CHAPTER 7

Development of a Geospatial Database of Soil-Transmitted Helminthiasis using the Geographic Information System (GIS) and Remote Sensing (RS) Derived Environmental Data

7.1 INTRODUCTION

In Malaysia, soil-transmitted helminth (STH) infections are considered largely controlled with significant reduction of infection rates particularly among urban populations (Jamaiah & Rohela, 2007; Aaron et al, 2011). However, this reduction trend remains significantly unchanged with high prevalence rates and significant morbidity among communities in rural and remote areas (Lim et al, 2009; Aaron et al, 2011). Lim et al. (2009) summarized studies that have been conducted since the Colonial era in Malaysia and demonstrated that foci for high endemicity remain largely unchanged with alarming high prevalent rates, in some cases up to 100% in these rural dwellers. Although Malaysia is still known to have high prevalence of STH infections particularly in rural dwellers (Lim et al, 2009), this disease is recognized as not notifiable by the local public health authorities. Since the national deworming program among school children was discontinued in 1983 (Anon, 1985), little attention has been given to combat this disease. Moreover, a precise estimate of the total disease burden has not been fully described as collation of systematic information on STH infections in the country is not currently available. Most of the information or record on the prevalence of STH infections is scattered across the literature and not catalogued systematically. These data are seldom available in an accessible format for policy makers or public health authorities. Hence, previous approach in describing the distribution of STH infections have typically been made at the national level using prevalence data from few available published reports, which are then extrapolated to the country as a whole. Such approach however has limited practical importance to effectively target control efforts.

The World Health Organization (WHO) recommends once-yearly mass drug administration (MDA) intervention with abendazole or mebendazole to be carried out in areas where the prevalence of STH infections exceeds 20% or twice-yearly MDA for prevalence exceeding 50% especially among vulnerable group such as school-aged children (Anon, 2002). This has encouraged many endemic countries especially in African continent to establish and implement their national control program for STH infections. The main strategy of MDA program is the delivery of anthelminthic drug through public school system which has been proven as a cost-effective way to reduce infection and morbidity rates (Brooker et al, 2006) and enhance educational outcome (Miguel & Kremer, 2004). Regardless of the implementation approach, reliable and updated information on the geographical distribution of STH infections are essential for developing and implementing effective control measures to those populations in greatest need particularly when the recourses for control program itself are finite and limited (Brooker et al, 2009).

In recent years, the geographical information system (GIS) and remote sensing (RS) has been widely used for effective storage, mapping, analysis and development of STH atlas (Brooker & Michael, 2000). Such approach also made the data integration and mapping more accessible and reliable. It also offers us the ability for modeling the spatial distribution of STH infections in relation to their ecological factors which are derived from remote sensed (RS) satellite data that are known to influence the distribution pattern, thus deepening our knowledge and understanding in the biology and epidemiology of the infections (Hay et al, 2000; Brooker et al, 2006). Likewise, it also allows us to predict the spatial distribution of infection and identify endemic areas, thus providing more precise estimates of populations at risk (Brooker & Michael, 2000). Thus, the GIS and RS approach have the potential in facilitating and assisting the design of sustainable development control program at realistic scale for national control program by providing the relevant authorities with relatively low-cost approach for both the upstream (e.g., survey and design) and downstream (e.g., targeting, monitoring and evaluation) control program, which significantly reduce the cost of practical program by identifying priority areas or simplifying the monitoring and evaluation processes (Brooker et al, 2006).

To date, the used GIS and RS tools to map, describe and identify the relative importance of different environmental factors in determining the geographic distributions and patterns of STH infections, however have been attempted only in African countries (Brooker & Michael, 2000; Brooker et al, 2000; 2002a; 2002b; 2004; 2009; Knopp et al, 2008; Pullan et al, 2011; Tchuem Tchuente et al, 2012). Until recently, GIS and RS approach for mapping of STH infections have been extended to Southeast Asia regions including Mekong countries (i.e., Cambodia, Lao PDR, Myanmar, Thailand and Vietnam) (Brooker et al, 2003) as well as Indonesia and the Philippines (Brooker, 2002c). By extending such approach, the present study attempt to develop a geospatial database for STH infections using available empirical survey data in order to explain the geographical distribution of infection, identify and prioritize target areas and estimates population at risk and its implications for sustainable of STH national control program in Malaysia.

7.1.1 Objectives of the study

General objective

To develop a geospatial database of soil-transmitted helminthiasis using geographic information system (GIS) and remote sensing (RS) satellite derived environmental data.

Specific objectives

1. To estimate combined prevalence of infection with any STH species when only separate prevalence of each species is reported using a simple probability law.

2. To collate and map the variation in the prevalence of STHs in Malaysia from any available empirical survey data.

3. To apply spatial analysis tool to prevalence data, environmental variables, thus identify ecological correlations with infection patterns.

4. To generate predictive risk map of infection in areas without comprehensive data.

5. To estimate total number of population and school-aged children who are at risk of infection and requiring anthelminthic treatment.

7.1.2 Research hypotheses

1. The number of individual with combined infection of any STH species is estimated accurately using a simple probabilistic model.

2. The prevalence map showed the geographical distribution of STH infections from any available survey data and highlighting where such data is lacking.

3. The spatial distribution of STH infections is influenced by the environmental factors.

4. The predictive risk map of STH infections in areas without comprehensive data is generated.

5. The total number of population and school-aged children who are at risk of infection and warranting anthelminthic treatment is estimated.

7.1.3 Significance of the study

The utilization of geographic information system (GIS) and remote sensing (RS) can play important roles and offer basic information for the rapid planning and sustainable control program of soil-transmitted helminth (STH) in Malaysia. GIS tools allow us to collate and map the geographical distribution of STH infections from any available survey data in Malaysia. Moreover, it offers the opportunity to investigate the geographical distribution of infection and highlighting where such information is lacking. Given that data from only few a survey is available for most regions in Malaysia, it is also important to generate predictive risk maps using available survey data of infection for areas without comprehensive data. This can be achieved by the use of remote sensing satellite data that provides proxy to the environmental factors and relate such factors with the prevalence data to identify ecological correlates that influence the infection patterns and generate predictive risk maps. This predictive risk maps can serve as baseline data to estimate the number of population at risk, numbers requiring treatment and cost of delivering treatment. Thus, establishment of such reliable database is essential for the development and implementation of effective control measures to those populations in greatest need particularly when the recourses for control program are limited.

7.2 MATERIALS AND METHODS

7.2.1 Data searches

Relevant information on the prevalence of soil-transmitted helminth (STH) infections in Malaysia were identified through a combination of (i) an extensive search in electronic bibliographic databases, (ii) manual search of local archives and libraries and (iii) direct contact with local researchers. In brief, an initial systematic search of published articles was undertaken in 2008 and repeated periodically between 2009 and 2012. The online database PubMed was used to identify relevant studies for STH by using the Medical Subject Headings (MSHs) hookworm, ascariasis, trichuriasis, *Necator americanus, Ancylostoma duodenale*, *Ascaris lumbricoides, Trichuris trichiura,* intestinal parasites, or soil transmitted helminth (STH) AND Malaysia. Other electronic sources of information such as Google and Yahoo were also used. The search included non-English language papers such as *Bahasa Malaysia* which is the national language of Malaysia. All articles were retrieved when the abstract indicated that they may contain potentially useful information. The second search strategy involved the identification of 'grey' literature sources such as university theses, unpublished surveys conducted by government institutions and Ministry of Health (MoH) archives. The third source of information includes personal contact with researchers known to have undertaken STH surveys in Malaysia. In addition to these data, we also conducted field investigations from January 2009 until December 2012 in randomly selected locations in Peninsular Malaysia. Briefly, the collected samples were processed for the presence of STH species by the formalin ethyl acetate concentration technique and microscopy examination following standard parasitological procedures. Only survey data between 1970 and 2012 were included in the current study. Figure 7.1 summarizes the conceptual framework of the present study.

7.2.2 Geo-positioning procedures

Geo-positioning is the termed that is used to determine the longitude and latitude of the preferred location (Guerra et al, 2007). In this study, the geographic coordinates of various surveyed locations were determined using combination of various electronic resources including GeoNet Names Server (http://earth-info.nga.mil), Google Earth (http://www.google.com), Wikimapia (http://www.wikimapia.org), Maplandia (http://www.maplandia.com) and Tageo (http://www.tageo.com). These sources are available freely on-line and provide varying degrees of coverage, functionality and ease of use. Each of the identified locations from one source was consequently cross-checked against other sources to ensure consistency of the identified coordinates. For the field investigation survey conducted by our group, the spatial location (i.e., *in situ* data collection) of the each survey location was recorded using handheld Garmin GPSMAP 60CSx. Subsequently, the recorded coordinates were downloaded from the GPS memory card into a computer using GPS Pathfinder software. All the digital data coordinate system were synchronized using World Geodetic System (WGS 1984) which serve the x (longitude or east-west) and y (latitude or north-south) that allows geographic positions to be expressed anywhere around the world.

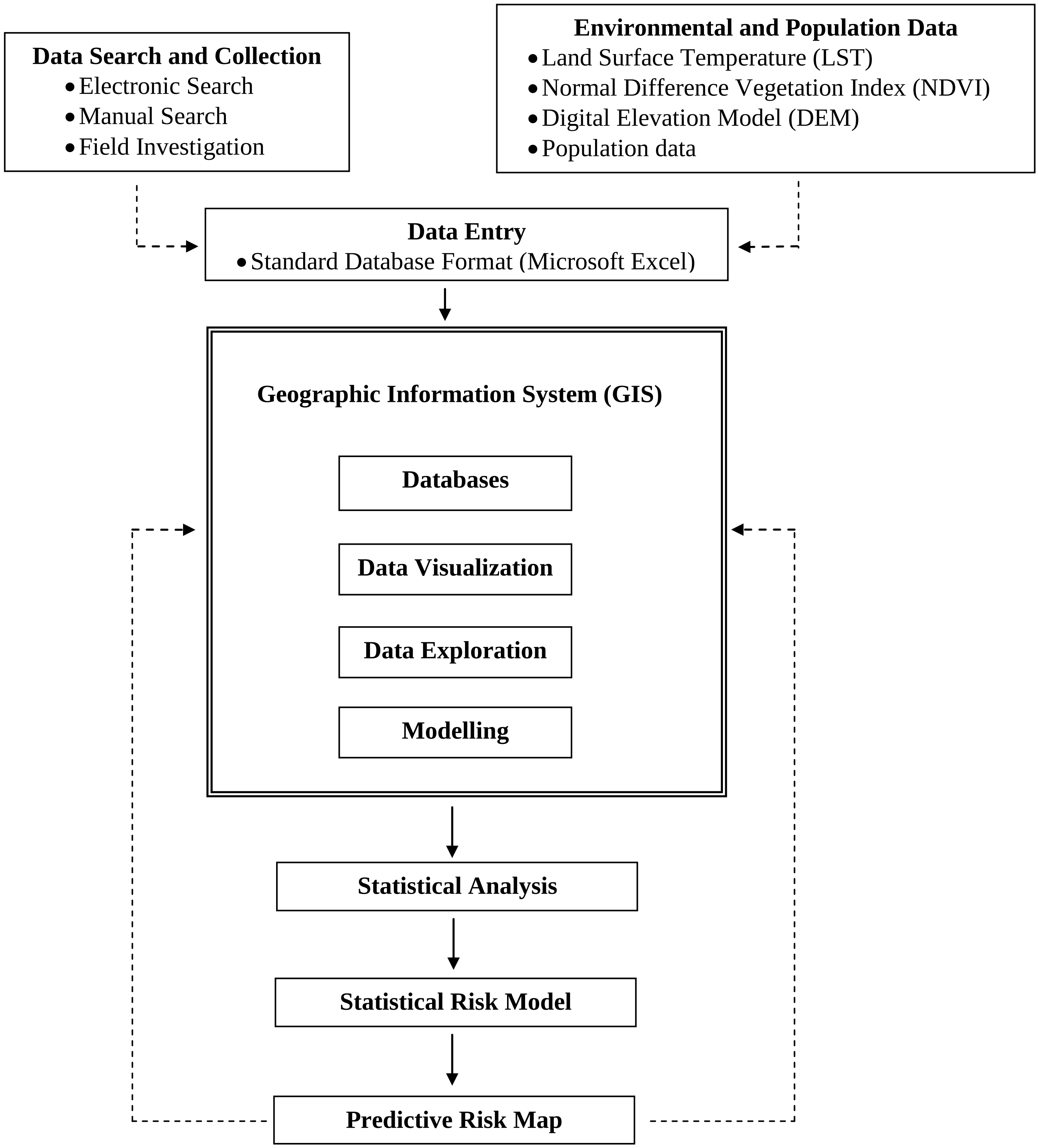

Figure 7.1: Conceptual framework of GIS study methodology

7.2.3 Selection and entry

Pre-determined inclusion and exclusion criteria were applied to information identified through the above searches mechanisms. Firstly, only cross-sectional surveys were included in the database. Multiple surveys may be available from same location but surveyed at different times, thus these surveys were included as separate entries. Data were excluded if they were hospital or clinic surveys. Survey data were also excluded if only prevalence was reported without a denominator (i.e., sample size of number of positive sample) or if there were inconsistent or errors in the calculation presented. In addition, any surveyed locations that could not be geo-positioned were excluded from this study. Each source of information was evaluated and extracted into a standard database format in Microsoft Excel following standard the format of Brooker and co-workers (2000). Information that were included in the database including the source of the data, location of survey, date of survey, survey methodology, survey population, sample size, examination methods and number of positive for each helminth species.

7.2.4 Estimating cumulative (combined) prevalence of any STH

The combined STH prevalence (i.e., proportion of infection with any STH species) is important when making decision about effectivly targeting groups for treatment. However, data on the combined prevalence of any of STH species is seldom reported in epidemiological studies as most of the survey reports typically only provide the proportion of individuals infected with a single worm species (de Silva & Hall, 2010). Thus, the cumulative prevalence of STH (i.e., combined STH prevalence) was calculated using a simple probabilistic model after incorporating a small correction factor to allow for non independence between species according to the methods of de Silva & Hall (2010). Briefly, the combined probability of having infection with any STH species is the simple probability law for the union between three aspects after assuming the probability of infection with a single species to be independent from each other. The proportion infected with combined STH species were then calculated according to the summarized formula:

$$\mathbf{P}_{ATH} = \boldsymbol{A + T + H - (AT) - (AH) - (TH) + (ATH)} \text{.......... } \mathbf{(7.1)}$$

Where:

PATH = Combined proportion of infected with all three STH species

A = Prevalence of *A. lumbricoides*

T = Prevalence of *T. Trichiura*

H = Prevalence of hookworm

AT = Prevalence of *A. lumbricoides* and *T. Trichiura*

AH = Prevalence of *A. lumbricoides* and hookworm

TH = Prevalence of *T. Trichiura* and hookworm

ATH = Prevalence of *A. lumbricoides, T. Trichiura* and hookworm

However, de Silva & Hall (2010) also reported that there was overestimation in the combined proportion of having infections with all STH species (P_{ATH}) as calculated using this probability model. Due to the non independence effect of each species, it has been demonstrated that the P_{ATH} proportion were increased by 0.6% for every 10% increase in the prevalence rate (de Silva & Hall, 2010). Thus, the true observed combined prevalence of STH can be calculated by incorporating the over-estimation factors as:

$$\boldsymbol{p = P_{ATH} \div 1.06} \ldots\ldots \textbf{(7.2)}$$

7.2.5 Geographic Information System (GIS) and Remote Sensing (RS) database

Peninsular Malaysia comprises 11 states and each state is divided into 81 districts, which are then further divided into the smallest administrative level defined as *mukim* or sub-district (Peninsular Malaysia comprises 842 *mukim*). Each of the extracted survey data were mapped at the sub-district levels. The sub-district in which each survey has been conducted was identified and linked to the Peninsular Malaysia boundary map referred to as the base map, which was obtained from Department of Surveying and Mapping, Malaysia (Anon, 2010a). Mean prevalence of each survey where more than one study was conducted in the same area or survey points less than 2 km apart were calculated by taking the weighted mean of the individual survey prevalence, with preference given according to sample size and treated as a single location (Brooker & Michael 2000). A set of environmental variables was gathered from a variety of sources. Monthly average Land Surface Temperature (LST) at 1 km resolution was derived from the WorldClim (http://www.worldclim.org). Briefly, these data were generated from global weather station temperature records gathered from various sources for the period of 1950 to 2000. A thin-plate smoothing spline algorithm was then used to interpolate the data, following the approach of Hijmans et al. (2005). Normalized Difference Vegetation Index (NDVI) data was obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) (Scharlemann et al, 2008). Other ecological covariates such the altitude was obtained from the interpolated Digital Elevation Model (DEM) from the Department of Surveying and Mapping, Malaysia (Anon, 2010a). For each environmental variable, minimum, mean and maximum values were extracted for each pixel that corresponded to the survey locations. Sub-district level population data was obtained from the most recent population estimates based on 2010 national census available from Department of Statistic, Malaysia (Anon, 2010b). Population density was calculated by dividing the population in a respective sub-district by the land area in square kilometer. All these data (i.e., geo-positioned survey data, environmental variables and population estimation data) were then exported and stored into ArcGIS 9.3 software (ERSI, Redlands, CA, USA) for further exploration and analysis. Appendix I summarizes the data and it sources that were used for analysis in the present study. For reference, Appendix J shows the NDVI, LST and DEM for Peninsular Malaysia.

7.2.6 Statistical analysis, mapping and modeled STH distribution

The geographic information system (GIS) application tool using ArcGIS 9.3 software (ERSI, Redlands, CA, USA) was used to integrate and analyze survey data and environmental variables that were derived from remote sensing (RS) satellite data. The statistical analysis for each test was performed using SPSS software (Statistical Package for the Social Sciences) program for Window version 17 (SPSS Inc, Chicago, USA). Logistic regression model was used to identify significant environmental variables that are known to influence the transmission of infections and for developing statistical risk models (Fielding & Bell, 1997; Pearce & Ferrier, 2000). Variables that are likely to have greater biological significance on transmission infection was selected and entered into the regression model first. Previous studies showed that maximum temperature is an important factor in determining STH distribution because the effect of heat and low humidity on the embryonation, development and survival of free-living infective stages (Brooker & Micheal, 2000). Therefore, this variable was entered into the regression model first followed by minimum and mean LST value. The remaining variables such as NDVI (minimum, maximum and mean) and altitude (minimum, maximum and mean) were added to the model in a step wise approach (i.e., introducing each variable in turn until all the three variables have fitted into the model).

The accuracy of the model was then assessed using the regression analysis by dividing the probability of infection into two groups with a cut value of 0.5, in which probability less than 0.5 were categorized as 0 (i.e., without infection) while 1 (i.e., with infection) for probability more than 0.5 (Menard, 2002). The Hosmer and Lemeshow Goodness-of-Fit test was also used to determine whether or not our model fits the observed prevalence data (Hosmer & Lemeshow, 1989). In other words, there is no difference between our model and collected data. In addition, the spatial autocorrelation test (i.e., *Moran's I* test) was used to determine whether or not the pattern of infection is spatially correlated (i.e., clustered, dispersed or randomly) (Moran, 1950). The test is determined by calculating the mean of each value at each location and comparing it with the mean value at all other locations (Moran, 1950). The *Moran's I* values ranges from -1 (i.e., strong negative correlation) to + 1 (i.e., strong positive correlation), while 0 indicates a spatially random pattern. The *Moran's I* test was performed using ArcGIS 9.3 software (ERSI, Redlands, CA, USA).

Following development of the statistical risk model, the best fit logistic regression model was then used to generate a predictive risk map of the probability of having STH prevalence of more than 50%. To define whether a sub-district would be a priority area for control according to prevalence threshold of 50% for MDA intervention as recommended by WHO (Anon, 2002), arbitrary criteria were used based on whether the average logistic probability is greater than 0.5 within a sub-district, following the approach by Brooker and co-workers (2002a). The observed and predicted prevalences were categorized according to the WHO prevalence threshold for treatment, denoting as 0, 0.1-9.9, 10-19.9, 20-49.9 and 50-100%. Since school-aged children are the primary target for treatment and also the school infrastructure is often used to deliver treatment, the population size that will receive treatment is estimated and calculated by overlaying the predictive prevalence risk map on a population density map. Details on calculation and estimation of the model development and turning logistic regression model into predicted probability risk map was provided in Appendix K.

7.3 RESULTS

7.3.1 Survey data and distribution of STH infections

The current database incorporates 99 survey locations conducted between 1970 and 2012 through our combined search strategies, of which all locations were successfully geo-positioned to actual coordinates (Table 7.1). Summary descriptive of the database on the prevalence of STH infections in Malaysia is presented was Appendix L. Of the included surveys, 80 were spatially unique locations, while the rest (i.e., 19 surveys) were undertaken in the same locations but at different period of times. With the exception of Terengganu and Perlis states where no surveys were performed, 26 surveys were undertaken in Pahang state, 25 in Selangor, 14 in Kuala Lumpur, 12 in Penang, 7 in Perak, 6 in Kelantan, 3 in Malacca and Negeri Sembilan respectively, 2 in Kedah and

1 in Johor, representing the examination of 47,118 individuals of all age group and gender. Overall, 22,790 (48.4%) individuals were infected with *Trichuris trichiura*, followed by 15,642 (33.2%) with *Ascaris lumbricoides* and 5,578 (11.8%) with hookworm infections. The estimated combined prevalence of individuals infected with any STH species as calculated using the simple probabilistic model was 74.5%.

Data from the published papers were the main source of data and accounted for 82.8% (82/99) of all survey points. Personal communications or direct contact with researchers known to be involved in STH research was the second most important source of data in the present study (10/99; 10.1%), while unpublished report from thesis accounted for 7.1% (7/99) of surveys data. Based on our communication and experience with the Ministry of Health and its relevant agencies, such as public health or non-communicable disease divisions, no studies or data related to STH infections were systematically available in their records. The majority of the surveys were undertaken between 2010 and 2012 accounting for 38 surveys while the least was in 2000 to 2009 with only 4 surveys. Of these, 75.8% (75/99) of the surveys were conducted as community-based studies while the rest (24/99; 24.2%) were conducted in schools (i.e., school-based studies). Although the majority of the surveys were conducted at community level involving all age groups, it is also believed representing school-aged children. The most common examination methods for the detection of STH species were the combination of more than one conventional microscopy technique (67/99; 67.7%).

Figure 7.2 (a) - 7.2 (d) shows observed geographical distribution of each STH species as well as the estimated combined prevalence based on all surveys data at sub-district levels. For reference, Appendix M shows the actual geo-positioned locations for each of the survey data points for all the three STH species and combined STH species.

For each STH species including combined STH, the prevalence of infections varies considerably with no clear pattern across the surveyed areas. With the exception of hookworm (i.e., Figure 7. 2 (c)), Figure 7.2 (a) - (d) shows that observed prevalence of *A. lumbricoides*, *T. trichuira* and combined STH species was high in most of the surveyed areas. In contrast, most of the areas had a low prevalence of hookworm infection. In addition to these geographical variations, there were also marked variations in the observed prevalence of STH infections over time (Table 7.2). For example, mean prevalence of *A. lumbricoides* was 61.8% in the period 1970-1979, but declined to 37.3% for 2010-2012. Similarly, mean prevalence of hookworm also shows distinct variations over time from 31.8% in the period 1970-1979 to 13.0% in the period 2000-2012.

7.3.2 Statistical and spatial analysis

Soil-transmitted helminths (STH) have direct life cycles, involving sexual maturation in the human hosts and the free living stages present in the environment. Their development and survival rate are dependent on surrounding environmental factors such as humidity and temperature. Studies have shown that such environmental factors will indirectly influence their transmission success and spatial patterns of infection (Brooker & Micheal, 2000). We have therefore investigated the ecological correlation of STH infections and predict their prevalence in un-sampled areas on the basis of satellite derived environmental data using logistic regression analysis. The results indicated maximum or mean Land Surface Temperature (LST) and minimum or mean Normalized Difference Vegetation Index (NDVI) were significant explanatory variables for *A. lumbricoides* infection (Table 7.3). The result showed that the odds of *A.*

lumbricoides was significantly negatively associated with maximum LST (OR = 0.88; 95% CI = 0.78-0.99) and minimum NDVI (OR = 0.98; 95% CI = 0.96-0.98). Only an *A. lumbricoides* model was developed. For *T. trichiura*, hookworm and estimated combined STH infections, no statistically significant explanatory variables were identified, thus no model could be developed.

The accuracy test shows that the overall percentage of the model to correctly predict areas with and without infections was 67.7%. This includes 63.7% ability of the model to predict only areas with infection while 70.4% to predict only areas without infection. Appendix N illustrates the model accuracy in which most areas without infection (i.e., denoted as 0) were plotted on the left side while areas with infection (i.e., denoted as 1) on the right side. The left side indicates areas with infection probability less than 0.5 while the right side with probability more than 0.5. Thus, the accuracy of the model was generally good and reliable. From the regression analysis, the value for Hosmer and Lemeshow Goodness-of-Fit test was statistically not significant (X^2 = 6.268; df = 8; p = 0.508). This indicated that the H-L goodness-of-fit test statistic is greater than p = 0.05, thus we fail to reject the null hypothesis which stated that there is no difference, suggesting that our model estimates are well-fitted to the data at an acceptable level.

The spatial distribution of *A. lumbricoides* infection was assessed using *Moran's I* index. The *Moran's I* index calculates spatial autocorrelation simultaneously based on both feature locations and values. As the index is an inferential statistic, the result of the analyses must be interpreted within the context of the null hypothesis. The null hypothesis for *Moran' I* indicates that values of each of the analyzed cases are randomly distributed in the dataset. In other words, the spatial process promoting any distribution pattern of cases occurred by random chance. Findings from *Moran' I* test demonstrated that there was significantly positive spatial autocorrelation existing for *A. lumbricoides* infection within sub-districts (*Moran's I* index = 0.04; z-score = 6.98; $p < 0.01$). Thus, we reject the null hypothesis as prevalence of *A. lumbricoides* was more spatially clustered. Result of the *Moran's I* test was shown in Appendix N.

7.3.3 Modeled helminth distributions

Following that, these environmental factors (i.e., maximum and mean LST and minimum and mean NDVI) were then used to model and predict the distribution of *A. lumbricoides* infection using logistic regression model. The predictive risk map of *A. lumbricoides* indicated that the prevalence of infection was clustered and higher (i.e., areas within blue color range with prevalence of at least 20% up to 100%) in central and northern plains of Peninsular Malaysia including central Pahang, Kelantan, northern Perak and Kedah particularly in areas which border with southern Thailand. In contrast, predicted prevalence of *A. lumbricoides* was lower (i.e., area within green color range with prevalence of ≤ 20%) along the west coast and southern part of Peninsular Malaysia (Figure 7.3). A visual comparison of our predicted map with observed prevalence map for *A. lumbricoides* showed some similar features and was in agreement. For instance, up to 70% of the surveyed areas with high observed prevalence showed similar levels with our predicted model.

A continuous probability contour map of prevalence exceed is 50% is illustrated in Figure 7.4. The areas within red color range (i.e., demonstrating probabilities more than 70%) are areas where there is high probability that the WHO mass drug administration (MDA) threshold of 50% is exceeded while areas within the green color range (i.e., indicating probabilities of at least 30%) are those where there is a low probability of the 50% MDA threshold being exceeded. Meanwhile, the yellow color range (i.e., indicating probabilities between 30% and 70%) can be assumed as areas of high uncertainty where further surveys would be helpful or continued surveillance program are recommended.

7.3.4 Estimated total number of infected at risk and requiring treatment

The model prediction presented here offer insight relevance for control program as we can estimate the number population at risk and identify priority areas where treatment should be delivered. Table 7.4 shows details the estimation of number of total population and school-aged children who will be infected and requiring MDA intervention at sub-district levels based on the model prediction for *A. lumbricoides*. For reference, Appendix O shows summary estimation number of total population and school-aged children who will be infected and requiring MDA intervention at district and state levels. In general, our model prediction indicates each state (i.e., either at district or sub-districts level) in Peninsular Malaysia requires MDA with the exception of Kuala Lumpur (assuming no MDA intervention is required). Based on our predicted estimation and number of population based on 2010 national census, there may be up to 3.5 million individuals of the total populations infected with *A. lumbricoides*. Using the national estimates of the proportion of school-aged children, we estimated 728,360 school-aged children who will be infected with *A. lumbricoides*. By overlaying our predictive map of infection on population map using average prediction being 50% or greater (i.e., once yearly MDA) based on a WHO intervention threshold, we were able to estimate the number of school-aged children that warrant treatment. On this basis, we estimated that a total of 391,232 school-aged children in 168 out of 842 sub-districts in the county will warrant twice yearly mass treatment with MDA intervention (Table 7.4). This corresponded to a total of 59 out of 81 districts in Peninsular Malaysia that were recommended for twice yearly MDA intervention (Appendix O). Given that there should be flexibility in the treatment threshold to suit local needs, the analysis were re-run using a 20% prevalence threshold (twice yearly MDA intervention). At this 20% threshold intervention, we estimated that 587,482 school-aged children in 365 out of 842 sub-districts or 75 out of 81 districts (Appendix O) would receive once yearly mass anthelminthic treatment. In addition, Figure 7.5 (a) and 7.5 (b) shows recommended intervention areas and population density (person per kilometer square) for the respective areas in Peninsular Malaysia. A visual comparison between both maps indicated that most of the recommended intervention areas were areas with population density between 10 and 100 persons per kilometer square.

Table 7.1: Summary of descriptive database on the prevalence survey of soil-transmitted helminth (STH) infections between 1970 and 2012 in Peninsular Malaysia

Characteristic	**Frequency**	**%**
Total number of survey indentified	99	-
Total of individuals examined	47,118	-
Total number infected with *Trichuris trichiura*	22,790	48.4
Total number infected with *Ascaris lumbricoides*	15,642	33.2
Total number infected with hookworm	5,578	11.8
Estimated combined prevalence of STH species [a]	-	74.5
Source of survey		
Published paper (Academic journal)	82	82.8
Unpublished report (Ministry of Health, thesis, symposium)	7	7.1
Personal communication (Direct contact with researcher)	10	10.1
Decade		
1970-1979	23	23.3
1980-1989	17	17.2
1990-1999	17	17.2
2000-2009	4	4.0
2010-2012	38	38.4
Study population		
Village	53	53.5
School-based	24	24.2
Fishing village	13	13.1
Estate	5	5.1
Squatter area	4	4.0
Age range examined		
Only among children	28	28.3
Across all age group	71	71.7
Examination method		
Kato-Katz	32	32.3
All others [b]	67	67.7

[a] Estimated combined prevalence of STH species was calculated using a simple probabilistic model following de Silva and Hall (2010)

[b] Other diagnostic method includes direct smear, formalin ether concentration, zinc-sulphate flotation, merthiolate-iodine-formalin (MIF), thiomersal-iodine-formol (TIF) and/or Harada-Mori techniques

Table 7.2: Mean prevalence of individual and estimated combined STH infections between 1970 and 2012

Decade	*Trichuris trichuira*		*Ascaris lumbricoides*		Hookworm		Estimated combined STH	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1970-1979	60.3	26.2	61.8	24.5	31.8	25.3	85.4	18.2
1980-1989	56.3	28.0	36.1	23.0	13.4	12.6	71.3	24.4
1990-1999	44.8	21.3	38.8	17.9	17.9	13.8	70.0	15.7
2000-2009	70.0	32.5	47.2	20.8	25.8	17.8	83.7	21.8
2010-2012	57.6	26.8	37.3	22.9	13.0	9.9	72.3	29.5

SD = Standard Deviation

Table 7.3: Regression coefficients used to estimate probability of person being infected in logistic regression model

Characteristic	Coefficient estimate (B)	Standard error of estimate	OR (95% CI)	p value
Ascaris lumbricoides				
Constant	28.992	0.248	-	-
Maximum LST	-0.127	3.942	0.88 (0.78-0.99)	0.047
Mean LST	0.113	4.019	1.12 (1.00-1.25)	0.045
Minimum NDVI	-0.020	4.747	0.98 (0.96-0.98)	0.029
Mean NDVI	0.026	5.819	1.03 (1.01-1.05)	0.016

LST = Land Surface Temperature; NDVI = Normal Difference Vegetation index; DEM = Digital Elevation Model
OR = Odd Ratio; CI = Confidence Interval

Table 7.4: Details of estimates of predicted prevalence, number being infected (total population and school-aged children) and number warranting mass treatment using 50% and 20% threshold at district level [a]

State	District	Sub-District (*Mukim*)	Total Population 2010	Total school-aged	Estimated *Ascaris*	Estimated total number of infected with *Ascaris*	Estimated total number of school- age infected with *Ascaris*	Estimated number receiving treatment using 50% threshold	Estimated number receiving treatment using 20% threshold
Johor	**Batu Pahat**	Bagan	1248	246	27.3	341	67		67
		Chaah Bahru	5426	1185	35.4	1921	420		420
		Kampong Bahru	11627	2516	26	3019	653		
		Linau	18325	3878	17.9	3278	694		
		Lubok	6594	1272	9.5	625	121		
		Minyak Beku	16634	3054	14.2	2362	434		
		Peserai	9143	1876	76.6	6999	1436	1436	1436
		Simpang Kanan	135911	26811	2.2	3032	598		
		Simpang Kiri	25455	5833	4.4	1130	259		
		Sri Gading	63903	15263	15.5	9894	2363		
		Sri Medan	22501	5283	10	2257	530		
		Sungai Kluang	15844	3211	9.1	1439	292		
		Sungai Punggor	10132	2183	55.4	5613	1209	1209	1209
		Tanjong Sembrong	34456	7693	8.2	2832	632		
	Johor Bahru	Bandar	112942	19156	4.3	4875	827		
		Jelutong	12776	2324	0.4	47	9		
		Plentong	446285	93299	0.3	1462	306		
		Pulai	2069	400	8.1	168	33		
		Sedenak	14441	3545	25.2	3635	892		892
		Senai	105432	24349	14.4	15161	3501		
		Sungai Tiram	11194	2673	9.4	1047	250		
		Tanjung Kupang	9629	1850	3.8	369	71		
		Tebrau	288268	59477	0.7	1890	390		
	Kluang	Kahang	7805	1601	40.4	3155	647		647
		Kluang	160049	32007	40.2	64296	12858		12858
		Layang-Layang	10556	2144	0.4	45	9		
		Machap	5243	943	0.7	37	7		
		Niyor	3965	863	0.3	13	3		
		Paloh	9782	1966	62.6	6128	1232	1232	1232
		Rengam	34848	7871	52.8	18392	4154	4154	4154
		Ulu Benut	21829	4922	9.8	2138	482		
	Kota Tinggi	Johor Lama	8864	1819	4.2	371	76		
		Kambau	1367	303	96.1	1314	291	291	291
		Kota Tinggi	57010	12320	7.7	4379	946		

	Pantai Timur	7133	1814	2.7	196	50		
	Penggerang	14106	2755	1.3	187	37		
	Sedili Besar	10014	1894	2	205	39		
	Sedili Kechil	13657	2296	2.1	288	48		
	Tanjong Surat	23696	4512	5.6	1331	253		
	Ulu Sungai	30094	6586	48.6	14627	3201	3201	3201
	Ulu Sungei	5415	1181	13	702	153		
Mersing	Jemaluang	3267	856	3.9	128	33		
	Lenggor	162	117	0.7	1	1		
	Mersing	35179	7683	3.6	1259	275		
	Padang Endau	10390	2365	4.2	441	100		
	Penyabong	985	260	96.6	951	251	251	251
	Pulau Aur	169	39	0.5	1	0		
	Pulau Babi	64	9	8.3	5	1		
	Pulau Pemanggil	58	19	7.7	4	1		
	Pulau Sibu	249	36	44.9	112	16		16
	Pulau Tinggi	160	46	31.4	50	14		14
	Sembrong	1114	212	28.9	322	61		61
	Tenggaroh	3029	739	2.7	82	20		
	Tenglu	5145	972	45.6	2345	443		443
	Triang Mersing	52512	12514	1.9	994	237		
Muar	Ayer Hitam	7559	1716	8.9	671	152		
	Bandar Muar	10889	2320	7.4	811	173		
	Bukit Kepong	8501	1906	23.3	1977	443		443
	Bukit Serampang	7827	1966	18.1	1415	355		
	Grisek	25882	5894	5	1301	296		
	Jalan Bakri	31540	7241	0.6	174	40		
	Jorak	17320	3402	11.3	1963	386		
	Kesang Muar	9475	2327	17.8	1687	414		
	Kundang	3458	717	3.2	109	23		
	Lenga	6317	1471	6	380	88		
	Parit Bakar	10978	2376	8.2	905	196		
	Parit Jawa	10534	2143	8.3	875	178		
	Serom	22894	5231	61.6	14113	3225	3225	3225
	Sg. Raya & Kg. Bkt. Pasir	6528	1290	1.6	104	21		
	Sri Menanti Muar	3179	522	1.7	54	9		
	Sungai Balang	12397	2756	29.7	3679	818		818
	Sungai Terap Muar	47388	9187	15.2	7195	1395		
	Tangkak	48668	10136	84.5	41148	8570	8570	8570
Pontian	Air Masin	4371	935	10.1	443	95		
	Api-Api	11626	2429	15.9	1854	387		
	Ayer Baloi	11403	3044	14.4	1647	440		
	Benut	13662	3021	6.2	852	188		
	Jeram Batu	22538	4791	1.2	272	58		

		Pengkalan Raja	1167	257	0.2	2	1		
		Pontian Pontian	33427	7239	20.2	6766	1465		1465
		Rimba Terjun	24964	5513	12.8	3188	704		
		Serkat	7512	1584	0.2	16	3		
		Sungai Karang Pontian	52626	12028	6.4	3387	774		
		Sungei Pinggan	6584	1515	3.6	235	54		
	Segamat	Bandar Segamat	2601	609	0	0	0		
		Bekok	4299	746	11.5	494	86		
		Buloh Kasap	22311	4260	34.5	7695	1469		1469
		Chaah	11598	1970	1.7	199	34		
		Gemas Segamat	11437	2055	19.9	2281	410		
		Gemereh	6120	1297	1.2	74	16		
		Jabi Segamat	15074	4271	8.3	1244	352		
		Jementah	16691	2513	35.5	5933	893		893
		Labis	29739	5935	8	2374	474		
		Pogoh	19422	3974	18.7	3623	741		
		Sermin	1261	243	20.4	257	49		49
		Sungai Segamat	40519	8156	4.5	1818	366		
Kedah	**Baling**	Bakai	13423	3217	3.8	510	122		
		Baling	7415	1548	9.4	699	146		
		Bongor	5848	1243	11.9	693	147		
		Kupang	26304	6064	75.4	19840	4574	4574	4574
		Pulai Baling	25406	5763	51.2	13008	876	13008	13008
		Siong	12786	2981	45.7	5840	1362		1362
		Tawar	21230	4747	41.4	8782	1964		1964
		Telui Kanan	17649	4291	69.4	12245	2977	2977	2977
	Bandar Baharu	Bagan Samak	14615	3235	15.6	2274	503		
		Kuala Selama	4641	1378	85.8	3980	1182	1182	1182
		Permatang Pasir	812	177	0.1	1	0		
		Relau	3674	891	2.9	106	26		
		Serdang	10832	2274	98.2	10636	2233	2233	2233
		Sungai Batu	3308	743	84.2	2785	626	626	626
		Sungai Kechil	2795	691	42	1173	290		290
	Kota Setar	Alor Malai	30096	5472	0	2	0		
		Alor Merah	9396	1574	7.9	739	124		
		Anak Bukit	10620	2035	1.8	195	37		
		Bukit Lada	6446	1437	0.2	15	3		
		Bukit Pinang	8465	1738	6	505	104		
		Derang	3832	845	53.8	2061	454	454	454
		Derga	31548	6260	1	302	60		
		Gajah Mati	12146	2156	3.5	423	75		
		Gunong	7409	1505	6.7	495	101		
		Hutan Kampong	7880	1524	22.3	1760	340		340
		Jabi Kota Setar	11517	2456	30.3	3488	744		744
		Kangkong K. Setar	8581	1833	0.4	33	7		

	Kota Setar	21733	3490	11.4	2487	399		
	Kuala Kedah	19892	4176	0.1	26	5		
	Kubang Rotan	6662	1369	0.3	18	4		
	Langgar K. Setar	8191	1783	22.1	1807	393		393
	Lepai	3307	689	45.7	1511	315		315
	Lesong	5948	1262	16.3	969	206		
	Limbong	1600	338	31.7	507	107		107
	Mergong	27199	5077	54.8	14906	2782	2782	2782
	Padang Hang	4379	860	0.9	41	8		
	Padang Lalang	9172	1744	0.7	67	13		
	Pengkalan Kundor	4055	923	5.4	220	50		
	Pumpong	17584	2885	0	4	1		
	Sala Kechil	6894	1276	7.7	534	99		
	Tajar	16043	3354	6.9	1106	231		
	Tebengau	4705	977	0.8	40	8		
	Telaga Mas	3470	756	1.8	64	14		
	Telok Chengai	6897	1479	0.5	32	7		
	Telok Kechai	9797	1932	10.8	1060	209		
	Titi Gajah	4944	923	5.7	281	52		
	Tualang	6708	1321	34	2280	449		449
	Lengkuas	1916	379	45.1	863	171		171
	Sungai Baharu	1967	430	93	1830	400	400	400
Kuala Muda	Bujang	13191	2387	53.3	7029	1272	1272	1272
	Bukit Meriam	5433	1178	9.6	524	114		
	Gurun	37699	8720	79.1	29837	6901	6901	6901
	Haji Kudong	1067	234	7.7	82	18		
	Kota K. Muda	4117	799	18.7	769	149		
	Merbok	13514	2817	4.5	608	127		
	Pekula	14675	3405	0.2	24	6		
	Pinang Tunggal	15882	3670	98.6	15659	3619	3619	3619
	Semeling	21846	4238	4.9	1074	208		
	Sidam Kiri	7714	1874	35.6	2747	667		667
	Simpor	5851	1207	0.9	53	11		
	Sungai Pasir	75075	16415	3.9	2916	638		
	Sungai Petani	192463	42185	43.4	83619	18328	18328	18328
	Telui Kiri	10536	2561	16.4	1728	420		
	Kuala	3042	712	24.9	756	177		177
	Rantau Panjang	2808	609	15.5	436	95		
Kubang Pasu	Ah	4163	822	9.5	395	78		
	Binjal	3437	668	10	342	66		
	Bukit Tinggi	6674	1430	27.9	1862	399		399
	Gelong	10598	2433	14.5	1539	353		
	Husba	3218	596	57.7	1857	344	344	344
	Jeram K. Pasu	2386	580	15.9	380	92		
	Jerlun	17124	3510	1.1	195	40		
	Jitra	23259	5011	61.1	14211	3062	3062	3062

	Kepelu	9152	1830	42	3842	768		768
	Kubang Pasu	2549	558	70	1784	391	391	391
	Malau	3152	628	28.3	892	178		178
	Naga	27690	5326	8.8	2433	468		
	Padang Perahu	3252	655	5.9	193	39		
	Pelubang	9257	2181	22.7	2104	496		496
	Pering	6611	1240	21.9	1448	272		272
	Putat	4946	1035	8	395	83		
	Sanglang	15811	3072	12.4	1965	382		
	Sungai Laka	12853	2728	34.5	4440	942		942
	Temin	33857	3626	30.9	10458	1120		1120
	Tunjang	6483	1321	17.9	1158	236		
	Wang Tepus	1588	345	15.3	243	53		
Kulim	Bagan Sena	6533	1530	17.3	1128	264		
	Junjong	4567	944	41.6	1898	392		392
	Karangan	8789	1919	78.4	6893	1505	1505	1505
	Keladi	30836	6447	86.6	26689	5580	5580	5580
	Kulim	59172	13476	9.7	5765	1313		
	Lunas	24630	6344	36	8867	2284		2284
	Mahang	14905	2449	24.6	3660	601		601
	Naga Lilit	22038	5442	55.2	12159	3002	3002	3002
	Padang China	26384	5803	45.1	11904	2618		2618
	Padang Meha	9203	2068	16	1468	330		
	Sedim	3140	612	70.6	2217	432	432	432
	Sidam Kanan	23310	6135	4.6	1069	281		
	Sungai Seluang	30213	7118	68.3	20632	4861	4861	4861
	Sungai Ular	10691	1573	50.7	5418	797	797	797
	Terap	3591	777	55.2	1983	429	429	429
Langkawi	Ayer Hangat	9931	3055	57	5657	1740	1740	1740
	Kuah	34380	7226	1.5	501	105		
	Bohor	6386	1441	19.4	1240	280		
	Padang Masirat	8841	1871	17	1499	317		
	Kedawang	11558	2617	56.6	6540	1481	1481	1481
	Ulu Melaka	12511	2692	23.5	2936	632		632
Padang Terap	Belimbing Kanan	11230	2443	10.8	1211	263		
	Belimbing Kiri	2454	536	12.1	298	65		
	Kurong Hitam	2992	694	70.7	2115	491	491	491
	Padang Temak	5133	1139	20.3	1041	231		231
	Padang Terap Kanan	1862	413	21.7	404	90		90
	Padang Terap Kiri	3796	730	79.4	3013	579	579	579
	Pedu	6319	1402	1.8	111	25		
	Tekai	20844	4614	56	11671	2583	2583	2583
	Tolak	2734	560	60.9	1665	341	341	341
	Batang Tunggang Kiri	1264	259	28.2	357	73		73
	Batang Tunggang Kanan	1785	395	13.3	237	52		

	Pendang	Ayer Puteh	32174	7166	17.3	5565	1239		
		Bukit Raya	12535	2508	12.3	1547	310		
		Guar Kepayang	7444	1575	5.3	397	84		
		Padang Kerbau	11960	2528	85.6	10241	2165	2165	2165
		Padang Pusing	9744	2122	33.3	3249	708		708
		Rambai	8800	1789	13.8	1217	247		
		Tobiar	6028	1200	33.3	2009	400		400
		Padang Peliang	3984	825	55.8	2223	460	460	460
	Sik	Jeneri	14964	3389	88.3	13212	2992	2992	2992
		Sik	40900	9072	70.8	28939	6419	6419	6419
		Sok	8931	2215	85.9	7673	1903	1903	1903
	Yan	Sala Besar	24796	5191	32.2	7989	1672		1672
		Sungai Daun	11618	2478	48.9	5683	1212		1212
		Dulang	5126	1100	18.9	970	208		
		Yan	21344	5118	27.5	5861	1405		1405
		Singkir	3066	756	11.5	352	87		
Kelantan	**Bachok**	Beklam	1061	289	6.2	66	18		
		Gunong Timor	5083	1255	37.6	1911	472		472
		Mahligai	20336	5029	13.9	2821	698		
		Melawi (Repek)	5135	1325	14.6	749	193		
		Perupok	861	203	60.3	519	122	122	122
		Tanjong Pauh	1976	514	81.9	1618	421	421	421
		Tawang (Mentuan)	1765	479	41.3	729	198		198
		Telong	5455	1134	72.2	3938	819	819	819
	Gua Musang	Bertam G. Musang	160	37	70.5	113	26	26	26
		Chiku	4428	1096	33.1	1465	363		363
		Galas	4583	1209	88	4031	1063	1063	1063
	Jeli	Bt. Melintang	1630	341	17.6	287	60		
		Jeli	10655	2885	95.5	10180	2757	2757	2757
		Kuala Balah	4797	1149	13.5	649	155		
	Kota Bharu	Badang	5485	1306	12.2	669	159		
		Beta	2328	585	1.7	40	10		
		Kadok	5090	1065	1.4	73	15		
		Kemumin	12010	1994	27	3241	538		538
		Ketereh (Pangkal Kalong)	4822	1050	0.5	24	5		
		Kota K.B	43515	7822	0	10	2		
		Kota Bharu	2940	641	16.1	474	103		
		Kubang Kerian (Lundang)	6372	1395	14.5	925	202		
		Limbat	6196	1449	3.1	190	44		
		Panji	19341	4015	26.1	5039	1046		1046
		Pendek	6623	1566	22	1454	344		344
		Peringat	6296	1451	2.2	137	31		
		Salor	8538	2103	1	83	20		
		Sering	4224	938	0.3	13	3		
		Banggu	4167	963	17.7	736	170		

	Kuala Krai	Batu Mengkebang	13414	3472	84.5	11341	2935	2935	2935
		Dabong	5348	1360	91	4864	1237	1237	1237
		Olak Jeram	355	96	53.8	191	52	52	52
	Machang	Pangkal Meleret	3000	682	7.3	220	50		
		Panyit	4042	946	70.8	2861	670	670	670
		Pulai Chondong	4278	1062	61.8	2643	656	656	656
		Temangan	9877	1837	0.1	5	1		
		Ulu Sat	9101	992	35.8	3259	355		355
	Pasir Mas	Alor Pasir	3723	966	11.2	419	109		
		Bunut Susu	2649	709	14.4	381	102		
		Chetok	4975	1213	63.9	3177	775	775	775
		Gual Periok	5206	1288	21.4	1112	275		275
		Kangkong P. Mas	2975	698	99.9	2972	697	697	697
		Kubang Sepat	1377	283	3.4	46	10		
		Kubang Gadong	2913	628	9.8	287	62		
		Pasir Mas	18980	4712	33.3	6312	1567		1567
		Rantau Panjang PMas	4434	1038	41.2	1829	428		428
		Kuala Lemal	3169	940	28.9	916	272		272
	Pasir Puteh	Bukit Abal	2110	613	19	400	116		
		Bukit Awang	620	201	31	192	62		62
		Bukit Jawa	2814	733	31.5	887	231		231
		Gong Datok	3174	787	15.7	498	123		
		Jeram P. Puteh	7814	1460	63.8	4987	932	932	932
		Limbongan	6800	1824	38.3	2606	699		699
		Padang Pak Amat	7398	1905	19.5	1440	371		
		Semerak	3374	669	5	170	34		
	Tanah Merah	Jedok	4078	1053	82.5	3363	868	868	868
		Ulu Kusial	2091	489	0	0	0		
		Kusial	5989	1555	66.1	3960	1028	1028	1028
	Tumpat	Jal Besar	3065	635	21	643	133		133
		Kebakat	2231	490	12.8	286	63		
		Pengkalan Kubor	60383	11782	10.7	6473	1263		
		Sungai Pinang	5970	1429	4.2	252	60		
		Terbok	691	178	21	145	37		
		Tumpat	7721	1931	9.2	713	178		
		Wakaf Bharu	5325	1145	12.2	651	140		
Melaka	**Alor Gajah**	Ayer Pa'Abas	2615	299	17.9	469	54		
		Belimbing	6624	1666	28.5	1885	474		474
		Beringin	1975	459	32.7	647	150		150
		Brisu	719	83	14.7	106	12		
		Durian Tunggal	18672	3663	53.6	10007	1963	1963	1963
		Gadek	3834	887	13.7	525	121		
		Kelemak	21743	3066	17.1	3724	525		
		Kemuning	1974	433	1.1	21	5		
		Kuala Linggi	1982	367	0.1	2	0		
		Kuala Sungei Baru	10104	1601	29.4	2974	471		471

	Lendu	3062	591	17	521	101		
	Machap Alor Gajah	4848	1099	66.2	3211	728	728	728
	Masjid Tanah	11731	2725	6.8	796	185		
	Melaka Pindah	5100	1211	34.4	1753	416		416
	Melekek	2118	585	5.2	110	30		
	Padang Sebang	3427	700	4	138	28		
	Parit Melana	1465	301	29.5	432	89		89
	Pegoh	2436	283	81.5	1984	231	231	231
	Pulau Sebang	7611	1327	4.1	313	55		
	Ramuan China Besar	3010	468	16.1	485	75		
	Ramuan China Kechil	2660	541	53.9	1435	292	292	292
	Rembia	6109	1198	85	5194	1019	1019	1019
	Sungei Baru Ilir	8949	1776	34.6	3094	614		614
	Sungei Baru Tengah	15089	2918	0	4	1		
	Sungei Baru Ulu	7421	1520	57.1	4238	868	868	868
	Sungei Petai Buloh	4643	923	23.1	1072	213		213
	Sungei Siput	1579	243	26.5	419	65		65
	Taboh Naning	6711	1012	13.5	909	137		
	Tanjong Rimau	604	88	6.4	39	6		
	Tebong AGajah	2544	629	4.8	122	30		
	Tanjung Tuan	8	0	47.3	4	0		
Jasin	Ayer Panas	13154	2781	22.7	2985	631		631
	Batang Malaka	3880	1025	3.4	134	35		
	Bukit Senggeh	1765	310	16.6	294	52		
	Chabau	4763	1080	10.8	515	117		
	Chin Chin	3791	736	15.9	604	117		
	Chohong	626	126	59.6	373	75	75	75
	Jasin	13650	2903	42	5728	1218		1218
	Jus	475	153	58.9	280	90	90	90
	Kesang Jasin	15805	3022	41.3	6535	1249		1249
	Merlimau	17573	2907	70.7	12425	2055	2055	2055
	Nyalas	7608	1752	20.7	1576	363		363
	Rim	4506	976	66.4	2990	648	648	648
	Sebatu	6427	1515	32.8	2110	497		497
	Selandar	5660	936	71.7	4058	671	671	671
	Sempang	4256	653	4.8	205	31		
	Semujok	1442	391	90.1	1299	352	352	352
	Serkam	8575	2010	58.8	5040	1181	1181	1181
	Sungei Rambai	7645	1651	4.8	364	79		
	Tedong	2972	613	21.3	632	130		130
	Umbai	8895	1982	26.3	2339	521		521
Melaka Tengah	Alai	7965	1580	0	0	0		
	Ayer Molek	10167	2375	21.4	2173	508		508
	Bachang	20097	2975	9.2	1843	273		
	Balai Panjang	17193	3187	38.3	6587	1221		1221

		Bandar Melaka	60735	8258	6	3664	498		
		Batu Berendam	39689	7331	0.7	263	49		
		Bertam Melaka	11425	2052	22.5	2569	461		461
		Bukit Baru	40997	5443	4.3	1776	236		
		Bukit Katil	40806	8149	8.5	3470	693		
		Bukit Lintang	10181	2152	22.2	2260	478		478
		Bukit Piatu	7199	1105	54	3887	597		
		Bukit Rambai	20226	4354	5.9	1200	258		
		Cheng	16986	3778	75.8	12868	2862	2862	2862
		Duyong	16459	3756	22.1	3632	829		829
		Kandang	4571	888	11.9	544	106		
		Klebang Besar	6232	883	49.9	3111	441		441
		Klebang Kechil	9423	1832	48.8	4596	894		894
		Krubong	12869	2513	71.6	9209	1798	1798	1798
		Padang Semabok	791	132	0.2	1	0		
		Padang Temu	4329	928	4.6	201	43		
		Paya Rumput	4953	897	11.2	556	101		
		Pernu	5973	1458	5.4	325	79		
		Pringgit	9170	1260	49.6	4546	625		625
		Semabok	7717	1512	1.1	86	17		
		Sungai Udang	21795	4922	36.3	7905	1785		1785
		Tangga Batu	10271	2117	75.3	7732	1594	1594	1594
		Tanjong Keling Melaka	9703	1919	1.9	189	37		
		Tanjong Minyak	20499	4967	17.3	3549	860		
		Telok Mas	7348	1592	98.2	7218	1564	1564	1564
		Ujong Pasir	2872	393	33.6	965	132		132
Negeri Sembilan	**Jelebu**	Gelami Lemi	9380	1722	8.5	794	146		
		Hulu Kelawang	1885	337	15.8	299	53		
		Kenaboi	1523	399	10.1	153	40		
		Kuala Kelawang	1316	280	56	737	157		
		Peradong	9082	1819	7.1	649	130		
		Pertang	12054	1843	14.8	1778	272		
		Teriang Hilir	4990	1193	35.5	1772	424		424
		Hulu Teriang	3795	808	0.2	9	2		
	Jempol	Jelai	23176	4750	19	4404	903		
		Kuala Jempol	4149	862	7	291	60		
		Rompin Jempol	2182	405	46.9	1024	190		190
		Serting Hilir	13509	2694	96.8	13078	2608	2608	2608
		Serting Ulu	41298	8010	70.4	29059	5636	5636	5636
	Kuala Pilah	Ampang Tinggi	11052	2108	17.2	1905	363		
		Johol	8068	1686	97.3	7854	1641	1641	1641
		Juasseh	8790	1924	70	6156	1347	1347	1347
		Kepis	630	123	9.2	58	11		
		Langkap	1157	226	11.2	129	25		
		Parit Tinggi	14973	2052	2	305	42		

		Pilah	712	161	8	57	13		
		Sri Menanti KPilah	24229	5145	5.2	1253	266		
		Terachi	4674	997	1.6	75	16		
		Ulu Jempol	2677	544	9.3	248	50		
		Ulu Muar	6692	1415	11.8	793	168		
	Port Dickson	Jimah	18027	3891	2.8	513	111		
		Linggi	134	32	42.4	57	14		14
		Pasir Panjang P. Dickson	7274	1489	59.1	4300	880	880	880
		Port Dickson	62444	14074	0.4	231	52		
		Si Rusa	843	148	2	17	3		
	Rembau	Batu Hampar	1940	407	56.6	1098	230	230	230
		Bongek	1179	207	5.6	66	12		
		Chembong	11816	2819	31.4	3716	886		886
		Chengkau	815	149	31	253	46		46
		Gadong	3637	693	4.6	169	32		
		Kundor	85390	16061	4.6	3955	744		
		Legong Hilir	524	110	20.7	109	23		23
		Legong Hulu	7978	1529	15.2	1215	233		
		Miku	791	138	50.6	400	70	70	70
		Nerasau	2633	439	34.4	905	151		151
		Pedas	1638	330	99	1622	327	327	327
		Pilin	39701	8277	7.5	2964	618		
		Selemak	495	110	0.5	3	1		
		Semerbok	31422	5615	55	17294	3090	3090	3090
		Spri	9397	3266	17.6	1653	574		
		Tanjong Keling Rembau	3144	762	29.5	928	225		225
		Titian Bintangor	2390	486	37.7	902	183		183
	Seremban	Ampangan	124845	27749	6.2	7705	1713		
		Bandar Seremban	55283	8975	6.6	3645	592		
		Labu Seremban	402	86	10.8	43	9		
		Lenggeng	6550	1252	15.1	987	189		
		Pantai Seremban	1292	57	7.6	98	4		
		Rantau	85148	16228	8.3	7039	1342		
		Rasah Seremban	2581	551	0.6	17	4		
		Seremban	25746	5181	0	12	2		
		Setul	27197	6329	1.3	359	84		
	Tampin	Ayer Kuning	3972	820	13.3	526	109		
		Gemas Tampin	29004	5712	13.6	3937	775		
		Gemencheh	18754	3657	20.5	3839	749		749
		Keru	10578	2342	0.6	69	15		
		Repah	35678	6687	6	2131	399		
		Tampin Tengah	3121	623	51.7	1613	322	322	322
		Tebong Tampin	727	139	59.3	431	82	82	82
Pahang	**Bentong**	Bentong	69442	12122	25.9	17977	3138		3138
		Pelangai	13719	2872	11.6	1597	334		

	Sabai	24779	5437	1.6	397	87		
	Bera	34178	7500	52.7	18020	3954		3954
	Triang Bera	2297	513	16.3	373	83		
Cameron Highland	Ringlet	7445	1261	0.6	46	8		
	Tanah Rata	11019	3024	0	3	1		
	Ulu Telom	13691	3443	28.3	3873	974		974
Jerantut	Burau	3377	721	7.1	239	51		
	Kelola	258	76	10.5	27	8		
	Kuala Tembeling	2163	469	63.2	1367	296	296	296
	Pedah	32568	7295	17	5544	1242		
	Pulau Tawar	19491	4380	35.1	6846	1538		1538
	Tebing Tinggi	1893	484	97.4	1844	471	471	471
	Teh	7763	1788	19	1474	340		
	Tembeling	5962	1273	98.2	5857	1251	1251	1251
	Ulu Cheka	7119	1580	87.1	6203	1377	1377	1377
	Ulu Tembeling	2279	513	35.5	808	182		182
Kuantan	Beserah	19149	4122	2.2	413	89		
	Kuala Kuantan	327485	63961	29.3	96104	18770		18770
	Penor	7431	1536	9.6	716	148		
	Sungai Karang Kuantan	1748	348	18.8	328	65		
	Ulu Kuantan	6188	1314	12.9	798	170		
	Ulu Lepar	15535	3166	43.9	6818	1390		1390
Lipis	Batu Yon	9874	2614	11.8	1165	308		
	Budu	4495	859	12.6	566	108		
	Cheka	4775	1140	14.3	681	163		
	Gua	3530	938	57	2013	535	535	535
	Kechau	4216	1110	98	4132	1088	1088	1088
	Kuala Lipis	14430	3245	99.8	14408	3240	3240	3240
	Penjom	12142	2538	65.3	7928	1657	1657	1657
	Tanjong Besar	2821	620	97.3	2745	603	603	603
	Telang	6296	1499	71	4472	1065	1065	1065
	Ulu Jelai	18215	5133	48.7	8872	2500		2500
Maran	Bukit Segumpal	10439	2148	37.3	3896	802		802
	Chenor	76764	14335	98.4	75499	14099	14099	14099
	Kertau	3992	836	65.4	2612	547	547	547
	Luit	15721	3779	89.5	14066	3381	3381	3381
Pekan	Bebar	15514	4091	34.5	5349	1411		1411
	Ganchong	1729	311	24.3	420	76		76
	Kuala Pahang	7874	1695	3.6	282	61		
	Langgar pekan	8032	1622	39.3	3160	638		638
	Lepar	5084	1147	16.7	851	192		
	Pahang Tua	11747	2724	1.2	147	34		
	Pekan	25798	6009	28.2	7280	1696		1696
	Penyor	23601	4821	22.8	5388	1101		1101
	Pulau Manis	1765	404	21.7	383	88		88

		Pulau Rusa	664	128	1.3	9	2		
		Temai	859	205	21.4	184	44		44
	Raub	Batu Talam	12038	3037	27.2	3273	826		826
		Dong	4540	1009	92.9	4217	937	937	937
		Gali	57049	11459	21.7	12355	2482		2482
		Sega	4408	1142	43.2	1903	493		493
		Semantan Ulu	3975	634	27.6	1099	175		175
		Teras	4852	1149	1.6	77	18		
		Ulu Dong	1607	460	10.5	168	48		
	Rompin	Endau	11708	2783	2.1	248	59		
		Keratong	58886	13065	15.2	8930	1981		
		Pontian Rompin	8913	2030	48.1	4286	976		976
		Rompin Rompin	18304	4763	70.4	12887	3353	3353	3353
		Tioman	3168	551	4.1	129	22		
	Temerloh	Bangau	6987	1669	12.9	898	215		
		Jenderak	19747	4297	0.9	178	39		
		Kerdau	4544	978	51.3	2333	502	502	502
		Lebak	1432	275	10.6	152	29		
		Mentakab	47575	10333	24	11425	2481		2481
		Perak	46290	10790	71.1	32929	7676	7676	7676
		Sanggang	5289	1002	69.8	3690	699	699	699
		Semantan	16021	3651	40.5	6494	1480		1480
		Songsang	1966	444	43.8	862	195		195
		Lipat Kajang	1436	442	75.7	1087	335	335	335
Perak	**Batang Padang**	Batang Padang	32176	6582	30	9662	1976		1976
		Bidor	30524	6166	45.3	13818	2791		2791
		Chenderiang	17801	3619	3.6	636	129		
		Slim	20570	4784	16.6	3420	795		
		Sungkai	27564	6305	67.5	18606	4256	4256	4256
		Ulu Bernam Timor & Barat	39404	5978	1.5	585	89		
	Hilir Perak	Bagan Datoh	12134	2512	87.6	10633	2201	2201	2201
		Changkat Jong	23380	5019	16.9	3956	849		
		Durian Sebatang	85522	17481	3.4	2925	598		
		Hutan Melintang	30845	6982	4.2	1296	293		
		Labu Kubong	10395	2486	3.2	337	81		
		Rungkup	10907	2352	0.4	45	10		
		Sungai Durian	3569	699	9	322	63		
		Sungai Manik	7919	1956	19.3	1531	378		
		Telok Baharu	8130	1725	6.5	531	113		
	Kerian	Bagan Serai	42930	9913	14.9	6414	1481		
		Bagan Tiang	13512	3126	11.8	1591	368		
		Beriah	13043	3168	2	260	63		
		Gunong Semanggol	17472	3702	2.6	450	95		
		Kuala Kurau	27132	5463	33.2	9008	1814		1814
		Parit Buntar	37602	9031	20.5	7714	1853		1853

	Selinsing	9805	2677	88	8625	2355	2355	2355
	Tanjong Piandang	12493	2763	40.8	5098	1127		1127
Kinta	Belanja Kinta	14195	2611	10.8	1527	281		
	Kampar	68492	11073	2.8	1928	312		
	Sungai Raia	28416	6013	68.5	19454	4117	4117	4117
	Sungai Terap Kinta	12062	2119	1.7	203	36		
	Tanjong Tualang	16279	3159	0.8	126	24		
	Teja	26033	4638	24.2	6311	1124		1124
	Ulu Kinta	620646	110585	0.2	1268	226		
Kuala Kangsar	Chegar Galah	8625	1786	13.6	1170	242		
	Kampung Buaya	10628	2281	56.1	5960	1279	1279	1279
	Kota Lama Kanan	8645	1568	42.1	3637	660		660
	Kota Lama Kiri	23598	4360	44.5	10491	1938		1938
	Lubok Merbau	4634	888	61.8	2864	549	549	549
	Pulau Kamiri	13026	3298	19.7	2564	649		
	Saiong	24857	5501	46.9	11652	2579	2579	2579
	Senggang	10881	2153	2.5	269	53		
	Sungai Siput	47552	9969	81.6	38796	8133	8133	8133
Larut dan Matang	Asam Kumbang	94964	20869	16.9	16039	3525		
	Batu Kurau	23638	5775	13	3082	753		
	Bukit Gantang	12547	2989	11.3	1419	338		
	Jebong	20494	5116	14.1	2894	722		
	Kamunting	35718	8407	1.5	552	130		
	Pengkalan Aor	37235	8293	30.9	11522	2566		2566
	Selama	13472	3331	35.4	4772	1180		1180
	Simpang	4865	1167	85.9	4180	1003	1003	1003
	Sungai Limau	3047	632	57.1	1739	361	361	361
	Sungai Tinggi Larut	10762	2138	42.4	4568	907		907
	Terong	4133	929	21.6	893	201		201
	Tupai	35065	5464	3.1	1090	170		
	Ulu Ijok	10901	2750	93	10135	2557	2557	2557
	Selama	12605	3161	65.6	8265	2073	2073	2073
Manjung (Dinding)	Beruas	8807	1782	32.2	2840	575		575
	Lekir	9558	2146	1.2	117	26		
	Lumut	54351	11459	3.1	1671	352		
	Pengkalan Baharu	27089	5612	3.8	1028	213		
	Sitiawan	119544	25524	10.8	12915	2758		
Perak Tengah	Bandar Perak Tengah	92134	17911	17.5	16097	3129		
	Belanja Perak Tengah	12490	3140	21.5	2683	675		675
	Bota	41469	6895	12.5	5202	865		
	Jaya Baharu	206	74	18.2	38	14		
	Kampong Gajah	7205	1803	35.2	2538	635		635
	Kota Setia	3310	761	56	1854	426	426	426
	Lambor Kanan	3235	739	6.9	222	51		
	Lambor Kiri	1944	518	59.2	1151	307	307	307
	Layang-Layang	3330	770	54.9	1829	423	423	423

		Pasir Panjang Ulu	2944	652	43.2	1273	282		282
		Pasir Salak	11712	2759	8	941	222		
		Pulau Tiga	3653	977	41.5	1515	405		405
	Ulu Perak	Belukar Semang	1576	335	7.3	115	25		
		Belum	778	229	87.6	681	201	201	201
		Durian Pipit	3345	542	92.4	3092	501	501	501
		Grik	28875	6956	61.8	17841	4298	4298	4298
		Kenering	9131	2389	8.9	811	212		
		Kerunai	7799	1750	77.2	6018	1350	1350	1350
		Lenggong	12185	2586	88.6	10796	2291	2291	2291
		Pengkalan Hulu	15687	3560	94.1	14768	3351	3351	3351
		Temelong	3460	762	24.5	846	186		186
		Temengor	4960	1533	31.2	1549	479		479
Perlis		Abi	2072	374	9.4	194	35		
		Arau	22074	2799	7.4	1638	208		
		Beseri	13310	2712	35.2	4690	956		956
		Chuping	12424	2468	7.1	882	175		
		Jejawi	1881	458	1.1	21	5		
		Kayang	10508	2183	1.6	165	34		
		Kechor	6442	1137	10.3	661	117		
		Kuala Perlis	19697	3471	0.1	29	5		
		Kurong Anai	15682	2436	1.3	209	32		
		Kurong Batang	3237	664	10.8	349	71		
		Ngolang	3069	602	16.9	518	102		
		Oran	3638	677	12.8	466	87		
		Padang Pauh	4139	738	24.4	1011	180		180
		Padang Siding	6118	1158	3.9	238	45		
		Paya	2113	515	12.5	265	64		
		Sanglang	11786	2414	1.3	148	30		
		Sena	16170	2992	8	1295	240		
		Seriap	7555	1642	17.2	1301	283		
		Sungai Adam	1841	360	0	1	0		
		Titi Tinggi	15173	2957	4.2	643	125		
		Utan Aji	17596	3367	7.6	1344	257		
		Wang Bintong	11490	2047	9.4	1075	192		
Pulau Pinang	**Barat Daya**	Mk. C (Permatang Pasir)	2473	520	10.4	258	54		
		Mk. D (Bagan Ayer Itam)	1932	329	35.9	694	118		118
		Mk3 (S.Rusa&S.Pinang)	1383	240	21.2	293	51		51
		Mukim 1 (Pantai Acheh)	4801	974	84.5	4055	823	823	823
		Mukim 10 (Bkt. Relau)	2648	476	42.9	1137	204		204
		Mukim 11 (Telok Kumbar)	14975	2738	94.8	14203	2597	2597	2597
		Mukim 12 (Bayan Lepas)	114193	19238	2.6	2967	500		

	Mukim 2 (Telok Bahang)	2569	466	21.4	549	100		100
	Mukim 4 (Batu Itam)	2228	364	98.7	2200	359	359	359
	Mukim 6 (Pondok Upeh)	7781	1366	19.6	1527	268		
	Mukim 7 (Bkt. Ginting)	1444	280	17.1	247	48		
	Mukim 9 (Bkt. Gemuroh)	14638	3059	0.8	114	24		
	Mukim A (Sg. Pinang)	1656	326	46.4	768	151		151
	Mukim E (Titi Keras)	1978	379	52.7	1042	200	200	200
	Mukim F (Kongsi)	2810	494	8	225	40		
	Mukim G (Kampong Paya)	2773	574	0.6	15	3		
	Mukim H (Sg. Burong)	1118	203	14.8	166	30		
	Mukim I (Pulau Betong)	1330	236	8.7	115	20		
	Mukim J (Dataran Ginting)	1099	188	9.8	108	18		
	Mukim B (Sg. Rusa)	1865	407	7.8	145	32		
	Mukim 5 (Bkt. Blk Pulau)	180	28	24.3	44	7		7
	Mukim8 (Bkt.Pasir Panjang)	1170	198	8.7	101	17		
Seberang Perai Selatan	Mukim 1 SPS	37962	5833	4.9	1858	286		
	Mukim 10 SPS	10825	1584	13.1	1417	207		
	Mukim 11 SPS	24709	3676	3.6	882	131		
	Mukim 12 SPS	6689	1251	8.1	545	102		
	Mukim 13 SPS	17192	3252	77.6	13341	2524	2524	2524
	Mukim 14 SPS	31408	5716	3.2	1021	186		
	Mukim 15 SPS	55651	9706	74.4	41423	7224	7224	7224
	Mukim 16 SPS	14813	2866	0.3	48	9		
	Mukim 2 SPS	5014	946	3.9	195	37		
	Mukim 3 SPS	7041	1514	76.8	5409	1163	1163	1163
	Mukim 4 SPS	9657	1701	10.1	977	172		
	Mukim 5 SPS	4220	894	12.3	517	110		
	Mukim 6 SPS	45299	7458	98.2	44466	7321	7321	7321
	Mukim 7 SPS	5037	970	72.6	3657	704	704	704
	Mukim 8 SPS	7353	1219	84	6180	1025	1025	1025
	Mukim 9 SPS	10940	1713	15.8	1732	271		
Seberang Perai Tengah	BandarPrai (Mukim1A)	13347	2213	9	1207	200		
	Mukim 1 SPT	8641	1787	100	8641	1787	1787	1787
	Mukim 10 SPT	4470	896	3.7	167	33		
	Mukim 11 SPT	19096	3816	33.9	6466	1292		1292
	Mukim 12 SPT	25124	5522	0.1	15	3		
	Mukim 13 SPT	7063	1533	20.8	1467	318		318
	Mukim 14 SPT	63859	9844	1.9	1226	189		
	Mukim 15 SPT	22687	3600	95.8	21734	3449	3449	3449
	Mukim 16 SPT	11223	2065	34.8	3910	719		719

		Mukim 17 SPT	2507	346	1.2	30	4		
		Mukim 18 SPT	3538	393	0	0	0		
		Mukim 19	3579	696	1.7	59	11		
		Mukim 2 SPT	6562	1369	1.5	98	20		
		Mukim 20	13157	2469	9.8	1290	242		
		Mukim 21	4215	916	7.2	302	66		
		Mukim 3 SPT	9671	1983	1.7	164	34		
		Mukim 4 SPT	11592	2835	0	5	1		
		Mukim 5 SPT	8148	1682	40.9	3335	688		688
		Mukim 6 SPT	36513	7898	0.1	31	7		
		Mukim 7 SPT	17181	3475	37	6353	1285		1285
		Mukim 8 SPT	16013	2944	1.6	254	47		
		Mukim 9 SPT	11453	1913	11.4	1309	219		
	Seberang Perai Utara	Mukim 1 SPU	3074	630	0.1	2	0		
		Mukim 10 SPU	9544	2081	0.1	6	1		
		Mukim 11 SPU	23902	4580	0.5	126	24		
		Mukim 12 SPU	2610	455	99.9	2607	454	454	454
		Mukim 13 SPU	5452	1369	36.4	1987	499		499
		Mukim 14 SPU	22043	4624	7.6	1680	352		
		Mukim 15 SPU	27465	5739	0	0	0		
		Mukim 16 SPU	308	73	0	0	0		
		Mukim 2 SPU	2016	476	17.2	347	82		
		Mukim 3 SPU	1944	407	25.6	498	104		104
		Mukim 4 SPU	8524	1866	15.1	1283	281		
		Mukim 5 SPU	8298	2057	9.7	808	200		
		Mukim 6 SPU	3324	744	8.7	290	65		
		Mukim 7 SPU	17645	3336	1.1	190	36		
		Mukim 9 SPU	19900	4504	53.3	10608	2401	2401	2401
		Mukim 8 SPU	2692	431	34.8	937	150		150
	Timur Laut	Bandaraya Georgetown	187665	24142	0.5	901	116		
		Mk14 (Bkt.Paya Terubong)	1681	241	100	1681	241	241	241
		Mukim 13 (Paya Terubong)	215441	30280	0	41	6		
		Mukim 16 (Ayer Itam)	15936	1720	90.8	14464	1561	1561	1561
		Mukim 17 (Batu Feringgi)	14820	2474	52.9	7834	1308	1308	1308
		Mukim 18 (Tg. Tokong)	43772	5859	60.8	26612	3562	3562	3562
		Mukim 15 (Bkt. Ayer Itam)	4	0	49.8	2	0		0
Selangor	**Gombak**	Batu Gombak	267831	45167	24.9	66744	11256		11256
		Rawang	185528	40938	1.3	2362	521		
		Setapak Gombak	65681	11294	3.6	2389	411		
		Ulu Kelang Gombak	98597	18634	0.1	103	20		
	Klang	Bandar Klang	9247	1281	17.7	1640	227		
		Kapar	237384	48216	0.1	147	30		

	Klang	520509	100476	3.7	19345	3734		
Kuala Langat	Bandar K.Langat	4820	1221	17.6	847	215		
	Jugra	6610	1042	7.7	506	80		
	Kelanang	18835	4439	13.8	2591	611		
	Morib	3559	755	55.4	1972	418	418	418
	Tanjong Dua Belas	94426	19203	15.5	14637	2977		
	Telok Panglima Garang	59526	13590	3.4	2041	466		
	Batu K. Langat	15910	3464	16.6	2642	575		
Kuala Selangor	Api-Api K. Selangor	20921	4417	14.1	2942	621		
	Batang Berjuntai	21845	3017	25.7	5624	777		777
	Ijok	51712	13161	29.3	15144	3854		3854
	Jeram K. Selangor	42860	9472	1.2	532	118		
	Kuala Selangor	11384	2471	0.9	105	23		
	Pasangan	6844	1509	18.9	1293	285		
	Tanjong Karang	30269	3741	29.9	9056	1119		1119
	Ujong Permatang	9662	2244	25.6	2475	575		575
	Ulu Tinggi	117	30	27.4	32	8		8
Petaling	Bandar Petaling Jaya	55706	7373	40.3	22424	2968		2968
	Bukit Raja	114073	18516	42.2	48136	7813		7813
	Damansara	465399	69123	0.4	1659	246		
	Petaling Petaling	269161	43669	0.7	1898	308		
	Sungai Buloh	428626	68908	0.1	585	94		
Sabak Bernam	Bagan Nakhoda Omar	11342	2072	7.5	855	156		
	Pancang Bedena	38362	9126	14.5	5560	1323		
	Pasir Panjang S. Bernam	23612	5008	4.7	1108	235		
	Sabak	19367	4199	9	1748	379		
	Sungai Panjang	8446	1914	17.9	1511	342		
Sepang	Dengkil	152220	29673	2.1	3195	623		
	Labu Sepang	8039	2181	25.5	2047	555		555
	Sepang	27154	5523	88.6	24066	4895	4895	4895
Ulu Langat	Ampang	312686	46593	0.3	1039	155		
	Beranang	46329	10592	11.9	5523	1263		
	Cheras U. Langat	9105	1317	0	1	0		
	Kajang	311785	55521	0.2	724	129		
	Semenyih	92491	19340	0.2	163	34		
	Ulu Langat	51789	11406	0	0	0		
	Ulu Semenyih	3367	740	11.5	386	85		
Ulu Selangor	Ampang Pechah	13409	2648	11.7	1566	309		
	Batang Kali	31723	7632	33.4	10607	2552		2552
	Buloh Telor	108	25	9.4	10	2		
	Kalumpang	2380	380	4.2	101	16		
	Kerling	3610	690	17.4	626	120		
	Kuala Kalumpang	3446	769	78.4	2701	603	603	603
	Peretak	1406	322	6.4	90	21		

		Rasa	2887	551	29.5	852	163		163
		Serendah	79164	19727	83.7	66284	16517	16517	16517
		Sungai Gumut	1624	313	5.8	94	18		
		Sungai Tinggi Ulu	1613	291	5.6	90	16		
		Ulu Bernam	25263	4374	47.4	11972	2073		2073
		Ulu Yam	19617	4412	12.9	2535	570		
Terengganu	**Besut**	Bukit Kenak	9504	2334	4.4	419	103		
		Bukit Peteri	8514	2450	19.9	1696	488		
		Hulu Besut	4536	1131	19	860	214		
		Jabi Besut	6801	1208	36.3	2471	439		439
		Kampong Raja	14913	3591	8.1	1211	292		
		Keluang	9160	2309	39	3576	901		
		Kerandang	8343	2186	62.4	5202	1363	1363	1363
		Kuala Besut	15993	4130	2.1	342	88		
		Kubang Bemban	3430	876	5.6	191	49		
		Lubok Kawah	2212	620	10.2	226	63		
		Pasir Akar	5588	1425	26.4	1477	377		377
		Pelagat	11852	3244	87.3	10343	2831	2831	2831
		Pengkalan Nangka	4336	1105	9.2	399	102		
		Pulau Perhentian	1838	318	43	790	137		137
		Tembila	7205	1782	1	70	17		
		Tenang	4816	1210	75.2	3620	910	910	910
	Dungun	Besul	2275	681	49.7	1131	339		339
		Hulu Paka	6892	1990	48.6	3348	967		967
		Jerangau	12718	2872	62.8	7983	1803	1803	1803
		Kuala Abang	4224	932	38.3	1618	357		357
		Kuala Dungun	33752	8230	53.6	18106	4415	4415	4415
		Kuala Paka	30289	7895	86.6	26225	6836	6836	6836
		Kumpal	2813	769	39.3	1106	302		302
		Pasir Raja	1505	386	26.7	402	103		103
		Rasau Seremban	12931	2803	93.6	12105	2624	2624	2624
		Sura	38737	7782	80.5	31185	6265	6265	6265
		Jengai	1183	236	76	899	179	179	179
	Hulu Terengganu	Tanggul	10480	2528	10.7	1120	270		
		Hulu Berang	4158	893	18.7	776	167		
		Hulu Telemung	8180	2134	99.5	8140	2123	2123	2123
		Hulu Terengganu	20	3	7.1	1	0		
		Jenagur	6268	1335	41.2	2585	550		550
		Kuala Berang	18454	4020	38.9	7186	1565		1565
		Kuala Telemung	5972	1240	2.7	162	34		
		Penghulu Diman	11197	2628	46.9	5247	1231		1231
		Tersat	3988	836	6.2	248	52		
	Kemaman	Bandi	9710	2227	70.3	6824	1565	1565	1565
		Banggul	6942	1620	6.8	471	110		
		Binjai	13866	3791	8.2	1131	309		
		Cukai	53458	13159	8	4271	1051		

		Hulu Cukai	8603	2204	10.7	922	236		
		Kemasik	6841	1488	11	750	163		
		Kerteh	23691	5791	14.5	3445	842		
		Kijal	10086	2138	97.5	9833	2084	2084	2084
		Pasir Semut	2226	512	3.8	84	19		
		Tebak	7029	1558	11.8	832	184		
		Teluk Kalung	13359	3283	16.1	2151	529		
		Hulu Jabor	6148	1244	13.7	844	171		
	Kuala Terengganu	BandarK.Terengganu	11870	1754	6.9	814	120		
		Atas Tol	2877	687	75	2159	515	515	515
		Batu Buruk	13527	2712	0	0	0		
		Batu Rakit	36752	8296	7.7	2840	641		
		Belara	17407	4291	30.7	5338	1316		1316
		Bukit Besar	22593	4864	1.4	327	70		
		Cabang Tiga	14285	2987	71.7	10245	2142	2142	2142
		Cenering	13633	2793	91.5	12478	2556	2556	2556
		Gelugur Kedai	6548	1320	7	459	92		
		Gelugur Raja	2060	447	7.2	148	32		
		Kepung	7093	1649	1.3	91	21		
		Kuala Ibai	13059	2971	9.8	1277	291		
		Kuala Nerus	82986	17638	26.5	21981	4672		4672
		Kubang Parit	7260	1532	8.3	603	127		
		Losong	9314	1999	0.3	31	7		
		Manir	28332	6227	26.7	7552	1660		1660
		Paluh	8699	1755	100	8699	1755	1755	1755
		Pengadang Buluh	13914	3146	5	692	157		
		Pulau Redang	1881	342	26.6	500	91		91
		Pulau-Pulau	3918	758	48	1879	363		363
		Rengas	2991	641	16.4	491	105		
		Serada	7059	1609	13.2	931	212		
		Tok Jamal	5169	1193	12.9	667	154		
	Marang	Alur Limbat	20000	4882	14.1	2827	690		
		Bukit Payung	26525	6417	16.3	4330	1048		
		Jerung	4551	1001	31.8	1447	318		318
		Mercang	7731	1716	46.2	3570	793		793
		Pulau Kerengga	17045	3949	93.3	15905	3685	3685	3685
		Rusila	17999	4305	60.8	10944	2618	2618	2618
	Setiu	Caluk	14625	3689	37.1	5433	1370		1370
		Guntung	7384	2042	4.9	364	101		
		Hulu Nerus	11932	2936	11	1315	324		324
		Hulu Setiu	3161	853	34.9	1103	298		298
		Merang	3257	801	41.7	1357	334		334
		Pantai Setiu	5966	1611	40.3	2402	649		649
		Tasik	7145	1700	64.5	4607	1096	1096	1096
Kuala Lumpur		Ampang KL	38173	6290	4.7	1784	294		
		Bandar K.Lumpur	209354	34357	3.3	6897	1132		

		Batu KL	291831	49048	2	5698	958		
		Cheras KL	232306	40509	15.6	36279	6326		
		Kuala Lumpur	322132	43530	0.2	761	103		
		Petaling KL	553200	92342	15.7	86699	14472		
		Setapak KL	274639	45896	0	82	14		
		Ulu Kelang KL	25763	4482	4.8	1243	216		
Country	**Total**		20,362,522	3,776,360	38.7	3,506,186	728,360	391,232	587,482

[a] Summary estimate of predicted prevalence, number being infected (total population and school-age children) and number warranting mass treatment using 50% and 20% threshold at sub-district level (*mukim*) was provided in Appendix O.

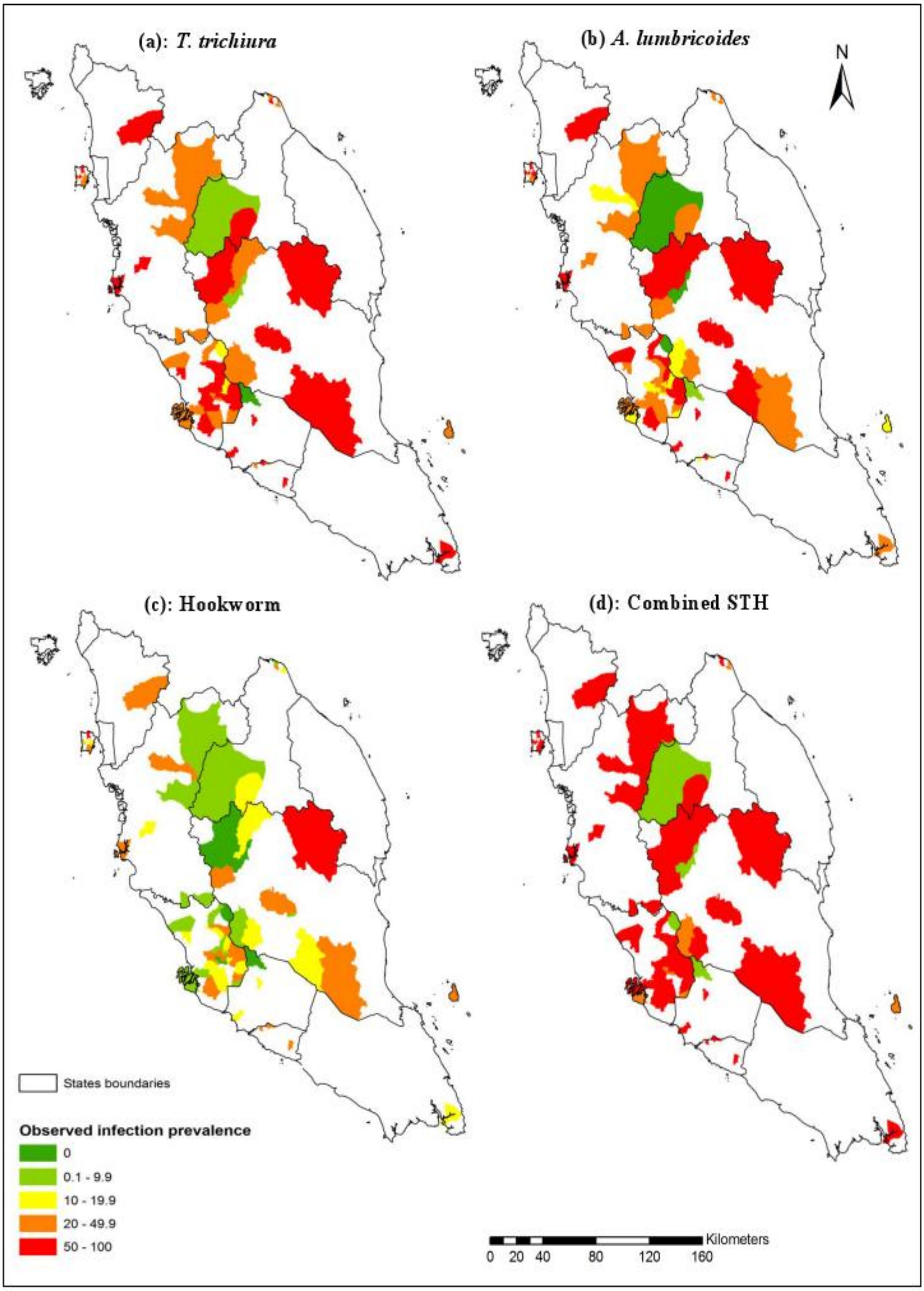

Figure 7.2 (a) – (d): Maps distribution of STH species, i.e., (a) *T. trichiura*, (b) *A. lumbricoides*, (c) hookworm, (d) combined STH at sub-district levels in Peninsular Malaysia (1970-2012) from available survey data. White indicates areas where no relevant data were located at present

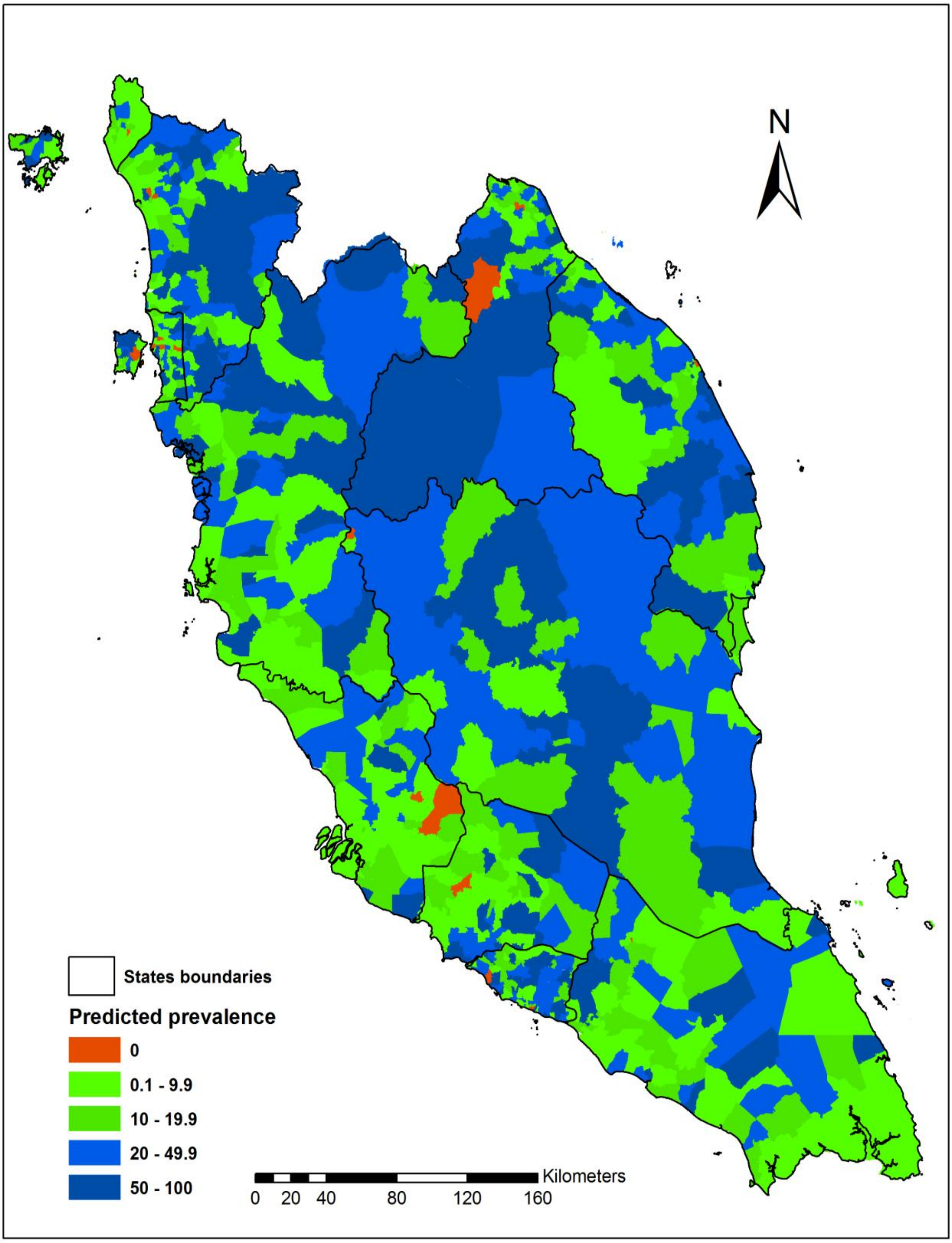

Figure 7.3: Predicted prevalence map of *A. lumbricoides* as derived from logistic regression model of the relation between observed empirical prevalence survey data and remote sensing (RS) - satellite sensor environmental variables

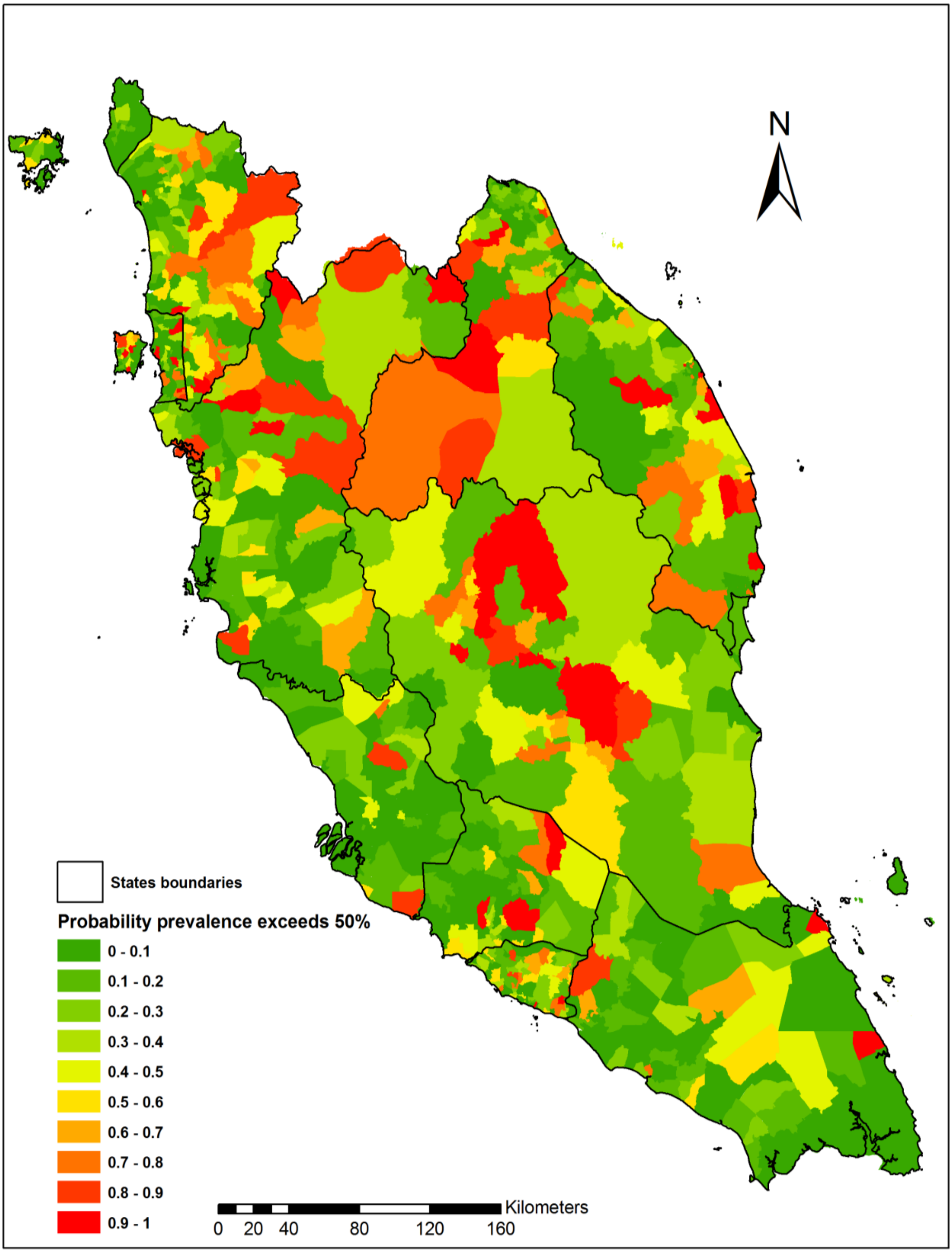

Figure 7.4: The continuous probability map shows the spatial distribution probability prevalence of *A. lumbricoides* exceeds 50%

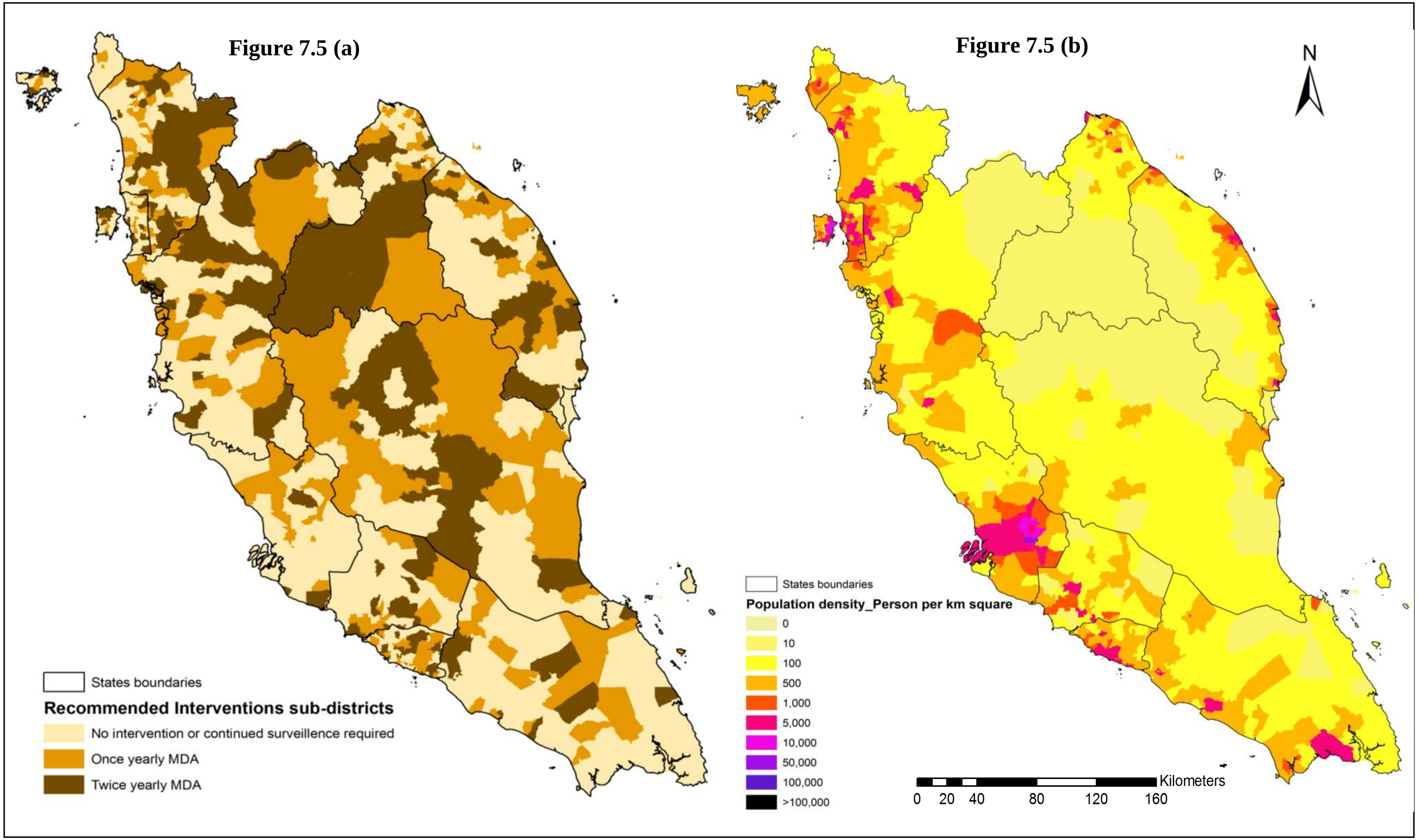

Figure 7.5: Public health control planning maps. (a) Recommended intervention sub-district and (b) population density (person per kilometer square) for the respective sub-districts in Peninsular Malaysia

7.4 DISCUSSION

The present study provides a description of the distribution and prevalence of soil-transmitted helminth (STH) infections in Peninsular Malaysia from available empirical data sources using geographic information system (GIS). This approach offers basic information for us to investigate the geographical distribution of STH infections. It also provides a tool which could be used to guide decision making in rapid planning and development of STH control in Malaysia. Findings of the present study indicate that there is considerable geographical variation in the STH distribution and that geographically targeted control program are required to maximize the resources of the program to those populations in greatest need particularly when the resources are limited. In the absence of easily accessible database, the identification of priority areas for control usually has been made using unsystematic data collection. For example, absence of such information has sometimes led in the deworming program being included as a component of control program by public health authorities in areas with absent or low prevalence of STH infections (Brooker et al, 2009).

The assembled database here represents one of the largest and detailed survey coalitions of STH infections in the country, incorporating 99 survey locations between 1970 and 2012 through our combined search strategies. Majority of these surveys (82.8%) were identified through published sources (i.e., academic journal from searchable biomedical databanks) highlighting the importance of these means in providing key stake holders such as policy makers and public health planners with greater access to the data. This study also highlighted that personal contact with researchers who are involved in STH research and unpublished report from thesis are also important sources for data access. Unfortunately, no data on STH infections were available from the Ministry of Health and it related agencies (e.g., public health or non-communicable disease division) records. In contrast, mapping of STH infections in East African countries (i.e., Kenya and Rwanda) indicated that more than half of the surveys were extracted from unpublished reports from the Ministry of Health including Division of Vector Borne Diseases record, conforming the importance of these exercise as data sources (Brooker et al, 2009). Similarly, mapping of filariasis in Vietnam also demonstrates the significance of unpublished reports of Ministry of Health and its related agencies as importance data sources (Meyrowitsch et al, 1998). Likewise, mapping of malaria infection in Kenya also identifies extra information from unpublished locally archived sources (Omumbo et al, 1998). In our present study, such data on the STH infections are not available for Ministry of Health or its related agencies records although STH infection remains highly prevalent with alarming morbidity rates in certain areas in Malaysia (Lim et al, 2009, Aaron et al, 2011; Ahmed et al, 2011; Nasr et al, 2013). Although many areas of the country for which little or no data available, the prevalence maps for STH infections as illustrated in the current study presents the most detailed data currently available on geographical distribution of STH infections in Malaysia.

In addition to this geographical variation, our analysis also indicated that the observed prevalence of STH infections was varied over times with gradually decreased pattern with year. For example, mean prevalence of each STH infection is high for the period of 1970-1979, but gradually declined over time across the country especially for the period of 1980-1999. One possible explanation for this trend may be due to the positive impact of school-based deworming program. In 1974, the Ministry of Health launched the National Worm Control Program involving 1468 schools with more than 3 million children receiving single dose of 20 mg pyrantel pamoate at least twice a year until it discontinued in 1983 (Anon, 1985). Additionally, other factors such as urbanization process which usually leads to improvement in the socioeconomic status will have indirect impacts on the improvement in living standard, environmental sanitation and personal behavior which may also result in the decline of prevalence rates over time.

While considering the value of the mapping approach, it is also important to identify the limitation of the current data. Different parasitological methods and techniques employed in the surveys might reduce comparability of the data and ability of the map to represent infection prevalence accurately in every survey areas (Brooker et al, 2003; 2009). For example, most of the parasitological survey reports the detection of STH infections based on single fecal examination which could lead to potential biasness in the presented data due to several factors such as poor sensitivity in detecting light infection or day-to-day fluctuation (i.e., intermittent excretion) in egg excretion by the adult worm (Engels et al, 1996; Booth et al, 2003). Additionally, previous studies indicated that Kato-Katz techniques were more sensitive compared to other microscopic method for the examination of fecal sample (Goodman et al, 2007; Knopp et al, 2008). However, only one-third of the reported prevalence survey in our current work used Kato-Katz techniques as the main diagnostic tool. Another potential biasness in the observed prevalence surveys was delays in sample processing after collection particularly for hookworm infections (Dacombe et al, 2007). While this inherent potential biasness should be borne in mind when interpreting prevalence data, they are unlikely to lead to any different conclusion at policy decision level. This is because current treatment guidelines are still relying on the prevalence data as determined by any gold standard of parasitological diagnostic tools that are currently available as recommended by WHO (Montresor et al, 1998). Despite these limitations, the information included in the current database can help to identify and highlight where such information is lacking, thus can serve as a stimulus to collect new or additional data for further investigate on the geographical distribution of STH infections in the country.

Although it is possible to estimate the national average prevalence of STH infections based on observed prevalence figures, it is clear that such exercise are potentially misleading (Brooker et al, 2000). This is particularly relevant, for instance in country where very few prevalence studies have been conducted and data were obtained from endemic areas known with high prevalence were extrapolated as national prevalence. This suggests that such extrapolation more often reflects the number of studies carried out and their locations, rather than reliable indications of true prevalence rate of infection. This illustrates the potential inaccuracy and biasness of prevalence estimated based on few studies conducted within the country and then extrapolated as national prevalence rate across the country, as this also contradicts the geographical heterogeneity within country (Brooker et al, 2000). Moreover, much of this published data were more than few years, making the interpretation to the present day uncertain. Despite these limitations, however the current data provide a crude estimation of overall picture of STH infections and their distribution in Malaysia.

Building on these limitations and sparseness of the available prevalence survey in Malaysia, it proved essential to generate predictive distribution of STH infections using environmental variables derived from remote sensing (RS) satellite data, thus allowing us to examine the ecological limits of their transmission and infection. The used of RS data can provide proxy to ecological and climatic factors that may be known to influence the development and survival of free-living transmission stages and observed patterns of infection (Brooker & Michael, 2000). The correlations between infection patterns and ecological factors can serve as tools to extrapolate risk estimates in areas for which no data are available. Such predictive risk maps can be used as a baseline data to identify priority areas or populations at greatest needs. Results of the present study indicated significant association between observed prevalence of *A. lumbricoides*, Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) with. In addition, the result also indicated negative association between observed prevalence of *A. lumbricoides* with maximum LST and minimum NDVI, in other words as the temperature increases, transmission and prevalence of infection decrease. Such observations are most probably due to the effects of heat and low humidity on the embryonation and survival of ova. For *A. lumbricoides* including *T. trichiura* and hookworm, temperature and humidity are the density-independent factors influencing their transmission and infection patterns as measured by the basic reproductive number (R_o) (Anderson & May 1991; Brooker et al, 2006). The R_o is defined as the average numbers of female worm offspring produced by one adult female parasite reaching reproductive maturity, in the absence of density dependent constraints (Anderson & May 1991). Increases in R_o leads to increases in the prevalence and intensity of infection (Brooker & Michael, 2000).

The thermal limits of infection as reported in our current work were also in agreement with studies on the mapping of STH distribution in other countries. For instance, finding in Cameroon, Chad and Uganda suggests that *A. lumbricoides* and *T. trichiura* most unlikely to occur in areas where maximum LST exceeds 37^oC (Brooker et al, 2002a, 2002b). Similarly, observation in Vietnam also reports low prevalence of *A. lumbricoides* and *T. trichiura* infections (i.e., less than 10%) in areas where maximum LST above 37^oC (Brooker et al, 2003). More recently, mapping of STH infections in Kenya by Pullan and co-workers (2011) also reported that the odd of *A.*

lumbricoides infections was significantly lower with maximum LST. Such thermal limits are also supported by several experimental data. For example, previous studies have been reported that the optimal temperature for the embryonation of *A. lumbricoides* ova is 31°C (Seamster, 1950) and do not develop at temperature more than 38°C (Anon, 1967). As for *T. trichiura*, experimental data also shows that the ova requires different days to develop and hatch at different temperature (i.e., takes 28 days to develop at 25°C, 15 days at 30°C and 13 days at 34°C), while do not survive at temperature above 37^{o}C (Beer, 1976). In addition, few studies also suggest that an upper limit of 40^{o}C is considered to be environmental or biological transmission limits for both *A. lumbricoides* and *T. trichiura* infections (Hotez et al, 2003; Pullan et al, 2011). Studies in South Africa showed that the average prevalence of *A. lumbricoides* and *T. trichiura* were below 20% in areas with mean annual temperature below 15°C, postulating that the lower thermal limit might be around 15°C or below for both STH species (Appleton & Gouws, 1996; Appleton et al, 1999). The presence of vegetation also tends to prevent evaporation and conserve soil moisture, offering favorable condition for the development and transmission of infection (Hotez et al, 2003).

This observation was further supported by several field investigations. For example, the national parasitic survey in China demonstrates that the prevalence of STH infections were significantly associated with temperature and humidity factors (Xu et al, 1995; Lai & His, 1996). In addition, the low prevalence of STH infections particularly *A. lumbricoides* and *T. trichiura* were also observed in northern China where estimated LST is less than 20°C and in northern India and Pakistan where estimated LST is more than 40°C, indicating the thermal limits of the STH infections (Brooker et al, 2006). To date, only one survey has been conducted looking into this factor in Malaysia. Dunn (1972) conducts a field survey to investigate the intestinal parasitism among different rural communities living in different habitat in the Malaysian rain forest, ranging from lowland to the hill forest. The study indicated communities that lived at higher and cooler elevation suffered less from STH infections, presumably due to the lower soil temperature which may reduce the embryonation rate of ova compared to those who lived in warmer lowland areas which typically harbored more STH infections (Dunn, 1972).

As for hookworm, most of the previous studies fail to identify ecological correlates between hookworm infection and environmental variables (Appleton & Gouws, 1996; Appleton et al, 1999; Brooker et al, 2001, 2002a; 2003), findings that corroborated with the current study. It has been suggested that this may reflect the absence of species specific diagnosis tool to differentiate hookworm species (i.e., *Necator americanus* and *Ancylostoma duodenale*) which might have different thermal limits (Schad et al, 1973) and perhaps the predominance of behavioral factors (Brooker et al, 2002b). For example, mapping of STH infections in Chad suggests that hookworm also occurred in areas where mean LST was more than 47°C particularly in southern Chad (Brooker et al, 2002b). This finding was in accordance with the mapping of STH in Mali which indicated hookworm infection were still occurring in areas where the mean LST exceeds 40°C while infection of *A. lumbricoides* and *T. trichiura* were at negligible level (i.e., less than 0.5%) (de Clercq et al, 1995). In contrast, experimental data indicated that larvae of *N. americanus* died at 35^{o}C while the optimal temperature for hatching occurred at 30^{o}C (Udonsi & Atata, 1987). This is a particularly interesting observation as to why hookworm apparently have thermal limit exceeding 47°C based on survey data and not for *A. lumbricoides* and *T. trichiura*. One possible explanation was that microhabitats provide suitable foci for hookworm transmission in areas where temperature is high although similar argument would be expected for both *A.*

lumbricoides and *T. trichiuris* species (Brooker et al, 2002b). Another explanation involved the ability of hookworm particularly *A. duodenale* to undergo arrested development in order to achieve synchronization with external conditions (Schad et al, 1973).

Although the current predictive model can serve as an important tool in identifying important ecological factors and biological determinants that influence the distribution and transmission of STH (Brooker et al, 2009), of course there will be some other small-scale residual spatial variation due to spatial random effects remains that may under predict true prevalence (Brooker & Michael, 2000; Brooker et al, 2009; Pullan et al, 2011). Factors such as differences between rural and urban may influence the distribution of infection. Other factors including poverty, lack of education, poor hygiene, environmental and sanitary behavior were also known to influence the distribution pattern of infection especially at small-spatial scale. Unfortunately, such information was not incorporated in the current mapping survey, which may be a topic for future study. However, we must also bear in mind that this information on socio-economic and behavior variables is difficult to collect over large spatial scale (Brooker et al, 2003; 2009). Apart from this small-scale spatial variation, other factors such as uneven data distribution or the needs for a better understanding impact of the different life-cycle stages biological with environmental factors is also essential (Brooker & Michael, 2000), which may also be a topic for future study. Despite the fact that predictive model may under-predict true prevalence which may arise as consequences of these small-scale spatial variations, it still provide a reliable indication of whether or not MDA intervention is warranted in prioritize areas and populations at greatest needs in accordance with WHO recommendation (Anon, 2002; 2005).

The ability to predict the distribution of infection on the basis of their ecological limits has important consequences for control planning, targeting program at national level. The predictive risk map as illustrated in this study indicated that low prevalence of infection can be found along the west coast and southern part of the country, whilst high prevalence along the central plain and northern part, suggesting that MDA is most warranted in the central and northern plains of the country, as illustrated by a high probability that infection prevalence exceeds 50%. Based on national census 2010, the total populations of Peninsular Malaysia in 2010 were estimated to be more than 20 million, of whom almost 4 million are school-aged children (Anon, 2010b). On this basis, it is estimated that 3.5 million individual of the total populations were infected with *A. lumbricoides*. Using the national estimates of the proportion of school-aged children, we estimated that there were 587,482 school-aged children in 75 out of 81 districts (i.e., corresponds to 359 out of 842 sub-districts) in the country would warrant MDA treatment at least twice a year. WHO recommends MDA intervention to all school-aged children twice a year, or even three times if resources are available in communities where infection prevalence ≥ 50% while once yearly MDA treatment for infection prevalence ≥ 20% but < 50% (Anon, 2002; 2005).

Furthermore, the estimation of uncertainty in un-surveyed area is also another additional advantage of such approach, which takes existing empirical prevalence data to generate continuous map by interpolating prevalence at un-sampled location on a grid system. Such approach recognizes error or ambiguity associated with potential biasness in data by generating the possible prevalence value (i.e., probability prevalence for each prediction location). Factors such as lack or low number of survey location, error in survey measurement, data quality and the unavoidable presence of apparently random or variation in prevalence which may result with these uncertainties (Pullan et al, 2011).

For example, WHO recommends one yearly intervention for MDA in areas where the mean prevalence is exceeds 20% (Anon, 2002; 2005). As results of these uncertainties, however such predicted prevalence of 25% may or may not reflect a high probability that the true prevalence exceeds 20% (Diggle et al, 2007; Pullan et al, 2011). Thus, such problem may necessary need to be considered and addressed before any control decisions are being made (Clements et al, 2006). However, the probability contour map as presented here help to distinguish not only those areas where we can be certain that infection prevalence exceeds 20%, but also those areas with high uncertainty so that additional survey may be required before making any decision for control planning.

7.5 CONCLUSIONS

The present study has successfully developed a geospatial database of soil-transmitted helminthiasis using geographic information system (GIS) and remote sensing (RS) satellite derived environmental data. It also demonstrates the potential of GIS and RS approach in acting as effective data storage, mapping and analysis tools for the development of STH atlas. Additionally, such approach offers us the ability for modeling the spatial distribution of STH infections in relation to the ecological factors which derived from remote sensed satellite data that known to influence their distribution pattern, thus deepening our knowledge and understanding in the biology and epidemiology of infection. Likewise, such approach can also serve as important tools in STH control program given their abilities in identifying endemic areas, providing more precise estimates of populations at risk and map their distribution by facilitating the stratification of areas using infection risk probabilities to provide basic information on treatment intervention or public health measure delivery systems.

The following conclusions are a synopsis of the analysis undertaken through this study in which they were discussed:

1. The current database incorporates 99 survey locations conducted between 1970 and 2012 through our combined search strategies, of which all locations were successfully geo-positioned to an actual coordinates representing 80 spatially unique locations, while the rest were undertaken in the same locations but at different period of times.

2. The current database represents the examination of 47,118 individuals without discriminatory towards age group and gender. Overall, 22,790 (48.4%) individuals were infected with *Trichuris trichiura*, followed by 15,642 (33.2%) of *Ascaris lumbricoides* and 5,578 (11.8%) hookworm infection. The estimated combined prevalence of individuals infected with any STH species as calculated using simple probabilistic model was 74.5%.

3. The published papers (i.e., academic journal was the main and importance resource for data collection) accounted for 82 (82.8%) of all data points followed by personal communication or direct contact with researchers (10.1%) and unpublished report from thesis (7.1%). No data on STH infections was available from the Ministry of Health and its related agencies such as public health or non-communicable disease division.

4. The geographical distribution maps of each species including estimated combined STH prevalence varies considerably with no clear pattern across the surveyed locations.

5. In addition to these geographical variations, there were also marked variations in the observed mean prevalence of STH infections over time for each of the species.

6. The logistic regression analysis to determine the ecological limits of infection indicated that maximum and mean Land Surface Temperature (LST) and minimum and mean Normalized Difference Vegetation Index (NDVI) were significant explanatory variables for *A. lumbricoides* infection.

7. The result indicated that the odds of *A. lumbricoides* was significantly negatively associated with maximum LST (OR = 0.88; 95% CI = 0.78-0.99) and minimum NDVI (OR = 0.78; 95% CI = 0.96-0.98).

8. Only predictive model for *A. lumbricoides* was developed. As for *T. trichiura*, hookworm and estimated combined STH prevalence, no model could be developed since no statistically significant explanatory variables were recorded.

9. The accuracy of the model was generally good and reliable with an overall 67.7% ability to correctly predict areas with and without infections.

10. The model estimates was also well-fitted to the data at an acceptable level as assessed by Hosmer and Lemeshow Goodness-of-Fit test (X^2 = 6.268; df = 8; p = 0.508).

11. The spatial distribution of *A. lumbricoides* infection was assessed using *Moran's I* index. Findings from *Moran' I* test showed that distribution of *A. lumbricoides* was spatially clustered (*Moran's I* index = 0.04; z-score = 6.98; p <0.01).

12. The predictive risk map of *A. lumbricoides* shown that prevalence is higher in central and northern plains of Peninsular Malaysia (i.e., areas within blue color range). In contrast, predicted prevalence of *A. lumbricoides* was low along the west coast and southern part of Peninsular Malaysia (i.e., areas within green color range).

13. The continuous probability contour map showed areas with probabilities of more than 70% (i.e., areas within red color range) that mass drug administration (MDA) threshold of 50% will be exceeded whilst areas within green color range (i.e., indicating probabilities of at least 30%) are those areas whereby low probability of 50% MDA threshold is exceeded. The maps also indicated areas of high uncertainty (i.e., areas within yellow color range) with probabilities between 30% and 70% in which further surveys would be helpful or continued surveillance program are recommended.

14. On the basis of our prediction model for *A. lumbricoides*, it is estimated that there may be up to 3.5 million individuals of the total populations are infected with *A. lumbricoides*. Of these, 728,360 are school-aged children.

15. Using the national estimates of the proportion of school-aged children and based on WHO intervention threshold, it is estimated that 587,482 school-aged children in 75 out of 81 districts (or corresponds to 359 out of 842 sub-districts) in the country would be targeted with mass treatment with MDA intervention at least once yearly.