# APPLICATION OF REMOTE SENSING AND GIS FOR PREVENTION-RISK WARNING OF MALARIA IN GIA LAI AREAS

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## ABSTRACT

Malaria is a disease transmitted by blood, which unaffected directly by parasites Anopheles mosquito but affected through infected vector from mosquitoes to humans, closely related to the environmental and socio-economic conditions. Diseases of community and very popular, endanger public health, ease of generation and transmission in the wild mountainous terrain or soil plains, caused by parasitic protozoa named Plasmodium. This is a common disease in tropical and subtropical areas. There are four kinds of parasites in Vietnam, which is dominant by *P.falciparum*, followed by *P.vivax*, *P.malariae* and *P.ovale*. The component of each parasite is various depending on characteristics of local ecosystem. The application of remote sensing and GIS for malaria study has been applying in many countries, however, this kind of integrated technology study is still quite few in Vietnam.
In our research, Gia Lai Province is a place of medium mountain and plateau of Vietnam, is a typical ecosystems were chosen for study malaria distribution. This study aimed to find out the relationship between anopheles mosquito and environmental parameters and socio-economic factors, and then identify and predict the high risk areas of malaria disease for malaria monitoring during dry and rainy seasons. SPOT, LANDSAT satellite images were used in this research for extracting different indices and factors, such as: land covers, vegetation index, wetness, drainage, landform, land surface temperature and surface water... The socio-economic information was collected from through local government statistic database and field survey. Multi-criteria assessment approach was used to calculate the weighting scores for each factor. Then, spatial modeling was applied to establish the potential malaria risk maps in each study areas. The results of this study was used as early warning and prevention of malaria for malaria monitoring as well as a contribution of integrated technological and scientific methodology for public health management with the aspect of the medicine geography.

## INTRODUCTION

Although malaria has been known and studied for many years, it was not until recent time, malaria cases have only decreased significantly due to some effective treatments. However, in the world as well as in Vietnam, a lot of residential areas remain their habitations in such places where malaria endemic frequently happens. And malaria mortality remains, the risk which malaria re-occurs and spreads out is present; hence, reducing the cases and deaths from malaria is still an unsolved problem of Health sector. In terms of geo- medical aspect, malaria is also considered a type of natural disaster – which has seasonal origination and development with clear local character. This shows that malaria depends significantly on natural, economic - social factors and is likely to happen in mountainous areas, highland and remote areas, including Gia Lai province.
In this study, we applied remote sensing and GIS method to learn about spatial and time distribution of malaria in Gia Lai and had great effects on the process of preventing this disease. Research results have been applied for malaria prevention in local area effectively, in particular, implementing prevention methods in areas and time which have high risk of malaria and reducing costs of malaria prevention activities.

## 1. DOCUMENTARY FOUNDATIONS AND RESEARCH METHODS

### 1.1. Documentary foundations

Documents used for this research include: 1) Landsat, Spot images taken at different times with good quality, less than 10% of cloud cover and detailed parameters expressed in table 1 used for analyzing situation of cloud cover and indexes; 2) topographic map with rate of 1:50 000 serving for researching terrain, building elevations, slope and correcting images; 3) Documents of natural, economic and social conditions of research areas which serve for defining the factors affecting to the risk of malaria outbreaks

Table 1: The parameters of satellite images used in the study

| No. | Image | Year | Parameters | | |
|---|---|---|---|---|---|
| | | | **Band** | **Wavelength** | **Resolution** |
| 1 | Landsat 8 | 2013 | Band 1 - Coastal / Aerosol | 0.433 - 0.453 µm | 30 m |
| | | | Band 2 - Blue | 0.450 - 0.515 µm | 30 m |
| | | | Band 3 - Green | 0.525 - 0.600 µm | 30 m |
| | | | Band 4 - Red | 0.630 - 0.680 µm | 30 m |
| | | | Band 5 – NIR | 0.845 - 0.885 µm | 30 m |
| | | | Band 6,7 - SWIR | 1.560 - 1.660 µm | 30 m |
| | | | **Band** | **Wavelength** | **Resolution** |
| 2 | Spot 5 | 2012 | B1 - Green | 0,50 - 0,59 µm | 10m x 10m |
| | | | B2 - Blue | 0,61 - 0,68 µm | 10m x 10m |
| | | | B3 – NIR | 0,79 - 0,89 µm | 10m x 10m |
| | | | SWIR | 1,58 - 1,75 µm | 20m x 20m |
| | | | PAN | 0,51 - 0,73 µm | 5m x 5m |

### 1.2. Scientific foundations and research methods

#### 1.2.1. Scientific foundations

***a. Identification of the main malaria vector in Gia Lai***

Malaria is a disease which is not transmitted by parasites (malaria transmitting protozoa– *Plasmodium*), but transmitted from person to person through mosquito vector as female Anopheles mosquitos which carry the parasite (Le Đinh Cong. 1992).

Previously, we had defined 4 types of malaria parasites which cause diseases in human as: *P.falciparum, P.vivax, P.malariae* and *P.ovale*. Now, thanks to advanced technologies, we have further defined more sub-types of malaria parasites. There are 4 sub-types of malaria parasites: *P.vivax hibernans, P.vivax St Elizabeth, P.vivax Chesson* and *North Korean.* Distribution of malaria parasites depends on areas and regions which govern epidemic characteristics of malaria. We can meet malaria in most of temperate zones *P.vivax* while in tropical zone *P.falciparum*, malaria can be met in Africa *P.malariae*.

In Viet Nam, we have found all of the four types of malaria parasites with the structure as: *P.falciparum (80-85%), P.vivax (15-20%), P.malariae (1-2%)* and rare *P.ovale.*

Malaria infecting sources are sick patients and people with cold malaria parasites (called healthy person with malaria parasites but without any symptoms).

In 1990, by experiences, Manson demonstrated the role of *Anopheles* mosquitos in malaria infection. The organic relationship among mosquitos – malaria parasites – human is the major factor in malaria infection. Currently, there have been nearly 300 mosquito determining tables and more than 422 types of Anopheles mosquitos, including about 70 types with capacity of malaria infection and 40 types considered as main malaria vectors.

As in mathematics, malaria vectors are characterized by following features:

- Having direction, original and destination points: director of malaria vectors is expressed through the relationship between human and mosquitos: sick people- mosquitos – infected people.
- Having degrees: each vector is characterized by a specific degree expressed through biting density of mosquitos.

In term of composition, Anopheles mosquitos in Gia Lai have been found to be different from those in Central Highland region, especially *Anopheles* species. Species belonging to Cellia sub-group are often distributed widely, so they seem to be likely in areas as: *An.aconitus, An.maculatus, An.philippinensis, An.vagus*... In *Anopheles* sub-group, some types had narrowed distribution and rarely met so they had few relations with human such as *An.bengalensis, An.nitidus* (Pham Gia Cong. 2003).

Currently, some researchers have used technologies such as cytogenetic, electrolyte, molecular biology ... to classify *Anopheles*, particularly for homological species. However, the determination of *Anopheles* mosquitoes in Gia Lai has still mainly based on external morphological basis of the published routing tables. Thus, composition of mosquitoes in Gia Lai is relatively abundant and presents two main malaria vectors as: *A.dirus* and *An.minimus.*

***b. Natural factors affecting to the capacity of disease outbreaks***

There are many different factors affecting to malaria disease but they can be included in 2 main factor groups; Natural factors and socioeconomic factors affecting to ecological characteristics of anopheles mosquito as follows (Vu Thi Phan. 1996):

+ Natural factors:

- *Climate factors*: including 3 main factors as temperature, humidity and rainfall.

- *Geographical factors:* The two main factors are elevation and land forms.
- *Hydrologic factor and surface water:* hydrologic types, hydrological network density, and flow velocity are the main indicators reflecting the density of mosquitoes and larvae (grubs).
- *Vegetation:* There are targets interested within this factor relating to existence, growth and reproduction of malaria vector are coverage level and type of vegetation coverage
+ Socio-ecologic factors define the ability of generating and spreading malaria disease, particularly: population density, quantity and quality of health centers, capacity and awareness of disease protection ….

### 1.2.2. Research methods and models

#### *a. Remote sensing and GIS methods*

The method of processing remote sensing images provides information relating to soil surface. Main methods used in this research are tested with Landsat and Spot images to find information of coverage layer. Calculation of NDVI (Normalized Difference Vegetation Index) (Rouse et al, 1973) index from red and near-infrared channels is used to evaluate coverage level. GIS method helps overlay and integrate natural and socio-economical information with weight to calculate and evaluate capacity of malaria outbreaks.

#### *b. Analytical Hiearchy Process (AHP) method.*

To define weight of target layers, the study used results of research works, expert's opinions, field investigation and analysis of the geographical characteristics of the area combined with Analytical Hiearchy Process (AHP) (Saaty, T.L., 1980) method. Generally, the comparison of the criteria's importance was based on the actual density variation of malaria per sensitivity of the different indicators. The larger variation are, the more important these criteria affect to malaria outbreaks.

Table 2: The comparison of criteria based on Analytical Hiearchy Process (AHP) method of Saaty

| The importance | The value | Explanation |
|---|---|---|
| Equally important | 1 | Two activities (variables) contribute equally |
| Equally important to moderate | 2 | |
| Moderately important | 3 | The preference for moderate activity (variable) |
| Important moderate to slightly more | 4 | |
| Slightly more important | 5 | Strong priority for an active dynamic (variable) |
| Slightly more important to very important | 6 | |
| Very important | 7 | An activity (variables) is very important |
| Very important to extremely important | 8 | |
| Extremely important | 9 | Is the highest priority |

The nature of AHP is a matrix structure representing connection of elements' values. For each element, there is a matrix for comparisons of its sub-elements.

#### *c. Research model*

Theoretical models of malaria research in Gia Lai was based on capability of overlaying, integrating and analyzing information from GIS tools, capacity of analyzing models from simple to complex, depending on the requirements of users. With factors relating to malaria in Gia Lai, we would present the theoretical model as follows:

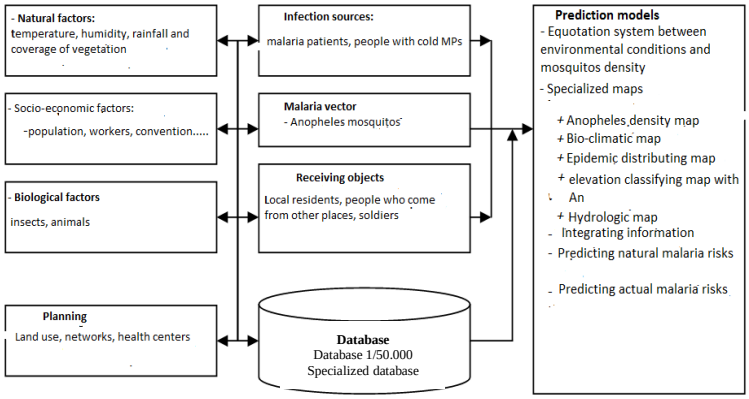


Figure 1. The model concept integrates remote sensing - GIS in malaria research

## 2. DATA PROCESSING

### 2.1. Establishing input data layers

After defining natural and socio-economic factors affecting to the capacity of malaria outbreaks, the research group used available documents to correct and establish input data layers for the research models such as: elevation, rainfall, temperature, density of rivers and springs….

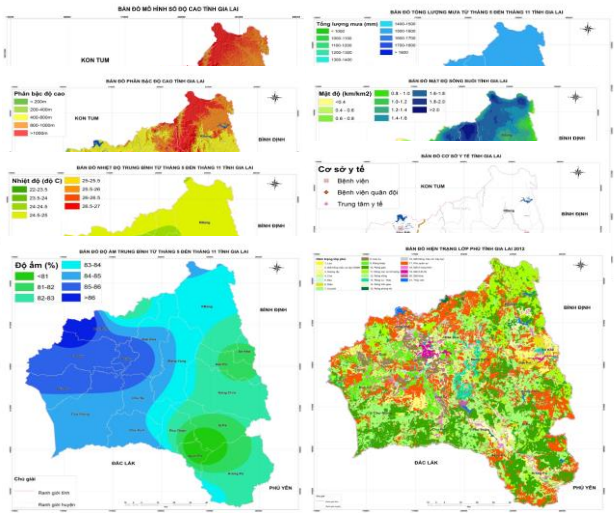


Figure 2. The layers of data on naturally affect the ability to generate malaria

### 2.2. Classifying data layers according to capacity of malaria outbreaks

Based on ecological characteristics of mosquito and effects of natural and socio-economic factors on malaria outbreaks, input data will be corrected according to a common standardized scale in order to integrate data processing in the next step.

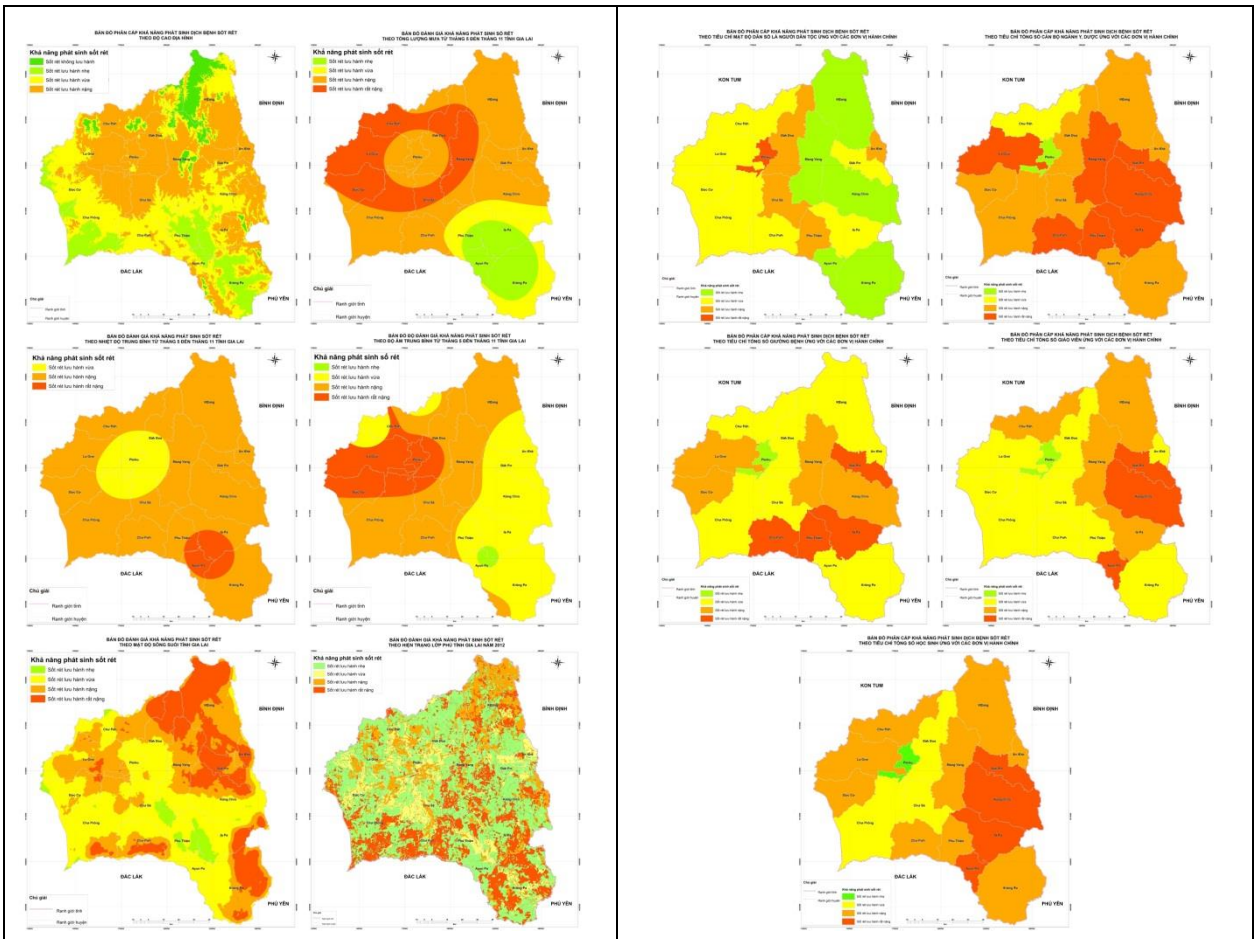
Table 3: Hierarchical group of natural elements

| **Malaria risk** | **Mosquito density An.** | **Temperature** | | **Humidity** | | **Rainfall** | | **Density of hydrological** | | **Stratified high** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **$^0$C** | **cd** | **%** | **cd** | **mm/năm** | **cd** | **km/km$^2$** | **cd** | **m** | **cd** |
| Potential | No or low | <20 | 0 | <75 | 0 | <1000 | 0 | 0.5 | | 0-25 | 0 |
| No circulate | | | | | | | | | | 25 - 100 | 0 |
| | | | | | | | | | | >1000 | 0 |
| Hypoendemic | Low to moderate | 20 - 22 | 1 | 75 - 80 | 1 | 1000 - 1200 | 1 | 0.5 – 0.7 | 2 | 100 - 200 | 1 |
| Circulating medium | Average | 22 - 24 | 2 | 80 - 83 | 2 | 1200 - 1400 | 2 | 0.7 – 1.0 | 4 | 200 - 400 | 2 |
| | | | | >86 | 2 | >1800 | 2 | | 4 | 600 - 800 | 2 |
| Endemic | High | 24 - 26 | 3 | 83 - 85 | 3 | 1400 - 1600 | 3 | 1.0 – 1.4 | 6 | 400 - 600 | 3 |
| Heavy circulation | Very high | >26 | 4 | 85 - 86 | 4 | 1600 - 1800 | 4 | > 1.4 | | | |

Standardized scale includes 5 levels from non-circulated to circulated seriously corresponding to from green to red.

Table 4: The level incurred of malaria and corresponding color display

| Level | The ability to generate malaria | Color display |
|---|---|---|
| 0 | Malaria is not endemic | |
| 1 | Mild malaria | |
| 2 | Light malaria | |
| 3 | Malaria is endemic | |
| 4 | Severe malaria | |



The natural group of information

The Socio-economic group of information

Figure 3. The class information after decentralization

## 3. RESEARCH RESULT

Calculation of weight under AHP method for specific variables was implemented automatically by Expert Choice software to have a result as implemented manually.

Table 5: The weightings of matrix defined criteria

| Level | A | B | C | D | E | F | Average | Consistancy Measure |
|---|---|---|---|---|---|---|---|---|
| **Terrain (A)** | 0.07 | 0.09 | 0.04 | 0.07 | 0.05 | 0.05 | **0.06** | 6.13 |
| **Rainfall (B)** | 0.27 | 0.36 | 0.30 | 0.44 | 0.36 | 0.32 | **0.34** | 6.24 |
| **Temperature (C)** | 0.13 | 0.09 | 0.07 | 0.07 | 0.05 | 0.05 | **0.08** | 6.06 |
| **Humidity (D)** | 0.20 | 0.18 | 0.22 | 0.22 | 0.27 | 0.32 | **0.24** | 6.29 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Density of river (E)** | 0.13 | 0.09 | 0.15 | 0.07 | 0.09 | 0.08 | **0.10** | 6.17 |
| **The current state of overlay (F)** | 0.20 | 0.18 | 0.22 | 0.11 | 0.18 | 0.16 | **0.18** | 6.19 |
| **Consistent evaluation index** | | | | | | | **CI =** | 0.04 |
| | | | | | | | **RI =** | 1.24 |
| | | | | | | | **CR =** | **0.03 <0.1** (satisfactory) |

From calculation results of weight in above table, we conducted overlaying 6 layers of information by a tool in the software with weights to give an information layer of capacity of malaria outbreaks as follows:

Y = A *0.06+ B *0.34 + C *0.08 + D *0.24+ E *0.1 + F *0.18

Among them:

Y: Malaria risk arising

A, B, C, D, E, F in turn is assessing malaria arising from factors: topography, rainfall, temperature, humidity, density streams, overlay Status values from 0 to 4 as mentioned above grade.

After calculating and classifying, we received results as follows:

Table 6: The hierarchical possibility of malaria outbreaks potential under natural conditions (left) and fact (right)

| No. | The range of values | The possibility of infection | No. | The range of values | The possibility of infection |
|---|---|---|---|---|---|
| 1 | < 2.0 | Malaria is not endemic | 1 | < 2.0 | Malaria is not endemic |
| 2 | 2.0 – 2.5 | Mild malaria | 2 | 2.0 – 4.0 | Mild malaria |
| 3 | 2.5 – 3.0 | Light malaria | 3 | 4.0 – 5.5 | Light malaria |
| 4 | 3.0 – 3.5 | Malaria is endemic | 4 | 5.5 – 6.5 | Malaria is endemic |
| 5 | > 3.5 | Severe malaria | 5 | > 6.5 | Severe malaria |

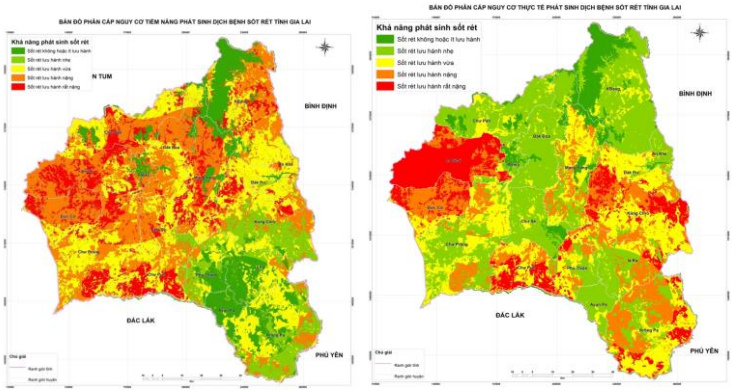



*Figure 4. The map of natural threats (left) and actual risk map (right) of malaria in the province of Gia Lai*

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