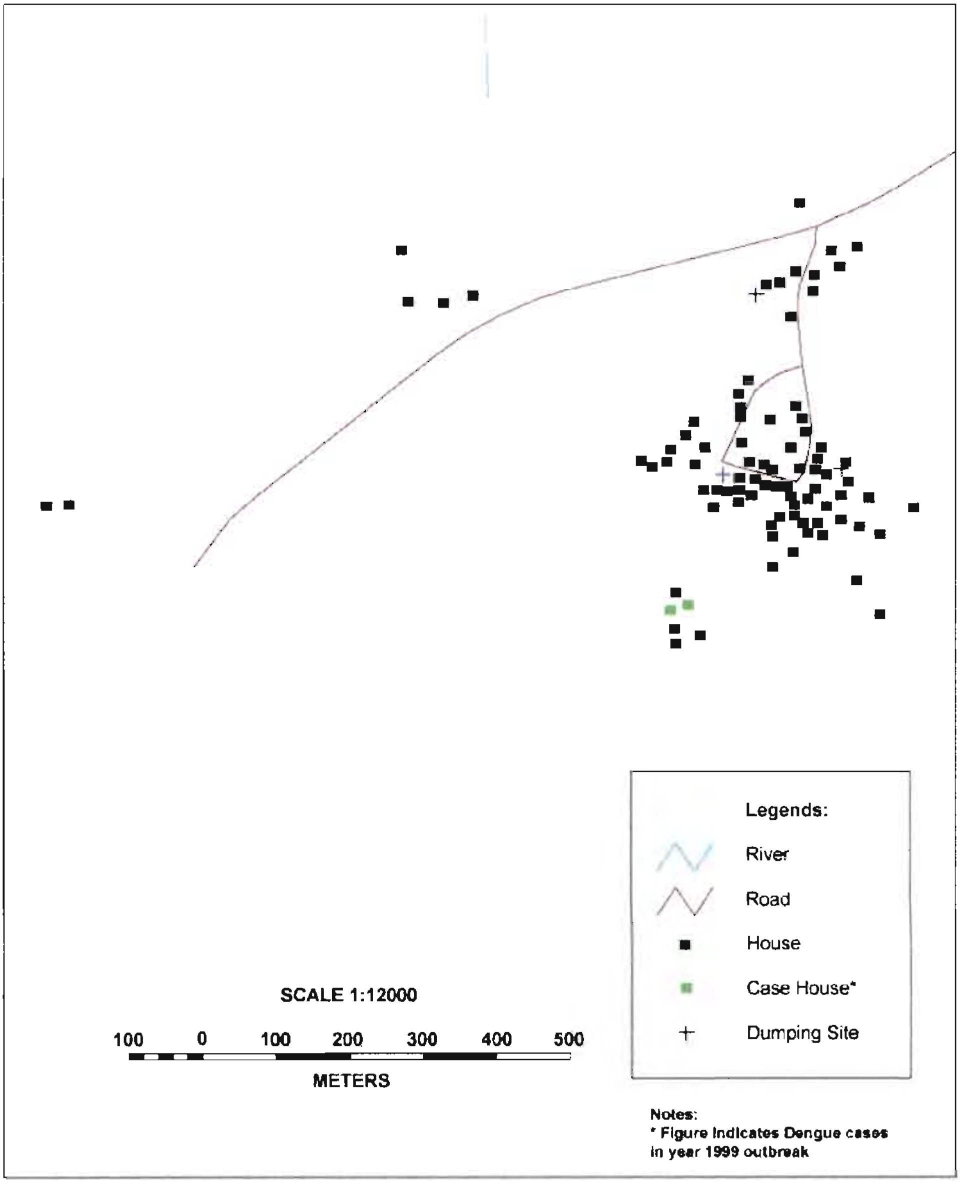
Kampong Semunin



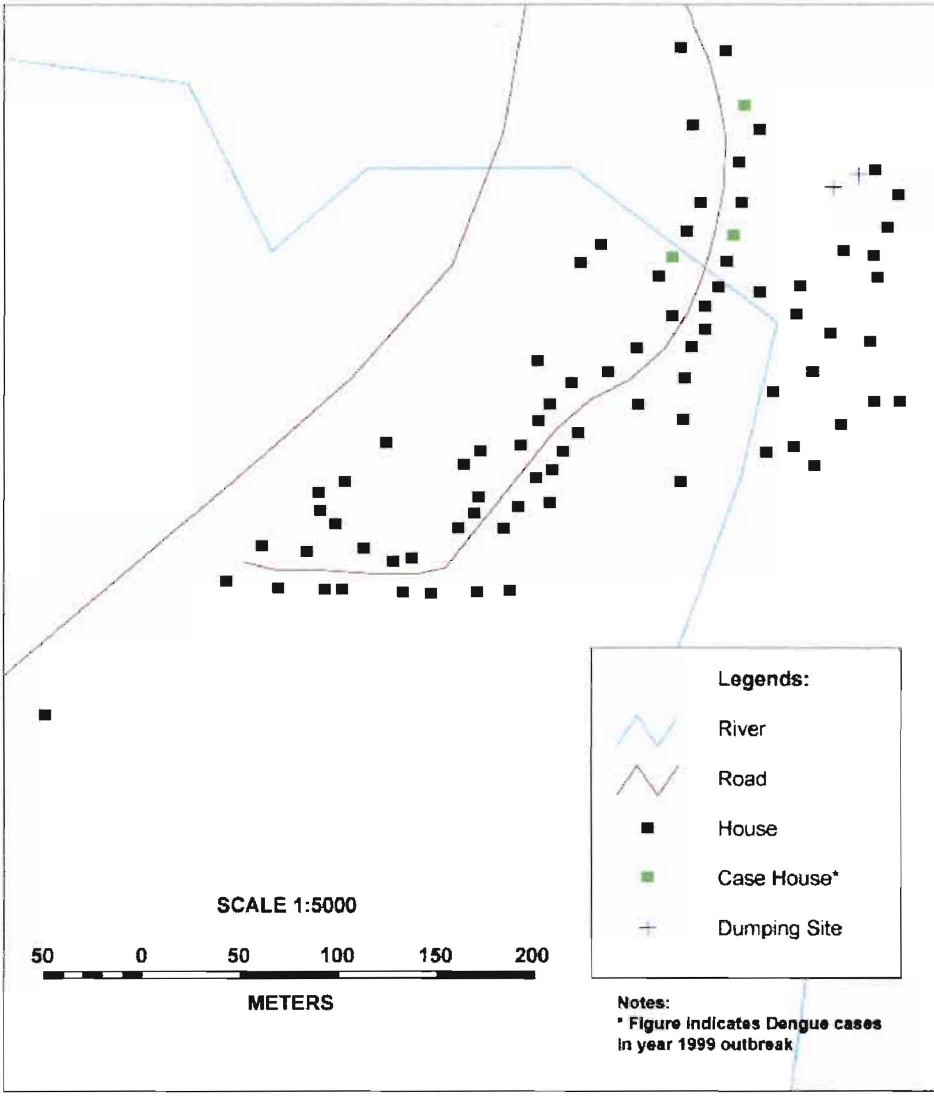
Kampong Stommuda



Kampong Bokah



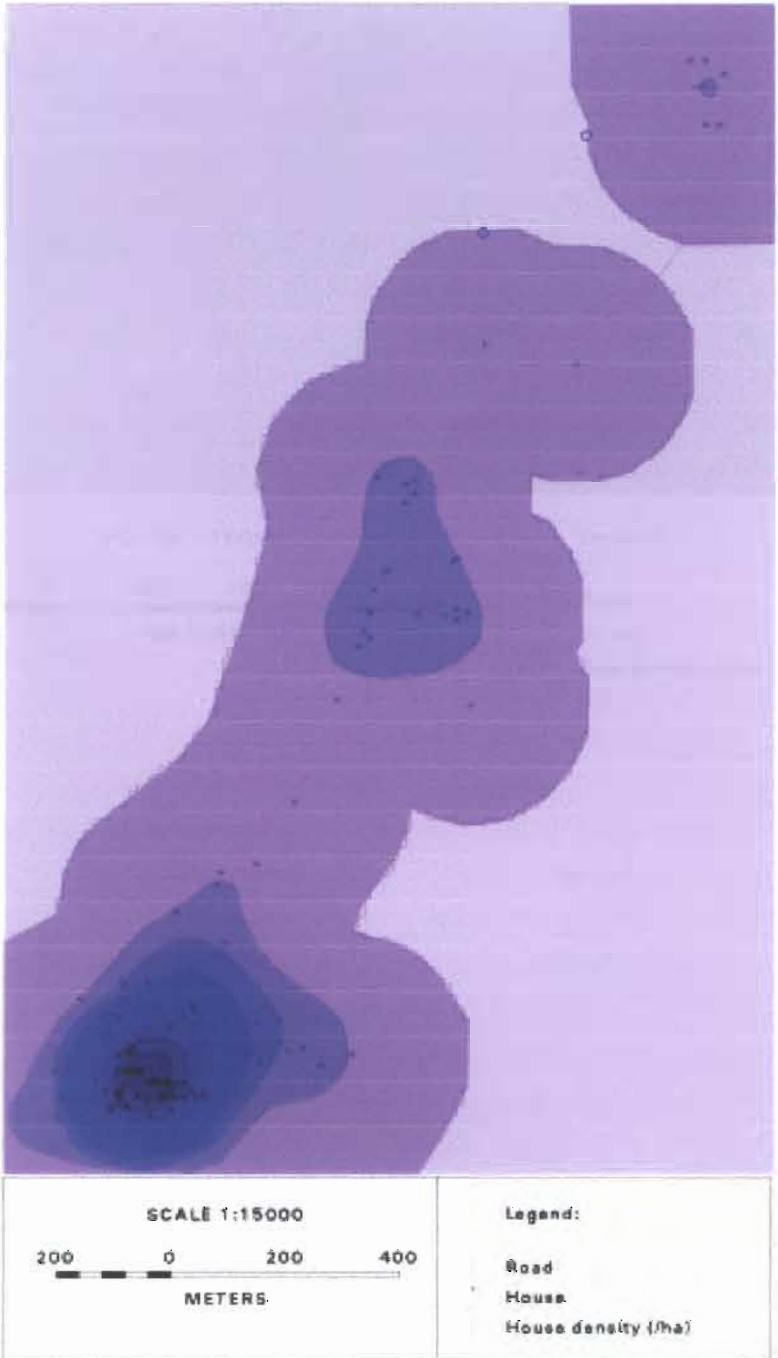
Kampong Stungkor Lama



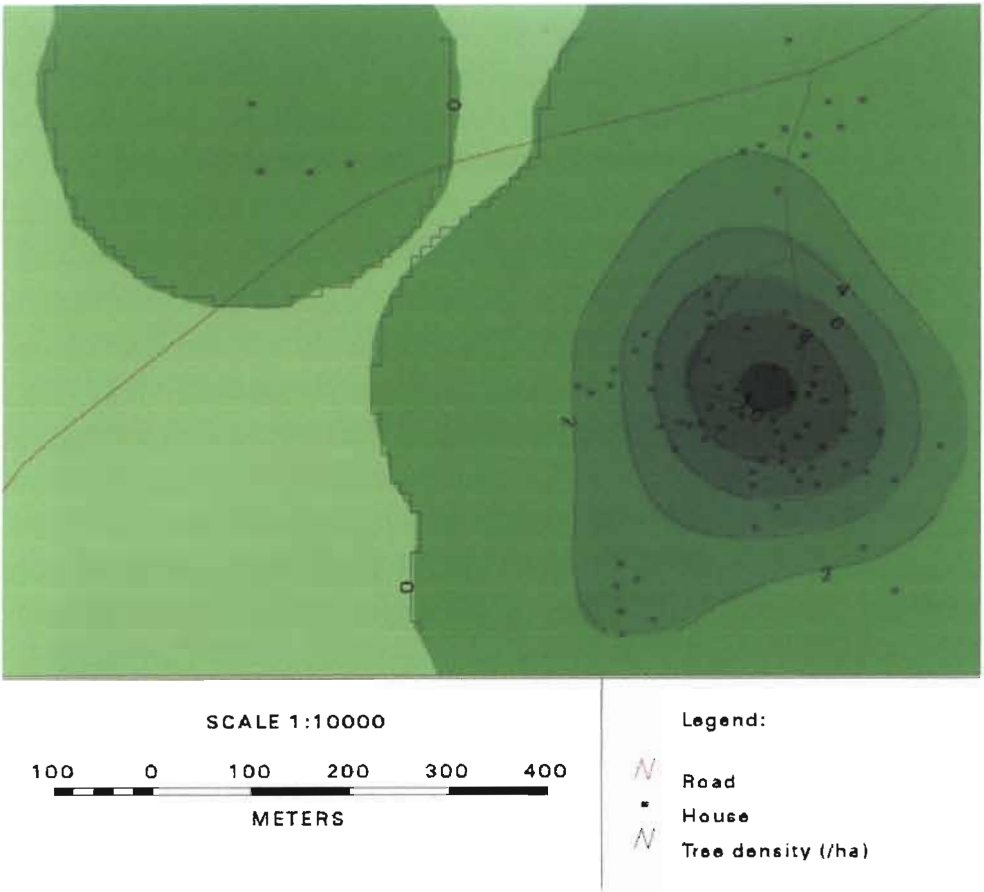
APPENDIX C

GIS generated Density Maps

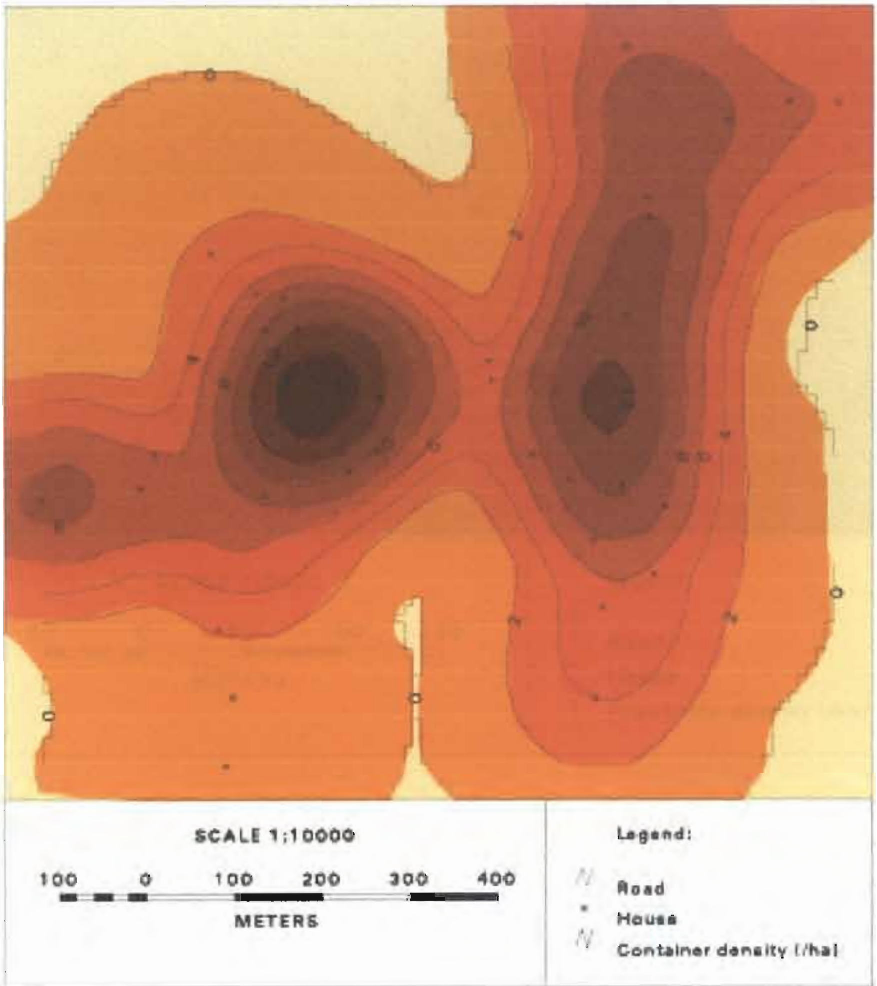
Kampong Biawak : House Density



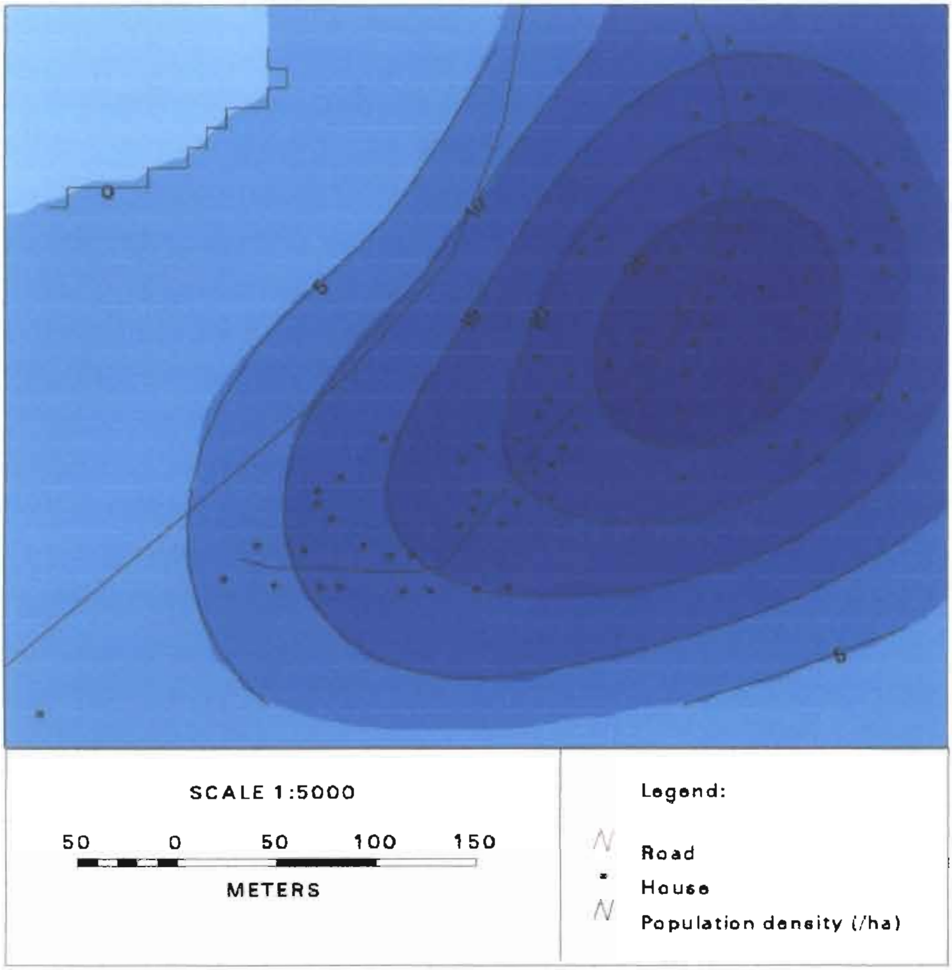
Kampong Bokah : Shading Tree Density



Kampong Semunin : Potential Container Density



Kampong Stungkor Lama : Human Population Density



APPENDIX D

Dengue Survey Form

Dengue Survey (village profile) : UNIMAS Research Project

Name of the Village :
Date of Survey:
Name of the interviewer:

	Characteristics		Notes
General information	House Number		
	Occupation		
	Name of the head of the house		
	No. of household members		
	No. of Dengue Cases (1999)		
Larvae	Larval sample collected	Yes/No	
	Ae.albopictus found/other, please specify	Yes/No	
Type of breeding sites < 5 m	Tin can	Yes/No	
	Plastic cup/pan/bowl	Yes/No	
	Coconut husk	Yes/No	
	Drum	Yes/No	
	Jar	Yes/No	
	Cocoa husk	Yes/No	
	Metal Pots	Yes/No	
	Tyre	Yes/No	
	Clay ware	Yes/No	
	Other, specify		
Indoor breeding sites	Flower vase	Yes/No	
	Jar	Yes/No	
	Storage tank (cement)	Yes/No	
	Drum	Yes/No	
	Others, specify		
Shading tree < 5 m	Number of trees		
Dumping Sites	Number		
	Obvious Breedings sites	No:	
	Estimate distance from the house (m)		
Water supply	JKR pipe water	Yes/No	
	Gravity feed	Yes/No	
	Water tank	Yes/No	
Animal	Any	Yes/No	
	What type		

Questionaire : Dengue Household Survey

1. Highest education level of the household
Taraf pendidikan yang tertinggi dalam keluarga
   - No formal education [ ]
     Tiada pendidikan formal
   - 1-6 years of school [ ]
     1-6 tahun persekolahan
   - 6-9 years of school [ ]
     6-9 tahun persekolahan
   - 9+ years of school [ ]
     9+ tahun persekolahan

2. Is dengue fever a problem in your village ? Yes [ ] No[ ]
Adakah deman denggi adalah satu masalah di kampung anda ? Ya [ ] Tidak [ ]

3. If yes, what is dengue fever ?
Kalau ya, apa itu deman denggi?

----

4. Can dengue be spread? How?
Bolehkah denggi merebak? Bagaimana?

----

5. What is Aedes mosquito? (if Aedes mosquito did not mentioned in question 3)
Apa itu nyamuk Aedes? (Sekiranya nyamuk Aedes tidak disebut dalam soalan 3)

----

6. Name three most common Aedes breeding sites in your village
Namakan tiga tempat pembiakan nyamuk Aedes di kampung anda?

----

7. How do you prevent yourself or your family from getting dengue fever?
Bagaimana anda mengelakkan diri atau keluarga anda dari mengidapi deman denggi?

APPENDIX E

Ovitrap Survey Form

Universiti Malaysia Sarawak

Dengue Vector Surveillance : Evaluation of *Aedes* Indices

Locality/Control Section : ______________________
House No./Address : ______________________
Date of Survey : ______________________
Name of Surveyor : ______________________

		Week							
		1	2	3	4	5	6	7	8
Collection Sites	**Indoor**								
	Larvae count								
	Pupae count								
	Total								
	Outdoor (5m)								
	Larvae count								
	Pupae count								
	Total								
Dumping Sites	**1**								
	Larvae count								
	Pupae count								
	Total								
	2								
	Larvae count								
	Pupae count								
	Total								
	3								
	Larvae count								
	Pupae count								
	Total								