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Health informatics model for helminthiasis in Thailand

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Abstract

At the beginning of the new millennium, helminth infections continue to be prevalent, particularly among impoverished populations. This study attempts to create the first health informatics model of helminthiasis in Thailand. The authors investigate how a health informatics model could be used to predict the control and eradication in a national control campaign. Fish-borne helminthiasis caused by *Opisthorchis viverrini* remains a major public health problem in many parts of South-East Asia, including Thailand, Lao PDR, Vietnam and Cambodia. The epicentre of this disease is located in north-east Thailand, where high prevalence coexists with a high incidence of cholangiocarcinoma (CHCA). The current report was conducted to determine a mathematical model of surveillance for helminthiasis while also using a geographic information system. The fish-borne helminthiasis model or the predicted equation was $Y1 = 3.028 + 0.020$ (elevation) − 2.098 (clay). For soil-transmitted helminthiasis, the mathematical model or the predicted equation was $Y2 = -1.559 + 0.005$ (rainfall) + 0.004 (elevation) − 2.198 (clay). The Ministry of Public Health has concluded that mass treatment for helminthiasis in the Thai population, targeting high-risk individuals, may be a cost-effective way to allocate limited funds. This type of approach, as well as further study on the correlation of clinical symptoms with environmental and geographic information, may offer a novel strategy to the helminth crisis.

Introduction

The World Health Organization (WHO) Initiative for Global Health has recommended evaluation and comparable assessment of mortality and loss of health due to diseases and injuries for all regions of the world. The latest WHO assessment of deaths by cause is for the years 2000–2012. Global, regional and country-level summary tabulations can be accessed interactively through the Global Health Observatory (WHO, 2016). Due to changes in data and methodology, the 2000–2012 estimates are not comparable to previously released WHO estimates (WHO, 2000). Today trends of global and environmental

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change, health and bioinformatics encircle issues from the local to global, among governments and international health organizations. The integrated and sustainable goal of a healthy population in the 21st century will require geographic information systems approaches to redesign care practices and integrate local, regional, national and global health informatics networks (Jongsuksuntigul *et al.*, 1992; Jongsuksuntigul & Imsomboon, 2003; Nithikathkul, 2000; Nithikathkul *et al.*, 2008; Wongsaroj *et al.*, 2012). The deaths and DALYs (death and disability-adjusted life years) in China have been reported and estimate the health impact of unsafe water and poor sanitation and hygiene. The report found unsafe water and poor sanitation and hygiene to be particularly detrimental to the health of young children under 5 years of age (Carlton *et al.*, 2012). Global control of helminthiasis is beginning, with the widespread use of drugs for treatment. Mass drug administration (MDA) has been a major approach to controlling human helminthiasis in developing countries (Hotez *et al.*, 2007, 2008). In the present environment of both the local and global change scenario, the physical phenomena and the health informatics issue are changing from the personal to the global range. Health information has been recorded about tropical disease outbreaks among all national and international health organizations. The improvement and sustainability of healthy populations in the 21st century will require systems engineering approaches to redesign care practices and integrate local, regional, national and global health informatics networks. Helminth infections are still present in a worldwide distribution and are particularly prevalent in low-income countries. The costs of interventions and animal health issues will drive the cost effectiveness of intervention strategies (Torgerson & Macpherson, 2011). Thailand is one of the tropical countries with environmental and economic changes that accompany rapid development. A health informatics model dealing with helminthiasis has been developed and implemented. However, even with these advances and the integration of informatics with alternative prevention and control programmes, helminthiasis still remains a serious concern for the public health system in Thailand.

Materials and methods

The phenomena of tropical diseases and bioinformatics have led to development of a health informatics and mathematics model for helminthiaisis in Thailand. This study was recommended and evaluated using the secondary data of national helminthiasis (the data obtained by the public health staff of the Bureau of General Communicable Diseases, Department of Disease Control, Ministry of Public Health) (Wattanayingcharoenchai *et al.*, 2011; Wongsaroj *et al.*, 2014). This was associated with geographic information data (land use and soil type data obtained from the Land Development Department, Ministry of Agriculture (LDD), Thailand). A geographic information system (GIS) database for the study of helminthiasis was implemented using an ArcGIS Desktop program (ESRI, Bangkok, Thailand). It mainly separates agricultural areas from urban areas and other man-made land uses. Geographic coordinates of each area were determined with a global positioning system. The generated geo-referenced database was overlaid on the digitized state coverage of remotely sensed satellite images with environmental data. The analysis of statistical data used the software EPI-INFO (Version 2, Centers for Disease Control and Prevention, Atlanta, Georgia, USA). The demonstrative statistics described the distribution of the geographic information and helminthiasis characteristics of the subjects. Odds ratio (OR), 95% confidence intervals of odds ratio (95% CI) and chi-square test were used to compare differences in the distribution of categorical variables. A statistically significant difference was determined when the P value was less than 0.05. The health informatics model for helminthiasis developed under stepwise multiple linear regression analysis was used to examine the multivariate association of fish-borne (or soil transmitted) helminths and geographic variables. We had checked the assumptions of the multiple linear regression (such as normality, homoscedasticity, multicollinearity and autocorrelation). The categorical independent variable with k groups was transformed to be $k-1$ dummy variables.

Results

According to policymakers in Thailand, a high prevalence of parasitic infection is one that affects 10% or more of the population. The distributions of fish-borne parasitic infection were 16.6% in the north-east region and 10.0 % in north region of Thailand (Wongsaroj *et al.*, 2014) (figs 1 and 2), while the distribution of soil-transmitted helminth infections relative to information on land use and soil type was 6.80% in the north of Thailand (Wongsaroj *et al.*, 2014) (figs 3 and 4). Multiple linear regression analyses were conducted to examine the relationship between the prevalence of helminthiasis and various geographic information data, including soil types, land use, amount of rainfall and elevation. Nine multiple regression models produced adjusted R^2 values between 0.029 and 0.220 (table 1). Elevation (X1) and rainfall (X2) were positively correlated with the prevalence of helminthiasis, indicating that either elevation or rainfall with higher values is expected to have higher prevalence. Soil type was negatively correlated with the prevalence of the helminthiasis (coded as D1 – sandy loam and D2 – clay) in many cases (apart fromY9 in which D2 had a positive value, 0.399), indicating that lower prevalences, ranging from 5.80 to 26.0%, occur in sandy loam and clay.

Examples of multiple linear regression equations of helminth infection are:

$$Y1 = 3.028 + 0.020\,(\text{elevation}) - 2.098\,(\text{clay})$$

where Y1 is fish borne (amount of *Opisthorchis viverrini* and minute intestinal fluke), and

$$Y2 = -1.559 + 0.005\,(\text{rainfall}) + 0.004\,(\text{elevation}) - 2.198\,(\text{clay})$$

where Y2 is soil transmitted (amount of hookworm, *Ascaris lumbricoides*, *Trichuris trichiura*, *Enterobius vermicularis and Strongyloides stercoralis*).

The risk factors of elevation ≥ 101 m (OR = 25.53, CI = 13.97–46.65), sandy loam (OR = 2.98, CI = 1.55–5.71)

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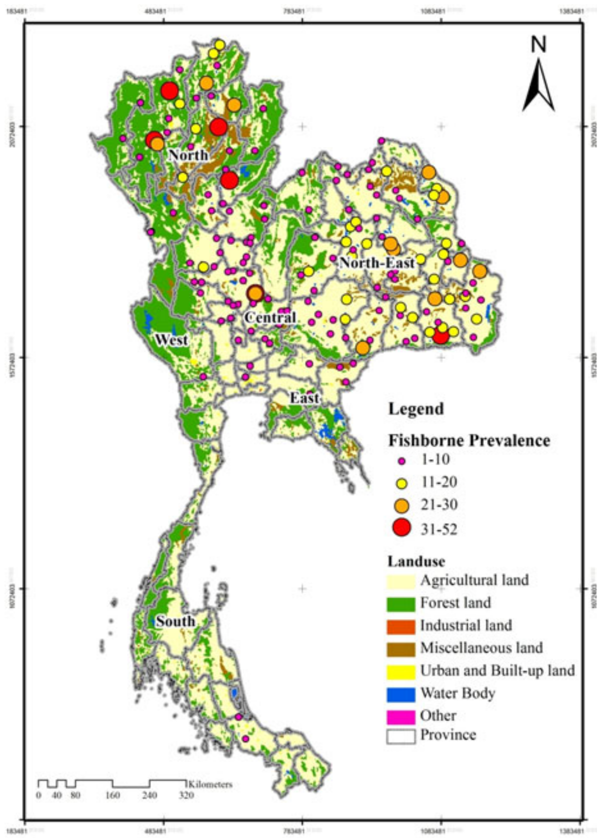

Fig. 1. The distribution of fish-borne infections relative to information on land use.

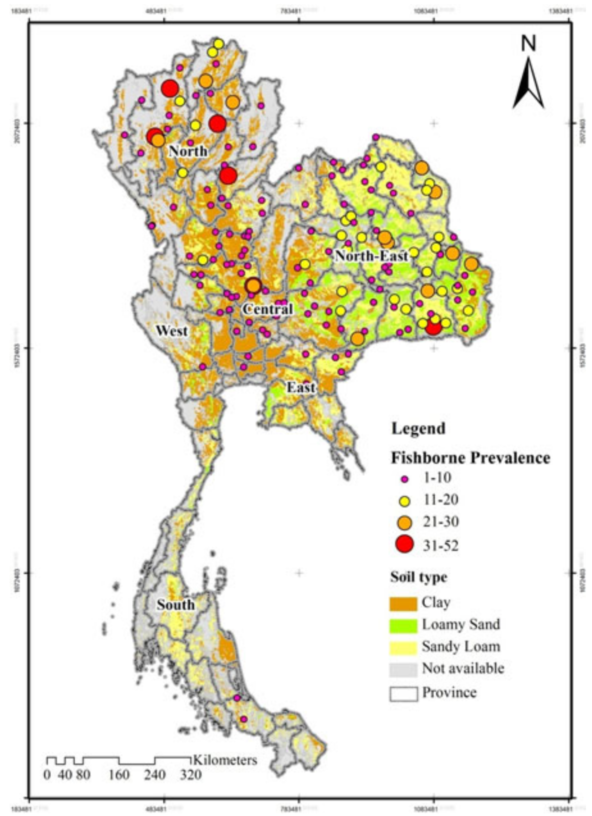

Fig. 2. The distribution of fish-borne infections relative to information on soil type.

and loamy sand (OR = 4.00, CI = 1.68–9.54) were higher with statistical difference in the relationship with the prevalence of fish-borne transmission (table 2). The risk factors of rainfall ≥ 1000 mm (OR = 2.71, CI = 1.57–4.66), elevation ≥ 101 m (OR = 4.46, CI = 2.46–8.05) and clay (OR = 0.41, CI = 0.20–0.81) were higher with statistical difference in the relationship with the prevalence of soil transmission (table 3).

Discussion

The results of the mathematical health model shown in table 1 predict the prevalence of helminthiasis by geographical type. These response factors include elevation, rainfall, land use and soil type. This modelling analysis has shown how the possibility of helminthiasis could be predicted. Previous studies on sexual reproduction have been applied to parasites with dynamic infections. According to Truscott *et al.* (2014), it is conceivable that there is material in the reservoirs for soil-transmitted helminthiasis, which correlates with the intensity of infection. The most recent studies in Africa, Asia and Latin America have integrated research in mathematics in their analyses of helminthiasis. The current emphasis on the evaluation of antihelminth drug efficacy against several helminths, such as *A. lumbricoides* and hookworm, is useful in the prevention and control of helminthiasis. The data investigation for mathematical modelling was performed under varying conditions of sample size, screening, diagnosis, level of excretion and aggregation of eggs within the host population (Levecke *et al.*, 2011, 2015). Tree-based models were then built that assess the impact of several factors of specificity and sensitivity to detect normal and/or reduced efficacy. The outcomes of these models were validated in different efficacy trials (Truscott *et al.*, 2014).

An earlier study was performed on visceral leishmaniasis (VL) (Rock *et al.*, 2015). WHO has recommended this infection for elimination as a public health problem on the Indian subcontinent by 2017. To date there is a surprising scarcity of mathematical models capable of capturing VL disease dynamics. Such models are widely considered to be central to planning and assessing the efficacy of interventions. In particular, the characterization and infectiousness of the different disease stages will be crucial to elimination. Modelling can assist in establishing whether, when and how the WHO VL elimination targets can be met (Rock *et al.*, 2015).

In the present study, several factors were not evaluated, including a detailed analysis of the physical environment of each area, population density, the clinical signs of the individual case, and the extent of the villagers' knowledge of public health and hygiene. Also, the current model

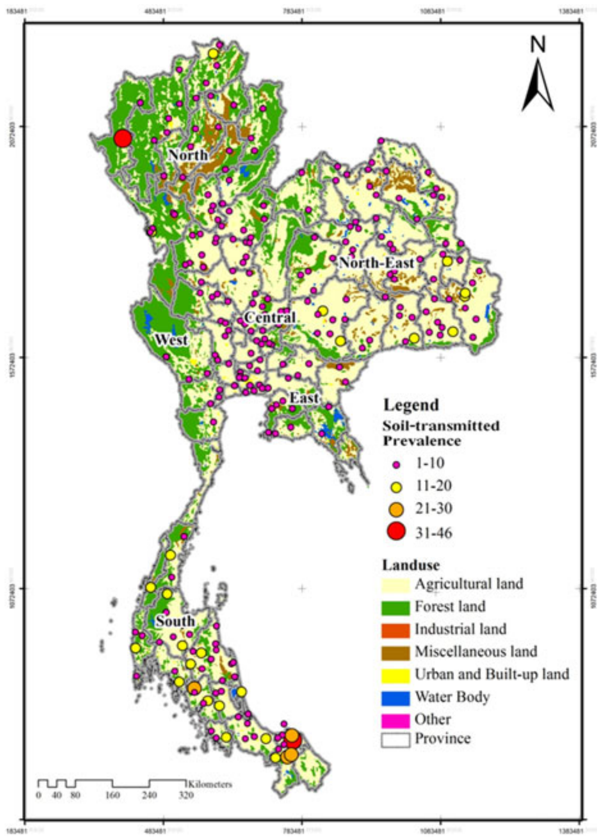

Fig. 3. The distribution of soil-transmitted helminth infections relative to information on land use.

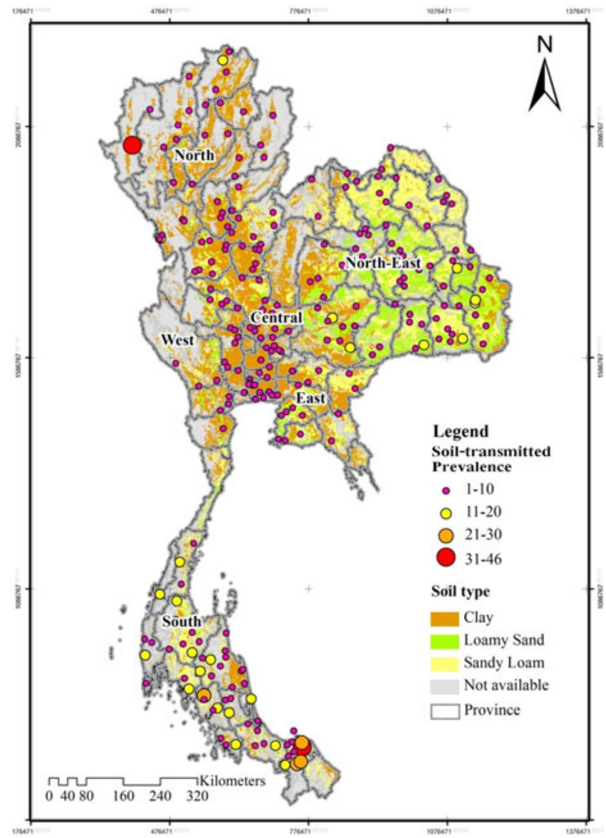

Fig. 4. The distribution of soil-transmitted helminth infections relative to information on soil type.

does not include clinical and behavioural characteristics which may relate to the clinical-behaviour model of transmission. The Ministry of Public Health (MOPH) in Thailand has made considerable progress in the reduction of the rates of helminthiasis over the past 50 years. However, *O. viverrini* and several helminths still remain prevalent among helminth infections. Our project and MOPH were involved in continuing the measurements for predictive surveillance and encouraging the strategy of a control programme. Remote regions are still high-risk areas, particularly among the hill tribes and the north-eastern population. These results demonstrate that geographic spatial analysis with fish-borne and soil-transmitted helminths can help to identify patterns of high risk for infections. This spatial analysis study is the first to use a health informatics model in helminthiasis. It will be a crucial tool for predictive and preventive models for helminthiasis.

Table 1. Multiple linear regression equations of fish-borne and soil-transmitted infections. D1, soil type as sandy loam; D2, soil type as clay; D3, land use as forest; D4, land use as a water body; X1, elevation in metres; X2, rainfall in millimetres; levels of significant differences include *$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$.

Dependent variables	Regression equation (with independent parameters and their *P* values in parentheses)	Adjusted R^2	*F* value
Y1 (fish borne)	Y1 = 3.028 + 0.020 X1(0.000***) − 2.098 D2(0.007**)	0.147	31.676***
Y2 (soil transmitted)	Y2 = −1.559 + 0.005 X2(0.000***) + 0.004 X1(0.033*) − 2.198 D2(0.000***)	0.201	30.847***
Y3 (*Opisthorchis viverrini*)	Y3 = 3.097 + 0.016 X1(0.000***) − 2.505 D2(0.000***)	0.142	30.486***
Y4 (hookworm)	Y4 = −0.905 + 0.003 X2(0.000***) − 1.558 D2(0.000***)	0.220	51.108***
Y5 (*Ascaris lumbricoides*)	Y5 = −0.541 + 0.002 X1(0.004**) + 0.0005 X2(0.022*)	0.029	6.287**
Y6 (*Trichuris trichiura*)	Y6 = −0.845 + 0.001 X2(0.000***)	0.075	29.944***
Y7 (*Enterobius vermicularis*)	Y7 = −0.014–0.053 D1(0.009**) + 0.00004 X2(0.033*)	0.021	4.760**
Y8 (*Strongyloides stercoralis*)	Y8 = 0.383 + 0.003 X1(0.000***) + 3.199 D4(0.001**)	0.092	19.000***
Y9 (minute intestinal fluke)	Y9 = −0.097 + 0.003 X1(0.000***) + 0.785 D3(0.005**) + 0.399 D2(0.012*)	0.123	17.684***

Table 2. Risk factor analysis for fish-borne transmission; *n*, number of samples; OR, odds ratio; CI, 95% confidence intervals; levels of significant differences include $*P < 0.05$, $**P < 0.01$ and $***P < 0.001$.

Risk function	Found ($n = 172$)	Not found ($n = 185$)	OR (P value)	CI	
Rainfall					
<1000 mm	37	39	1.00		
≥1000 mm	135	146	0.98 (0.921)	0.59	1.62
Elevation					
<50 m	34	140	1.00		
50–100 m	14	25	2.31 (0.027*)	1.09	4.90
≥101 m	124	20	25.53 (0.000***)	13.97	46.65
Soil type					
Not available	21	42	1.00		
Sandy loam	64	43	2.98 (0.001**)	1.55	5.71
Clay	63	88	1.43 (0.252)	0.77	2.65
Loamy sand	24	12	4.00 (0.001**)	1.68	9.54
Land use					
Miscellaneous	10	9	1.00		
Agricultural	144	156	0.83 (0.695)	0.33	2.10
Forest	15	17	0.79 (0.691)	0.26	2.48
Industrial	1	0	Not calculated		
Urban and built-up	1	1	Not calculated		
Water body	0	1	Not calculated		
Other	1	1	Not calculated		

Table 3. Risk factor analysis for soil transmission; n, number of samples; OR, odds ratio; CI, 95% confidence intervals; levels of significant differences include $*P < 0.05$, $**P < 0.01$ and $***P < 0.001$.

Risk function	Found ($n = 269$)	Not found ($n = 88$)	OR (P value)	CI	
Rainfall					
<1000 mm	45	31	1.00		
≥1000 mm	224	57	2.71 (0.000***)	1.57	4.66
Elevation					
<50 m	109	65	1.00		
50–100 m	33	6	3.28 (0.009**)	1.30	8.25
≥101 m	127	17	4.46 (0.000***)	2.46	8.05
Soil type					
Not available	50	13	1.00		
Sandy loam	95	12	2.06 (0.094)	0.87	4.85
Clay	92	59	0.41 (0.009**)	0.20	0.81
Loamy sand	32	4	2.08 (0.227)	0.62	6.94
Land use					
Miscellaneous	15	4	1.00		
Agricultural	222	78	0.76 (0.832)	0.25	2.36
Forest	27	5	1.44 (0.623)	0.34	6.19
Industrial	0	1	Not calculated		
Urban and built-up	2	0	Not calculated		
Water body	1	0	Not calculated		
Other	2	0	Not calculated		

The season of the year also has a significant influence on prevalence, as do geographic information factors such as humidity and temperature. These concerns should be addressed in future research. The present study provides innovative, integrative information concerning fish-borne and soil-transmitted infection in Thailand. Through theoretical addition, this health informatics model can be subsequently utilized to develop tools and programmes for the prediction, prevention and control of helminthiasis, and thus could lead to a decline in the prevalence of infection, especially in remote areas. Community participation is the most important and fundamental factor for implementing control programmes. This MOPH study provides fundamental information for the future study and monitoring of helminth infections in Thailand. Regular collection of data from the health informatics models is essential to the development of a strategy and road map for the containment and elimination of helminthiasis. This study will be useful in assessing the progress and merits of a variety of intervention programmes for prevention and control of helminthiasis in Thailand.

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Conflict of interest

None.

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