Assessing Malaria Risks in Greater Mekong Subregion based on Environmental Parameters

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Abstract – The Greater Mekong Subregion, which consists of Thailand, Myanmar, Cambodia, Laos, Vietnam, and a small part of China, is the world's epicenter of falciparum malaria. Depending on the country, approximately 50 to 90% of all malaria cases are due to this species. We have been developing techniques to enhance public health's decision capability for malaria risk assessments and controls using remote sensing data and technology. The data which we have used in this study include AVHRR Pathfinder, MODIS, TRMM, Ikonos, and SIESIP. The objectives are: 1) identification of potential larval habitats; 2) identification of the key factors that promote malaria transmission; 3) estimation of malaria transmission intensity based on environmental parameters. Preliminary results associated with these objectives are discussed.

Keywords: malaria, environment, spatial, simulation, neural network

1. INTRODUCTION

At 4,200 km, the Mekong River is the tenth longest river in the world. It directly and indirectly influences the lives of hundreds of millions of inhabitants in its basin. The riparian countries – Thailand, Myanmar, Cambodia, Laos, Vietnam, and a small part of China – form the Greater Mekong Subregion (GMS). This geographical region has the misfortune of being the world's epicenter of falciparum malaria (Kidson *et al*. 1999) which is the most severe form of malaria caused by *Plasmodium falciparum*. Depending on the country, approximately 50 to 90% of all malaria cases are due to this species.

We have been developing techniques to enhance public health's decision capability for malaria risk assessments and controls as a part of the efforts in NASA's Public Health Application Program. Our focus has been the countries in the Greater Mekong Subregion, in particular Thailand.

The approach that can be taken for malaria risk assessment and control in a region depends on the availability of epidemiological data and the environmental data of a suitable spatial resolution. For example, at the village scale or malaria hotspots, information on potential larval habitats facilitates mosquito control. Because insecticide and larvicide application can be more precisely targeted, the damage to the environment will be minimized. Certain environmental parameters are particularly important to malaria transmission, availability of these parameters and epidemiological data can be used to model malaria cases. The spatial resolution of the satellite data should be comparable to the scale of the epidemiological data. When detailed epidemiological data are available, such data may be used to identify the key factors that sustain malaria transmission.

Consequently, our main objectives are: 1) identification of the potential breeding sites for major vector species; 2) implementation of a dynamic malaria transmission model to identify the key factors that sustain or intensify malaria transmission; and 3) implementation of a risk algorithm to estimate the transmission intensity.

2. DATA

2.1 Environmental Data

The satellite data that have been used in this study include: the Advanced Very High Resolution Radiometer (AVHRR) (AVHRR web site), the Moderate Resolution Imaging Spectroradiometer (MODIS) (MODIS web site), the Tropical Rainfall Measuring Mission (TRMM) (TRMM web site), and Space Imaging's Ikonos (Space Imaging web site). In addition, the time series in the Seasonal-to-Interannual Earth Science Information Partner (SIESIP) dataset (SIESIP web site) has also been used.

2.2 Epidemiological Data

The monthly, provincial malaria cases were compiled by the Thai Ministry of Public Health. The compilation include such information as monthly malaria cases, population and mortality at provincial resolution. The Epidemiology Division data are based on passive detections, which are essentially the confirmed malaria cases at various levels of hospitals or clinics.

2.3 Population Data

Additional population data are obtained from the Chulalongkorn University's College of Population Studies (Chulalongkorn web site) and the Thai National Statistics Office (Thai National Statistics Office web site).

3. METHODS AND RESULTS

More than one method have been used in the analyses for each objective. In this section, the main methods and their respective results are described.

3.1 Larval Habitat Identification

Larger larval habitats, such as rice fields, large ponds, can be easily identified using medium resolution satellite data, such as ASTER (ASTER web site), EO-1 (EO-1 web site), or Landsat. For these habitats, regular ground cover classification techniques can be used to achieve reasonable classification accuracy.

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Identifying smaller habitats, such as ditches and small water bodies, requires high-resolution data, such as Ikonos or QuickBird (Digital Globe web site).

Higher spatial resolution has made some applications possible. But it has also brought about new challenges in ground cover classification. At a resolution around 1 meter, vegetation often displays distinct textures. Hence texture may make differentiation among some cover types possible. Previously, we have shown that spatial features derived from Ikonos panchromatic and multispectral data can be used to improve classification accuracy (Kiang 2002). In this study, textural features are extracted from co-occurrence matrices, contextual features are derived from neighborhood properties, and maximum likelihood method is used for classifications. It is shown that for the test data both types of spatial features, and especially the contextual measures, can significantly improve the classification accuracies. For example, Figure 1 shows that irrigation and drainage ditches can be so identified in pan-sharpened Ikonos images.

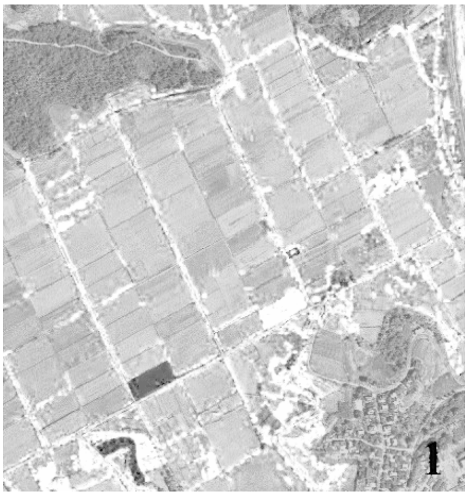

Figure 1. Classified irrigation and drainage ditches (in white) using pan-sharpened Ikonos imagery data.

3.2 Identification of Key Factors in Malaria Transmissions

Malaria transmission depends on multiple factors. It is, therefore, not straightforward to identify the most important factor that sustains or promotes malaria transmissions at a certain area. If the key factors are known, a cost-effective strategy can then be established to reduce endemicity or contain an epidemic.

In our current approach, we model the detailed interactions among the vector life cycle, the sporogonic cycle, and human disease cycle, under the influence of all extrinsic and intrinsic factors. The rules of interaction among the elements and with the surrounding of the elements are defined. And the outcome is manifested at the highest level – in this case, the health status of each individual at each household.

A basic arrangement for simulation is a hypothetical hamlet consisting of a square array of 5x5 houses with two houses replaced by cattle sheds. This array is surrounded by 24 larval habitats. Each household has 4 residents, and each resident has different social activities and immunity. There are 92 residents in this hamlet, which is approximately 1/7 of the size of a real test site. With the current software structure, a village of few thousands residents can be modeled easily.

Figure 2 shows a typical result – the total number of infected residents over a period of 1,000 days. In this example, a single transmission peak is used, although there are normally two transmission peaks in Thailand – with one sharp peak in mid-June and a much flatter peak in December. This example shows that a large fraction of the residents are infected but may be symptomless. Without symptoms, these residents will not seek or receive treatments. Normally, asymptomatic populations play an important role in prolonging the malaria endemicity.

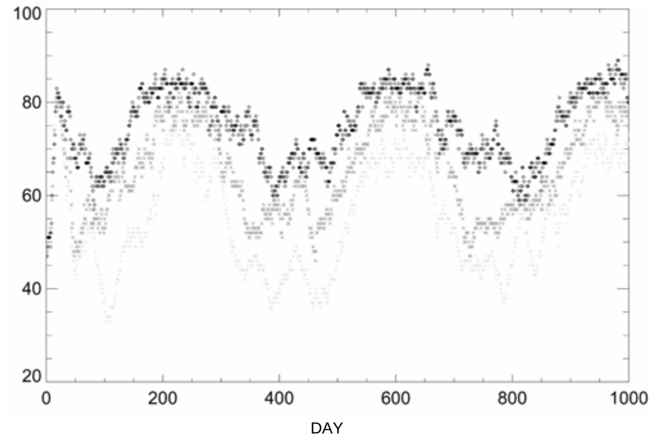

Figure 2. Number of infected residents at each day. Each shade is for a different mosquito loading.

3.3 Estimation of Malaria Risks

Regressions (Bates 1988), decision trees (Breiman 1984), and neural networks (Bishop 1966) are used for estimating malaria risks. A regression can be linear or nonlinear. A decision tree makes branching decisions at intemediate nodes and reaches conclusions at terminal nodes. A neural network learns from examples. Each method has its own merits and limitations. Which method performs best depends on data characteristics and data availability. While the functional forms used for decision may seem more explicit in the first two methods and less so in the neural network method, interpretation of these forms in any of the methods is not straightforward.

To train these methods to estimate malaria risks, we feed them with observed or measured parameters from the past. The input consists of environmental variables and the output is the corresponding malaria cases or risk indicators. Once trained, these methods will be able to estimate the unknown cases or risks using environmental parameters as input. Like all applications that are statistical in nature, the more samples one has, the more reliable the conclusion will be; hence, it is desirable to have long time-series for disease prediction.

Figure 3 shows the result of using 8 years of environmental data for training and the following 2 years of data for hindcasting malaria cases for the Tak Province of Thailand. Good agreement between the hindcasted and the real malaria cases is seen.

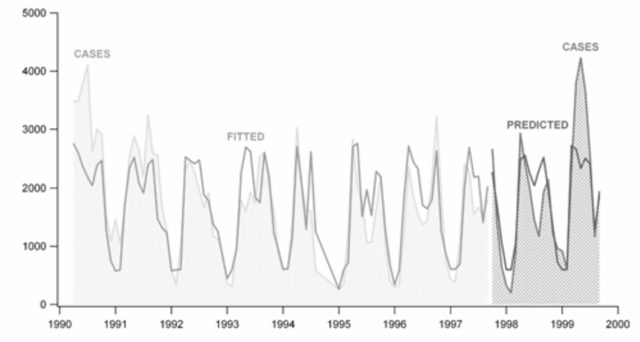

Figure 3. Fitted and hindcasted malaria cases compared with epidemiological data for Tak Province, Thailand.

4. CONCLUSIONS

We have shown that remotely sensed data is useful for assessing malaria risks and for epidemic prevention and containment. The potential benefits are: 1) increased warning time for public health organizations to respond to malaria outbreaks; 2) optimized utilization of pesticide and chemoprophylaxis; 3) reduced likelihood of pesticide and drug resistance; and 4) reduced damage to environment.

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TRMM web site. http://trmm.gsfc.nasa.gov

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