Myanmar Malaria Early Warning System (MMEWS): Multi-sensor satellite data fusion system for monitoring environmental predictors of malaria in the region of emerging artemisinin resistance
Good news about malaria

• Clinical cases of malaria have declined globally
Trends in malaria case incidence globally and by WHO region 2010-2016 (World Malaria Report 2017)

WHO Regions:
AFR – Africa
AMR – Americas
EMR – Eastern Mediterranean
SEAR – South-East Asia
WPR – Western Pacific
Good news about malaria

- Clinical cases of malaria have declined globally
- Malaria-caused death rate has dropped by nearly 30% (since 2010)
Trends in malaria death rate globally and by WHO region 2010-2016 (World Malaria Report 2017)

WHO Regions:
- AFR – Africa
- AMR – Americas
- EMR – Eastern Mediterranean
- SEAR – South-East Asia
- WPR – Western Pacific
BUT

- In 2015
  - 212 million malaria cases
  - 429,000 malaria deaths
Estimated malaria cases (millions) by WHO region, 2016 (World Malaria Report 2017)
As Malaria Resists Treatment, Experts Warn of Global Crisis

War on malaria: on the brink of a breakthrough?

Health

Malaria experts fear disease’s resurgence

By Michelle Roberts
Health editor, BBC News online

10 April 2018

Spread of insecticide resistance could derail malaria prevention

Study comes as the World Health Organisation warns efforts to eradicate malaria have "stalled"

WHO: Venezuela malaria cases jump by 69 percent

Nearly half a million people killed by malaria in 2016

For the first time in 10 years, global malaria cases are no longer falling, sparking concerns about a resurgence of the too often deadly disease.
Number of countries where a reduction (green) or increase (red) of more than 20% in malaria cases has occurred between 2015 and 2016, by WHO region (World Malaria Report 2017)

WHO Regions:
AFR – Africa
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“...We must ramp up quickly; drug resistance is spreading; if it spins out of control, we run the risk of a huge resurgence of malaria in other parts of Asia and especially in Africa.”
MYANMAR

Myanmar has the highest rate of malaria-related mortality in south-east Asia. The primary parasite is Plasmodium falciparum and there is also P. vivax present. Vectors include Anopheles dirus, A. minimus and A. epiroticus.
Premise

As the “malaria lake” is drained, malaria transmission separates into “pools” and then shrinks into “puddles”, understanding malaria risk as it varies over time and space becomes essential for effective targeting of interventions.
Fig 3 shows predictions categorized as:
- low risk - light red;
- intermediate risk - medium red;
- high risk - dark red.

The spatial distribution of *Plasmodium falciparum* malaria in 2010 stratified by endemicity class

Myanmar

Gething et al. 2011 – Available via Malaria Atlas Project

- $PfAPI < 0.1\%$
- $0\% > PfPR_{2-10} \leq 5\%$
- $5\% > PfPR_{2-10} \leq 40\%$
- $PfPR_{2-10} > 40\%$
Scope and objectives of MMEWS

- Support malaria eradication planning and implementation activities
  - Enable spatially-explicit monitoring of current conditions
  - Enable forecasting of potential surges in malaria burden
  - Inform stakeholders through the on-line visualization platform and tabular reports
Malaria Burden Potential

Population vulnerability

Population presence/density:
- urban centers
- rural sites

Occupation-related exposure:
- rice cultivation
- plantation work
- forest harvesting

Access to care:
- distance to roads and medical facilities
- political stability

Subclinical parasitemia:
- *Plasmodium* prevalence
- drug resistance

Vector abundance

- Standing water
- Vegetative stress
- Land surface temperature
Task 1

Base map development
Inferring land use patterns from forest cover change
Basemap circa 2016

Tree cover:
- Landsat 2015-2017 + existing Forest cover products

Non-tree cover:
- Non-tree cover:
  - VHR + Landsat archive

Global forest cover change products + VHR
- Global impervious cover
  - Landsat TM/ETM+/OLI archive
  - DEM
  - VHR + Landsat archive

Managed forest/plantation
- Natural Forest
- Urban centers
- Managed forest/plantation
- Shrubs and grass
- Unpopulated bare and sparsely vegetated

Perennial water bodies
- Ephemeral water
- Topographic depressions
- Croplands
- Villages
Multi-year 30m Surface Water Fraction

- All individual Landsat scenes for years 2013-2017
Basemap circa 2016

Tree cover:
Landsat 2015-2017 + existing Forest cover products

Non-tree cover:

Global forest cover change products + VHR

Global impervious cover

Managed forest/plantation
Natural Forest
Urban centers

Shrubs and grass
Unpopulated bare and sparsely vegetated
Perennial water bodies
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Topographic depressions
Croplands
Villages

Landsat TM/ETM+/OLI archive

DEM

VHR + Landsat archive

Global forest cover products

Perennial water bodies

Croplands

Villages
<table>
<thead>
<tr>
<th>Category</th>
<th>Prod Acc%</th>
<th>User Acc%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>71.79</td>
<td>100</td>
</tr>
<tr>
<td>Crop</td>
<td>79.17</td>
<td>79.17</td>
</tr>
<tr>
<td>Trees</td>
<td>100</td>
<td>88.14</td>
</tr>
<tr>
<td>Non-tree&amp;bare</td>
<td>63.95</td>
<td>98.21</td>
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<tr>
<td>Built</td>
<td>9.09</td>
<td>3.85</td>
</tr>
<tr>
<td>Cloud&amp;shadow</td>
<td>100</td>
<td>58.62</td>
</tr>
</tbody>
</table>

Overall Acc = 79.7

Kappa Coefficient = 0.73
Mapping population distribution from Landsat

Task 2

Monitoring capacity
Malaria Burden Potential

Population vulnerability
- Population presence/density:
  - urban centers
  - rural sites
- Occupation-related exposure:
  - rice cultivation
  - plantation work
  - forest harvesting
- Access to care:
  - distance to roads and medical facilities
  - political stability
- Subclinical parasitemia:
  - *Plasmodium* prevalence
  - drug resistance

Vector abundance
- Standing water
- Vegetative stress
- Land surface temperature

Update frequency and data source:
- 8-day update: Landsat OLI, Sentinel 2, Sentinel 1, MODIS, VIIRS
- Annual update: Landsat OLI, Sentinel 2, Sentinel 1, VHR
- As needed: Auxiliary geospatial data, expert opinion, medical studies
Downscaling meteorological parameters

- MODIS 8-day land surface temperature (MOD/MYD11A2)
- MODIS daily precipitable water (MOD/MYD05L2)
Downscaled Land surface Temperature change (Day and Night)
Landsat / MODIS NDVI assessment
Malaria Burden Potential

Population vulnerability
- Population presence/density:
  - urban centers
  - rural sites
- Occupation-related exposure:
  - rice cultivation
  - plantation work
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- Access to care:
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MONITORING FOREST COVER CHANGE

Annual Forest Loss in Ann (ha)
Malaria prevalence (all population)

- P. falciparum
- P. vivax
- P. mixed (F&V)
All malaria prevalence by age group (men)

- 2-10 years
- 11-17 years
- 18-40 years
- >40 years

All malaria prevalence by age group (women)

- 2-10 years
- 11-17 years
- 18-40 years
- >40 years
Task 3

Threat level reporting
Malaria Burden Potential (MBP)

MBP = 
0.5*(0.34*SW+0.33*VS+0.33*Ts) + 0.5*(0.25*PD+0.25*OE+0.25*AC+0.25*SP)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Category definitions</th>
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<tbody>
<tr>
<td><strong>Surface Water</strong></td>
<td>Very Low (1)</td>
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<tr>
<td></td>
<td>Low (2)</td>
</tr>
<tr>
<td></td>
<td>Moderate (3)</td>
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<tr>
<td></td>
<td>High (4)</td>
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<tr>
<td></td>
<td>Very High (5)</td>
</tr>
<tr>
<td></td>
<td>no water</td>
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<tr>
<td></td>
<td>coastal wetlands - low numbers of Anopheles spp.</td>
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<td></td>
<td>deep or running water (30m inward within perennial water bodies)</td>
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<tr>
<td></td>
<td>Shallow water edge (± 30 m buffer from perennial water bodies edge)</td>
</tr>
<tr>
<td></td>
<td>shallow stagnant water (water mapped within ephemeral water, depressions, and cropland classes)</td>
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<tr>
<td>Vegetative Stress (VS)(^1)</td>
<td>VS &gt; µ + 0.5σ</td>
</tr>
<tr>
<td></td>
<td>µ - 0.5σ &lt; VS &lt; µ + 0.5σ</td>
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<tr>
<td></td>
<td>µ - 1σ &lt; VS &lt; µ - 0.5σ</td>
</tr>
<tr>
<td></td>
<td>µ - 1.5σ &lt; VS &lt; µ - 1σ</td>
</tr>
<tr>
<td></td>
<td>VS &lt; µ - 1.5σ</td>
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<td>Land surface temperature (Ts)(^2)</td>
<td>33°C &lt; Ts &lt; 17°C</td>
</tr>
<tr>
<td></td>
<td>17°C ≤ Ts ≤ 20°C</td>
</tr>
<tr>
<td></td>
<td>30°C ≤ Ts ≤ 33°C</td>
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<tr>
<td></td>
<td>20°C &lt; Ts ≤ 25°C</td>
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<tr>
<td></td>
<td>25°C &lt; Ts &lt; 30°C</td>
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<td>Population presence/ density (PD)(^3)</td>
<td>PD ≤ 250 people or unknown</td>
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<td>250 people &lt; PD ≤ 1000 people</td>
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<tr>
<td></td>
<td>1000 people &lt; PD ≤ 10,000 people</td>
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<tr>
<td></td>
<td>10,000 people &lt; PD ≤ 100,000 people</td>
</tr>
<tr>
<td></td>
<td>PD &gt; 100,000 people</td>
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<td>Occupation-related exposure (OE)(^4)</td>
<td>urban areas</td>
</tr>
<tr>
<td></td>
<td>coastal fisheries - few Anopheles mosquitoes are present</td>
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<td></td>
<td>forest-related subsistence activities</td>
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<tr>
<td></td>
<td>rice-paddy agriculture</td>
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<tr>
<td></td>
<td>plantation, logging, and mining(^5)</td>
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<tr>
<td>Access to care (AC)(^6)</td>
<td>expert opinion</td>
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<td></td>
<td>expert opinion</td>
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<td>expert opinion</td>
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<td>expert opinion</td>
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<tr>
<td>Subclinical parasitemia (SP)(^7)</td>
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<tr>
<td>Malaria Burden Potential (MBP)(^8)</td>
<td>MBP &lt; 1.5</td>
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<tr>
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<td>1.5 ≤ MBP &lt; 2.5</td>
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<tr>
<td></td>
<td>2.5 ≤ MBP &lt; 3.5</td>
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<tr>
<td></td>
<td>3.5 ≤ MBP &lt; 4.5</td>
</tr>
<tr>
<td></td>
<td>MBP ≥ 4.5</td>
</tr>
</tbody>
</table>
MMEWS reporting (8-day update)

1. Spatial:
   Landscape object-level reporting - maps

2. Non-spatial:
   Township-level aggregated - tables
Task 4
Testing, verification, deployment
Questions?