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Development of GIS Database for Insecticide Usage and Toxicity among Thai Farmers in Ubon Ratchathani Province, Thailand

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Abstract:

Widespread use of pesticides in Thai agriculture has led to serious adverse health impacts on users. This study developed a GIS database using the QGIS tool to investigate insecticide usage and toxicity to farmers in Ubon Ratchathani Province in northeastern Thailand. Primary data collection involved recording exact locations of residential houses using geographic positioning system (GPS). Secondary data including transport routes, natural and environmental resources, and records of rainfall and ground temperatures were also collected. The data were integrated as GIS mapping data. Eighteen farmers participated in the study and submitted themselves to measurements of cholinesterase (ChE) levels and 2 blood sample collections for comparison with standard ChE levels. Results revealed the GIS database to be an effective tool to capture, store, manage, search, analyze, and represent spatial data and correlate them with insecticide usage. The GIS database revealed that ChE levels of volunteers for pre-post-exposure were within normal ranges. Liver enzymes (AST and ALT) were also within normal ranges. Further study should broaden collection of essential data including demographic information and basic knowledge and perceptions of self-protection regarding insecticides. Further evaluation and refining of the GIS database approach are recommended to improve its effectiveness as an analytical tool to enhance safe use of pesticides.

Keywords: GIS database; insecticides; pesticide toxicity

Introduction

Pesticides are important tools in modern agriculture to limit damage caused by insects, weeds and diseases; they are also used in public health to control communicable diseases. They differ from other toxic chemicals in that they are deliberately released into the environment and their application is not wholly confined to the target organism. In Thailand, imports of imported agricultural insecticides (mostly insecticides and herbicides) increased drastically from 2008 to 2012, reaching 164,383 tons in 2012, with a value of over 22.044 billion baht [1]. A survey of three major rivers along rice paddy areas in Thailand from 1999 to 2001 found the highest residues of the pesticides above the safety limit set by the European Union (0.1μg/L) [2]; the same residues were also found in soil, water, and agricultural products throughout the country. Several factors contribute to the direct health risks associated with pesticides. These include the practice of mixing high potency pesticides in the spray tank to make toxic cocktails, use of dosages exceeding recommended limits, a preference among farmers for strong and fast-acting pesticides, improper disposal of empty containers, and the lack of education regarding the handling of pesticides. sdafsdafsdafsddafsad

Ubon Ratchathani is an agricultural province known for backyard production of short-duration vegetables including broccoli, cabbage, green leaf vegetables, tomatoes and green onions. Pesticides are routinely used to prevent insect damage and enhance market quality. In September 2013, the Department of Public Health in Ubon Ratchathani province reported farmers were at high risk in certain areas (including Khud-Peng and Khud- Kaopoon) where 79% of farmers used pesticide [3]. Farmers in these areas suffered from at least one medical problem related to kidney, skin, and liver function abnormalities. Since symptoms of pesticide toxicity can typically include liver enzyme elevation, renal impairment and skin discoloration, Nimitpatana village of Khud-Peng was selected as the target area for this study. The village has a population approximately 300 villagers and 72 residential homes (Figure 1).

Pesticide application adversely affects farmers directly due to lack of protective clothing; consumers can also be indirectly affected through chemical residues in food. In 2012, a blood sample survey by the Bureau of Occupational and Environmental Diseases, Department of Disease Control [4] found 533,524 farmers in 74 provinces (32% of the total number of farmers) whose blood was contaminated by toxic levels of insecticides. Additionally, an annual report of pesticide poisoning between 2002 and 2012 revealed the reports of over 1,800 admissions per year. In 2012, the number increased to about 2,000 cases of exposure to agricultural chemicals, with two fatalities. Most victims (41.06%) were farmers. Reports of individual poisonings since 1985 show wide variation in both cause and severity of poisoning among Thai farmers [5, 6]. Also, in 2013 the European Union's Rapid Alert System for Food and Feed (RASFF) issued a total of 25 official warnings related to pesticide residues in exported Thai fruits and vegetables. Most concerned the residues of methomyl and organophosphate pesticides [7]. The World Health Organization (WHO) has identified pesticide ingestion as one of the world's leading methods of suicide. WHO estimates that there are up to three million cases of pesticide poisoning every year, resulting in more than 250,000 deaths by suicides, a substantial fraction of the 900,000 people who die as a result of pesticide application every year [8].

Thailand has several strategies to manage and mitigate environmental pollution from agricultural activities. However, these measures are insufficient and much more needs to be done to avoid contamination and health risks associated with highly toxic agrochemicals such as organophosphates and carbamates. Furthermore, farmers' decisions regarding pesticide usage are often based on information provided by retailers, other farmers, agricultural extension officers or the pesticide companies themselves. The Pollution Control Department [24] and the Department of Agriculture (DOA) have tried to determine the existence and health effects of pesticides in Thailand, but have found insufficient data and a lack of good surveillance and control (Office of Agricultural Economics, 2012) [9].

A number of studies showed increased use of geographic information systems (GIS) as an effective spatial tool in the investigation of pesticides. These studies included the assessment of nutrient and pesticide leaching in vegetable production by Chatupote and Panapitukkul [10] and by Fytianos and Christophoridis [11], and pesticide transport modelling (Chitra and Bhaget, 2005) [12]. GIS has also been used as an automated approach to locational and non-locational data synthesis, combining a system capable of data capture, storage, retrieval, analysis, manipulation, and display. This study aimed to develop a GIS database containing physiological, natural resource, and environmental data related to the use and toxicity of pesticides in Ubon Ratchathani province in North-East Thailand, and to integrate data related to local farmers' health issues into the GIS database.

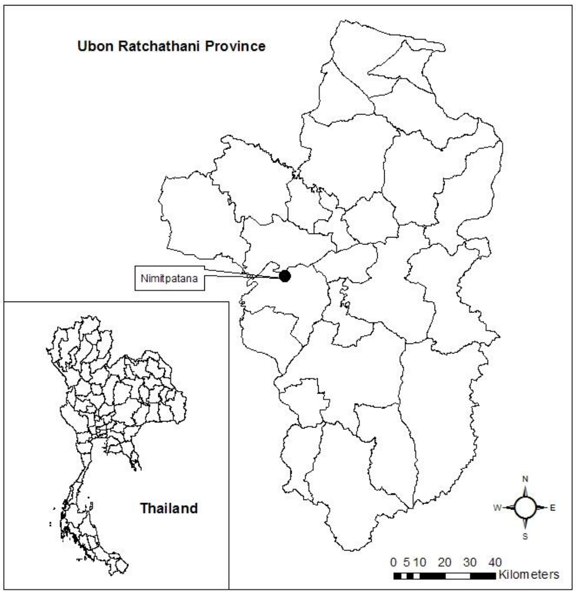

Figure 1 Nimitpatana Village, Khud-Peng, Ubon Ratchathani Province

Materials and Methods

1) Development of the GIS database using QGIS as a tool

QGIS was adopted in the study as a recognized freeware tool for integrating spatial and attribute data efficiently. It also has capabilities to search, edit, and analyze spatial data. This software has been utilized in various types of prevention and health care programmes related to pesticide usage among farmers. The research procedure is described schematically in Figure 2.

2) GIS application in liver enzyme monitoring

The monitoring procedure is described in Figure 3.

Results

1) GIS database for insecticide toxicity and usage

The target area was located in Khud-Peng, Warinchumrab District, Ubon Ratchathani Province, Thailand. Backyard vegetables grown in the area include broccoli, cabbage, Chinese kale, celery, tomato, and cauliflower. Nimitpatana was the village with the largest area of back-yard vegetable production in the Khud-Peng sub-district, located at 15°11′ 17.41″ north and 104° 50′ 32.95″ in the eastern part of the province of Ubon Ratchathani. The village comprises 304 people in 71 households, of which 23 households produced vegetables. A 400-bed local hospital serves the needs of a population of 160,300 people surrounding the study area.

The Chi River flows through Khud-Peng, originating from Paya-Pho in Petchabun Mountain in the east, and feeding into the 765-km long Moon River in Ubon Ratchathani. The rainy season in Thailand runs from June to October; estimated annual rainfall in Ubon Ratchathani is 1,587.60 mm, with an average 123.6 rainy days per year. From 1999 to 2008 the estimated rainfall during the rainy season in Ubon Ratchathani was 94.03±24.20 mm. The amount of rainfall increased between May and July (from 229.87 ±43.41 to 287.54±30.97 mm), and declining from August to November. The average tempe-rature is 27 degree Celsius and the average humidity 72 percent.

The GPS coordinates of each household growing backyard vegetables and using insecticides were recorded. Also, water resources, agricultural area, and transportation were integrated into the GIS database using the QGIS tool (Figure 4)

A pilot test was conducted to evaluate content validity. Officers of the Department of Agriculture (DOA) in Ubon Ratchathani participated in a developing the GIS database; adjustments to functionality and user inter-face were made based on comments received, including graphics quality, program functions, computer language, updated-installed data, and menu bars. A final version of the database was distributed to government officers responsible for pesticide surveillance and control. A further evaluation of the effectiveness of the GIS database was recommended by agricultural department workers, as there is still no GIS tool available for data collection regarding pesticide usage and toxicity of Thai farmers. In future, provision of a GIS database for public utilization will be available, but only for educational and research purposes, as the study was funded by the Office of the Higher Education Commission (HEC).

2) Liver enzymes test

Demographic data

Twenty out of the randomly selected 23 households enrolled in the study and the farmer of each house was tested for liver enzymes. Most of these farmers grew crops such as cabbage, Chinese kale, celery, cauliflower, and broccoli that could tolerate the harsh environment, grow rapidly and mature within 2 to 3 months, and command a high market price. While waiting to harvest these vegetables, farmers grew other crops including chilies, tomatoes, and flowers. During the study period, there was a severe flood in North-East Thailand, affecting production. Farmers were trying alternative approaches, such as raising animals and growing jasmine.

Types of insecticides

The GIS database showed farmers typically used organophosphate insecticides including malathion, parathion, gusathion, sumithion, mevinphos and diazinon due to their high efficacy in controlling insect pets. This is despite the ban on some toxic organophosphates such as parathion and mevinphos imposed a number of years ago. Regarding the mechanism of toxicity, carbamates are neurotoxic, inhibiting ChE and leading to uncontrolled nerve impulses, muscular damage, and even death. Chlorinated hydrocarbon can also inhibit nerve impulse transmission within axons, causing patholo-gical conditions to the human body.

ChE, AST, and ALT levels

Enzyme levels of 18 farmers were measured (the remaining two were unable to attend the measurement session). Blood sample collections were conducted on two dates (pre- and post-exposure). The overall results revealed that ChE of all 18 tested farmers during the pre- and post-exposure times were within the normal range (pre: 4,000 -11,447 U/ml, post: 4,003 – 10,700 U/ml) (Table 1).

During the pre-exposure period, AST levels of farmers were mostly within the normal range, except for three farmers (Table 1: AST levels of 91, 51, and 194 U/ml). However, those levels were still within the upper limit for AST enzyme. During the post-exposure period, most AST levels were still within the normal range. Only those three farmers still had high AST levels (Table 1: AST levels of 48, 56, and 151 U/ml). However, there remains a need for monitoring for further assessment.

During the pre-exposure period, most farmers had ALT levels within the normal range, except for three farmers (Table 1: ALT levels of 42, 51, and 127 U/ml). However, those values were within the upper limit (3 to 5 times normal values). These farmers were at risk of developing hepatotoxicity. Thus, close monitoring is strongly recommended.

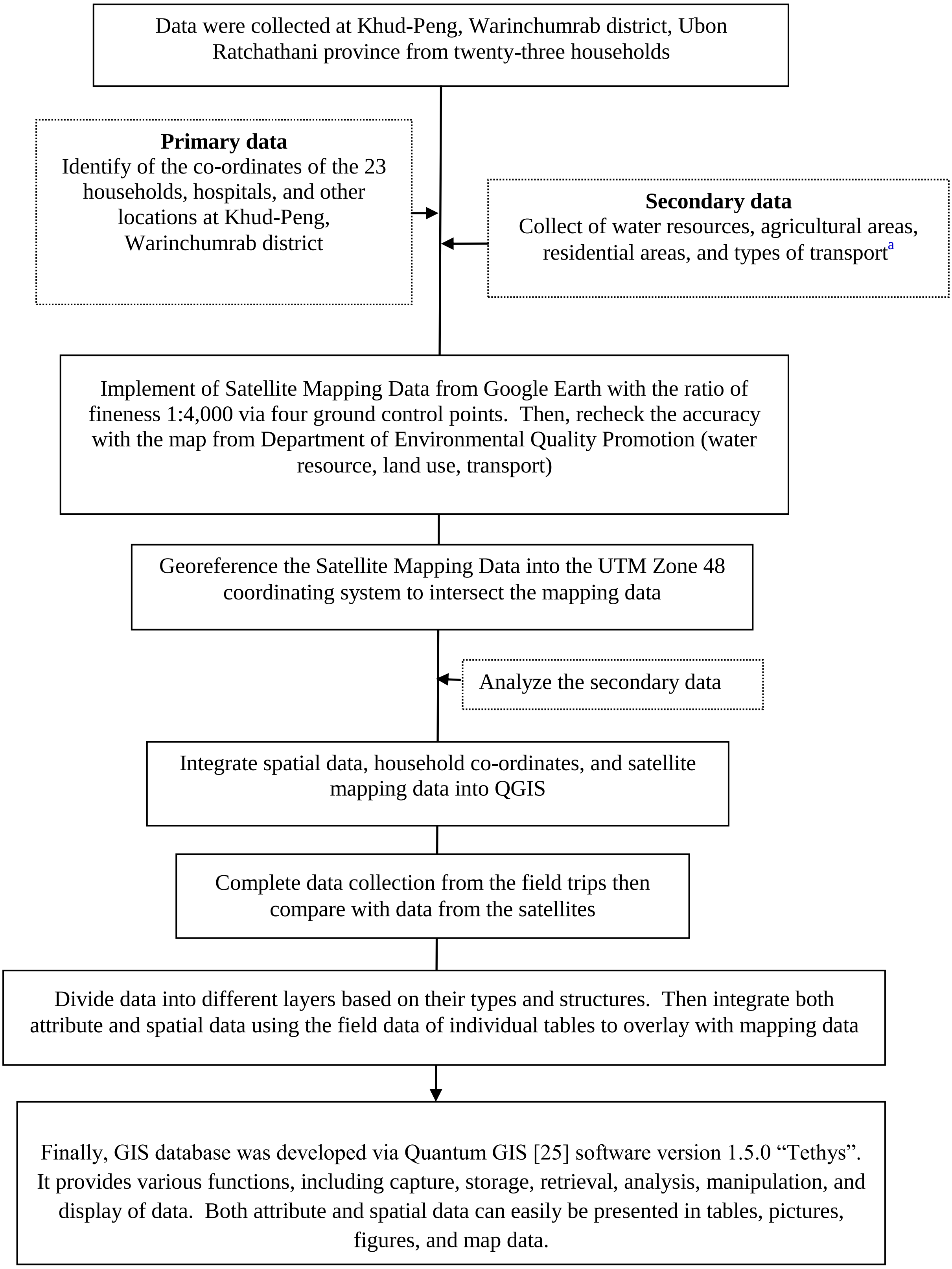

Figure 2 The procedure of GIS database development

Note:

[a] Secondary data were derived as follow: the rainfall and temperature (2011) data were derived from Northeastern Meteorological Center, Ubon Ratchathani province; the water resource, land use, and transport data (2000) with the resolution of 1:50,000 were derived from Department of Environmental Quality Promotion; the satellite image (2011) was obtained from Google Earth Version 6.0 with the resolution of 1: 4,000

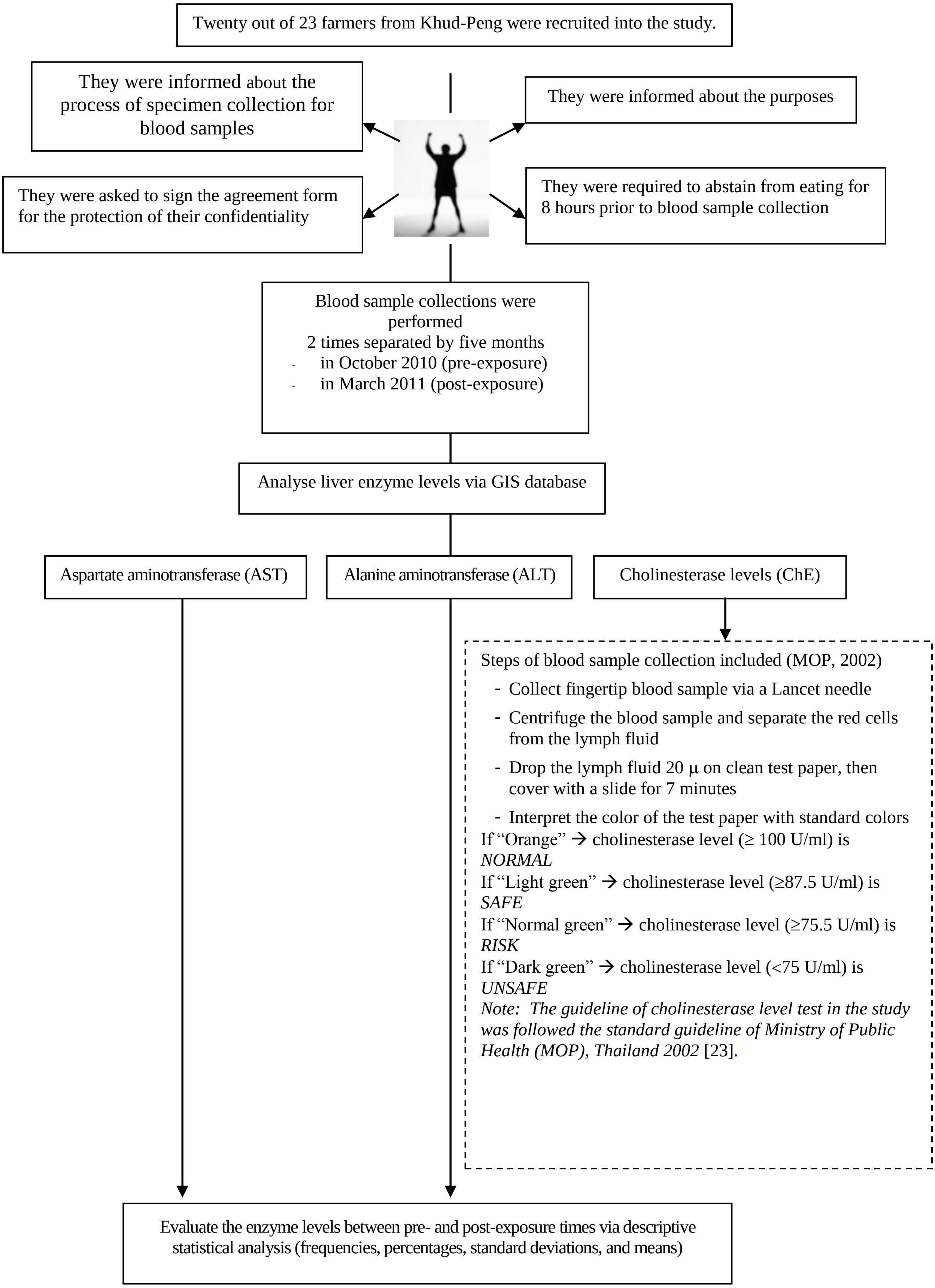

Figure 3 GIS application in liver enzyme levels monitoring

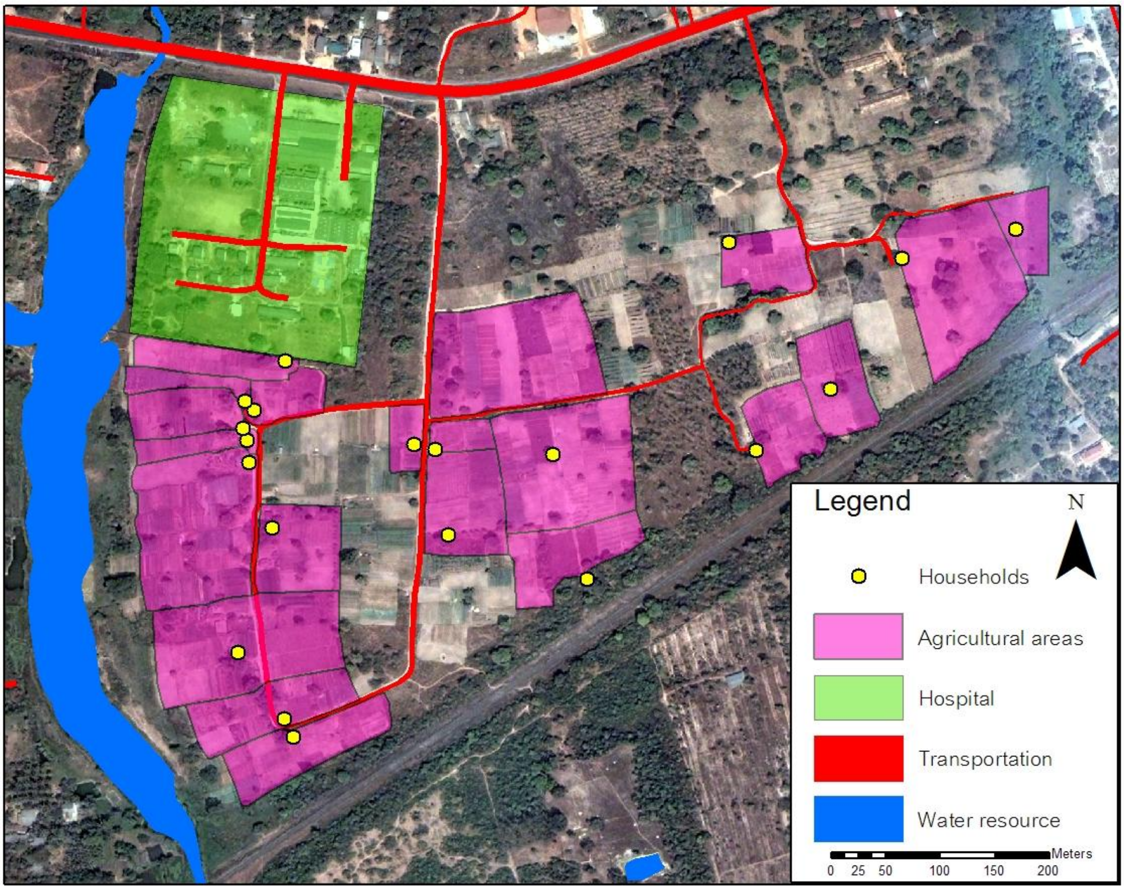

Figure 4 Households, water resources, agricultural areas, and transportation

Table1 Liver enzyme levels (U/ml) of 18 farmers, pre- and post-exposure

Sample number	Pre-exposure			Post-exposure		
	ChE	AST	ALT	ChE	AST	ALT
1	9,097	20	20	9,589	24	19
2	6,526	30	19	7,960	27	13
3	5,497	35	17	6,253	36	17
4	11,447	33	27	9,759	30	19
5	10,114	28	23	9,979	27	18
6	10,636	23	14	10,700	28	19
7	8,354	25	31	9,474	37	39
8	6,606	21	11	5,955	28	16
9	6,884	22	21	8,493	26	19
10	9,486	17	15	10,273	28	17
11	8,591	28	20	8,072	35	20
12	6,729	91	51	6,776	48	34
13	7,356	21	13	10,253	32	17
14	9,680	51	37	8,697	56	36
15	4,001	194	127	4,003	151	69
16	6,565	22	12	6,241	24	11
17	6,639	19	17	7,867	24	17
18	8,021	24	23	8,161	27	25

Discussion

The GIS database was developed as a tool to analyze use of insecticides and toxicity for a group of farmers in Ubon Ratchathani Province. The database offers an automated approach to locational and non-locational data synthesis, combining a system of data capture, storage, retrieval, analysis, manipulation, and display [13]. Users may easily seek information regarding types of insecticide use, types of common backyard vegetables, coordinates of households, demographic data, and pesticide toxicity, including hepatotoxicity. The format of maps supports the understanding of model results and also provides a convenient interface to spatially referenced data. The GIS database was designed to manage, analyze, and display all types of spatial data, and these capabilities make it a powerful tool in investigating insecticide usage and conducting toxicity assessments. GIS displays the spatial locations of wells and bores and provides tools to relate information regarding these to data contained in an external relational database. GIS also provides advanced tools for spatial analysis of the related data [14].

Although the general application of the GIS database are similar to those covered in previous studies as mentioned, until recently this technology had not been widely adopted in Thailand. However, governmental and non-governmental organizations are beginning to appreciate its utility and are implementing this advanced technology for many applications including agricultures, natural disaster management, route analysis, tax collection, and environmental pollution analysis. Some studies have been conducted using GIS datasets to assess the potential to enhance the capacity of rice production, fertilizer selection, cost reduction, and insecticide use [15]. Regarding concerns over insecticide use in agriculture, GIS datasets can assist government officers responsible for agricultural policy in creating strategies to control pesticide use and minimize physical contact with pesticides. The database can also be used as a predictive tool to forecast outcomes of overuse of pesticides on environmental and impacts.

A number of previous studies used GIS applications for agricultural purposes. The Department of Pesticide Regulation (DPR), California developed a GIS tool called "a permit mapping assistance program," a database system related to chemical pesticide uses among farmers. This database was connected to DPR to monitor the use of insecticides, control environmental pollution, and protect farmers from health risks 16]. In 1996 an algorithm was developed for use in a GIS to model the surface movement of insecticide in response to rainfall as modulated by slope, soil, management practices, and time of insecticide application. This algorithm estimated the loss of pesticides from field areas, run-off flow patterns, and the accumulation of pesticides at lower levels in response to rainfall [17]. GIS was also utilized to visualize and analyze four residual pesticides, endosulfan, diazinon, dichlorvos, and deltamethrim, in both land and water. This new computer technology enhanced and promoted research on ecological modeling and sustainable management [18].

GIS database still needs improvement in several respects: 1) to expand testing of other agricultural areas to standardize the results; 2) collect more demographic and pesticide exposure data for local farmers; and 3) collect additional data related to pesticide use in backyard vegetables, including quality of soil, water, and air. These essential data should be integrated into QGIS database for further applications.

Another factor is the high cost of satellite maps and GPS tools, which limit the capacity to collect, manage, and analyze geographical mapping data of agricultural areas. A possibility to overcome this limitation is to seek international financial sponsorship for future projects.

Results of the liver enzyme tests related to insecticide toxicity revealed that all three enzymes, cholinesterase, AST, and ALT, were within the normal ranges. There was some concern about the possible factors including the blood sampling collection procedure. Statements regarding the first blood sampling time (pre-exposure) included "collect blood samples either before use of insect-cides or 3 days after most recent insecticides spraying," an appropriate time. Statements regarding the second blood sampling time included "collect blood sample after spraying insecticides not more than 30 days." The researchers collected the second blood samples by the time the farmers harvested the back-yard vegetables for commercial sale (6 months later), a time that may be inappropriate to the above statement for the second blood sampling time. This may have caused the enzyme levels in the second blood samples (post exposure) to be in the normal ranges as reported in the study. The timing of the collection of the second blood samples was a result of difficulties in communication between researchers and farmers via the village headman. The research team found it very difficult to contact the village headman during the harvest season and, as a result, there was poor communication regarding the timing of the second blood sample. A possible solution would have been to collect blood samples at the standard time as per the statement.

Also, the enzyme levels should have been evaluated alongside other crucial information, including past medical conditions, lifestyles, lengths of pesticide usage, and types of insec-ticides to assess the possibility of pesticide residues left in the body. If liver enzyme levels were found to be above normal limits or classified in the "*RISK*" or "*UNSAFE*" categories, the farmers should be advised to suspend all pesticide spraying until the levels returned to normal.

Previous studies have indicated the possibility of farmer exposure to insecticides, including organophosphates, carbamates, and other substances, from consuming vegetables [19]. People exposed to these chemicals for a long time can possibly be affected by a decrease in ChE level [20, 21]. As a result, nerve impulse transmission could be impaired, causing muscular dysfunction. Other factors such as age, gender, medical conditions and current medications, can also affect ChE level [8]. Ponggraveevongsa [22] revealed farmers involved in agriculture for more than ten years had significantly less chance of exposure to insect pesticides compared to farmers with less than ten years' involvement in agriculture ($p<0.05$). This may be explained by the fact that those with longer involvement usually expand the crop lands and hire more labourers to work for them, reducing their own personal level of exposure. Farmers with less than 10 years' involvement in agriculture normally have to work harder and have more chance of exposure to chemicals while spraying.

The focus of future research will need to concentrate on pesticide toxicity, the use of personal-protective equipment (PPE), and risk behaviors related to pesticide exposure. These are the issues most important for farmers and public health workers in mitigation and/or prevention of occupational pesticide poisoning.

Finally, all responsible organizations, such as disease control units, departments of psychology, and departments of medical science, need to collaborate in development of a tool for pesticide exposure risk evaluation, enhancement of knowledge and facilities for public health workers, and implementation of health prevention policies in routine work. Such collaboration would necessarily also involve farmers, government officers, and health care providers at all levels reaching out to assist high-risk groups, and a continual monitoring of the situation to ensure an effective evaluation process.

Study limitations

The study has a number of limitations including, 1) The need for more participants and more target areas; 2) More information is required on past and current medications and basic knowledge and perceptions of pesticide toxicity; 3) GIS database needs to be piloted in different areas prior to further use; 4) Risk behaviors related to insect chemical toxicity need to be investigated; and 5) Long term evaluation of the effectiveness of QGIS database is required to assess the usability of the system.

Conclusion

The GIS database is an effective tool to capture, store, manage, search, analyze, and represent spatial and attribute data regarding the usage of insect pesticides by Thai farmers in Northeastern Thailand. Information provided by GIS helps policymakers, as well as extension and medical services provide an overall perspective of the current situation of pesticide use, and to represent the details of toxicity related to insect chemicals via tables, figures, and graphical data. Users can easily update and modify the database. Further evaluation of the effectiveness of GIS database for pesticide use and toxicity prevention at other target areas needs to be conducted to see the overall pictures of this issue.

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