Malaria Modeling and Surveillance
In Thailand and Indonesia

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Meteorological & Climatological Parameters

Vector Ecology
Predator Ecology
Local Environment
Anthropogenic Factors

AGRICULTURAL PRACTICE
ROAD BUILDING
DEFORESTATION
MILITARY CONFLICT
REFUGEES
ECONOMIC CRISIS
MEDICAL CARE

THE PROBLEM

- 40% of the world’s populations at risk
- 300-500 million cases per year
- 1-3 million deaths per year
- Highest risks for children, pregnant women, and people with depressed immunoresponse
- One death every 30 seconds
- Counterfeit and substandard antimalarial drugs abound.
- ACT is becoming less sensitive.
- Previously unaffected regions may have outbreaks due to climate change.

OBJECTIVES

- Risk detection
  Detection of larval habitats
  Textural-contextual classification

- Risk prediction
  Prediction of current and future endemicity
  Neural network methods

- Risk reduction
  Identification of key factors that sustain or promote transmissions
  Agent-based discrete event simulation

BENEFITS

- Applying larval control as a preventive measure
- Strengthening and mobilizing public health support
- Cost-effectively curtailing malaria transmission
Value & Benefits

• Reduced morbidity & mortality for US Forces
• Improved public health for local populations
• Reduced damage to the environment
• Reduced likelihood of larvicide, insecticide & antimalarial resistance

Research Partners

- GIS, census
- Demographic & animal data
- Operational data

Earth Sci. Model

- Climate prediction

Earth Observation

- ASTER
- MODIS
- TRMM
- AVHRR
- SIESIP
- Ikonos
- QuickBird

Malaria Models

- Local habitat detection
- Entomology estimation
- Forecast
- Dynamics

Decisions

• Preventative measures
• Countermeasures decisions

Malaria Risk

User Scenarios

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The Greater Mekong Subregion is the world’s epicenter of multi-drug resistant falciparum malaria.

40% of the 245M Indonesians Live in Malarious Regions

Most Thai provinces endemic with malaria are border provinces.

The largest refugee camp in Thailand (with >30,000 population)

Collecting larvae.

… mosquitoes.

… and blood samples.

Malaria Incidence in Aceh Increased Significantly After the Tsunami Disaster in December 2004

Annual Malaria Incidence: 8.6, 107

Detection of Ditches using Pan-sharpened Ikonos Data

Larval Habitats of Anopheles sinensis in Korea
Classification Accuracy using Pan-Sharpened Ikonos Data (1 meter resolution)

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy (Mean ± Standard Deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>0.90 ± 0.04</td>
</tr>
<tr>
<td>Original with &amp; without panchromatic sharpened per pixel only</td>
<td>0.95 ± 0.03</td>
</tr>
<tr>
<td>Sharpened plus neighborhood mean</td>
<td>0.97 ± 0.02</td>
</tr>
<tr>
<td>Sharpened plus neighborhood variance</td>
<td>0.98 ± 0.01</td>
</tr>
<tr>
<td>Sharpened plus neighborhood mean &amp; variance</td>
<td>0.99 ± 0.01</td>
</tr>
<tr>
<td>Sharpened plus median filter</td>
<td>0.98 ± 0.02</td>
</tr>
<tr>
<td>Sharpened plus low pass filter</td>
<td>0.97 ± 0.03</td>
</tr>
<tr>
<td>Sharpened plus dilation</td>
<td>0.96 ± 0.04</td>
</tr>
<tr>
<td>Sharpened plus mean, variance &amp; median filter</td>
<td>0.95 ± 0.04</td>
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</tbody>
</table>

Satellite-Observed Meteorological & Environmental Parameters For Four Thailand Seasons

- Surface Temperature
  MODIS Measurements
- Vegetation Index
  AVHRR & MODIS Measurements
- Rainfall
  TRMM Measurements

Actual Malaria Incidence

Hindcast Incidence

Dynamic Transmission Modeling Framework

For Four Thailand Seasons

- Surface Temperature
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Dynamic Transmission Modeling Framework

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Kong Mong Tia Test Site, Kanchanaburi, Thailand

In Collaboration with AFRIMS and WRAIR

Malaria Surveillance Study (Jun 99 – Jan 04)

Blood films from ~450 persons/month

Microscopy and Polymerase Chain Reaction

Larval and adult mosquito collection

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Example: A Small Hamlet

- 23 houses
- 2 cattle sheds
- 24 clusters of larval habitats
- 8 cows
- 23 adults
- 2 children
- 8 cows

Modeled and Observed Prevalence

Modeled and Observed Sporozoite Rates

Modeled and Observed Entomological Inoculation Rates

Sensitivity Studies and Simulations Performed

- Abundance of larval habitats
- Access to health care and appropriate treatment
- Asymptomatic cases
- Acquired immunity
- Active and passive case detections
- Bednets or personal protections
- Improved dwelling construction
- Parasite infectivity in mosquitoes
- Zoonotic prophylaxis
- Arrival of non-immune populations (such as migrant workers, refugees, foreign military forces)

Well Placed Farm Animal Sheds and Zoonotic Prophylaxis May Significantly Reduce Malaria Transmission

- Sheds relocated to where mosquitoes are more abundant
- Zoonotic prophylaxis also used
With over 18,000 islands and a decentralized government, it is challenging to implement malaria control policy.

Rainfall Pattern, Which Drives Malaria Transmission, Varies Significantly from Island to Island
Average Monthly Precipitation for the Major Cities on the 8 Islands 2000-2005

Precipitation Based on TRMM Measurements

Hindcasting Malaria Cases in Jawa Tengah, Indonesia
Actual (red), Modeled (blue), and Hindcast (green) Malaria Cases

Districts Involved in Menoreh Hills Project
– A MOH-WHO-NAMRU2-USAID Collaboration

Comparison of Kulong Progo and Purworejo ACD Cases (blue) with Jawa Tengah PCD Cases (red)
Thank you!