Development of Malaria Early Warning System (MEWS) using Remote Sensing and Geographical Information Systems

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1. INTRODUCTION

Improved prediction, prevention, and control of epidemics are key technical goals of the Roll Back Malaria (RBM) partnership. The International Research Institute for Climate and Society (IRI) is a Pan-America and World Health Organization (PAHO/WHO) Collaborating Centre on early warning systems for malaria and other climate sensitive diseases. To improve epidemic control in climate-sensitive regions, the WHO has proposed the development of integrated Malaria Early Warning Systems (MEWS) based on vulnerability assessment, seasonal climate forecasts, weather and environmental monitoring, and case surveillance (WHO, 2001).

The IRI is working with National Malaria Control Program (NMCP) in several countries in Africa to develop WHO-MEWS. By studying the pattern of historical malaria incidence, an epidemic vulnerability map is produced. By investigating the relationship between environmental variables (rainfall and vegetation) and year-to-year variability of malaria, epidemic risk monitoring opportunities are identified. The use of satellite data to monitor rainfall and vegetation is then developed through the use of the IRI Data Library to provide the satellite data and analysis to the NMCP. This presentation describes the methodology, the results obtained and the delivery of a MEWS using the example of the NMCP in Eritrea.

2. METHODS

The MEWS framework sets out a series of activities that together form the basis of an integrated monitoring process to identify changes in epidemic potential and increased risk of transmission in areas prone to epidemics (Figure 1). The first MEWS monitoring component involves consideration of the dynamic factors that may make populations more vulnerable to severe epidemics. Drought, inadequate food security, and nutritional and economic status are important factors that increase a region's level of vulnerability. Increasing levels of drug or insecticide resistance, reduction in health service provision, or a high burden of other diseases, such a HIV/AIDS, may also compromise any immunity and increase vulnerability to epidemics. While these factors are unlikely to indicate when an epidemic might occur, they do provide some warning of the severity that can be expected if one does occur. The second MEWS monitoring component considers the forthcoming season's climate. Will it be a drier, normal, or wetter season? What does this mean for epidemic risk considering the recent history? The third MEWS component is monitoring the weather as it occurs. Are temperatures unusual for this time of year? Is the rainfall higher than would normally be expected? Due to the extensiveness of the areas affected, remote sensing is an ideal source on which to base an early warning system for monitoring rainfall and vegetation (Ceccato *et al*., 2005). The fourth monitoring component is epidemiological surveillance. Detection of an epidemic through a rapid increase in the number of confirmed cases is the most reliable mechanism; however, routine case reporting systems in most African countries are unable to detect epidemics in sufficient time to enable an effective response.

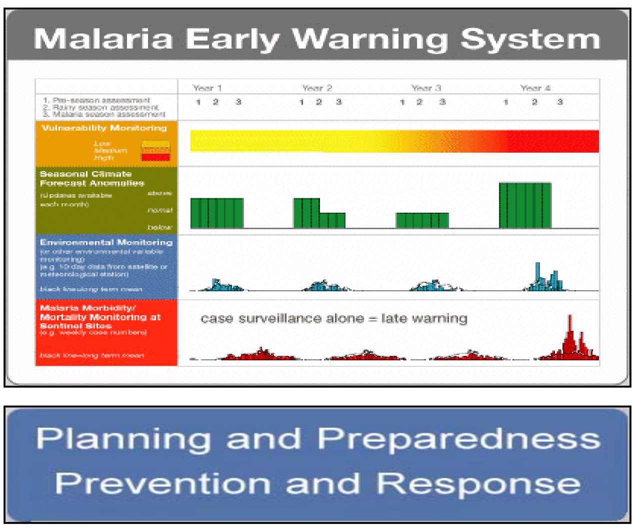

Figure 1: Malaria Early Warning System Framework (WHO, 2001)

Based on this framework, studies are conducted to (1) identify where and when the population is at risk of malaria based on historical malaria incidence data and create a stratification map; (2) analyze the usefulness of climate forecast; (3) analyze the links between rainfall and vegetation and malaria incidences; and (4) integrate and deliver a MEWS to the NMCP.

3. RESULTS

The following examples illustrate the MEWS developed for the NMCP in Eritrea.

3.1. Stratification map for vulnerability:

A stratification map was developed to assist decision makers to identify where and when to implement malaria intervention programs. The map was created using a principal component analysis and a nonhierarchical clustering procedure to group administrative districts according to similarities in the timing and intensity of malaria transmission based on historical clinical malaria monthly incidence data from Eritrea for 1996 to 2003 (Figure 2).

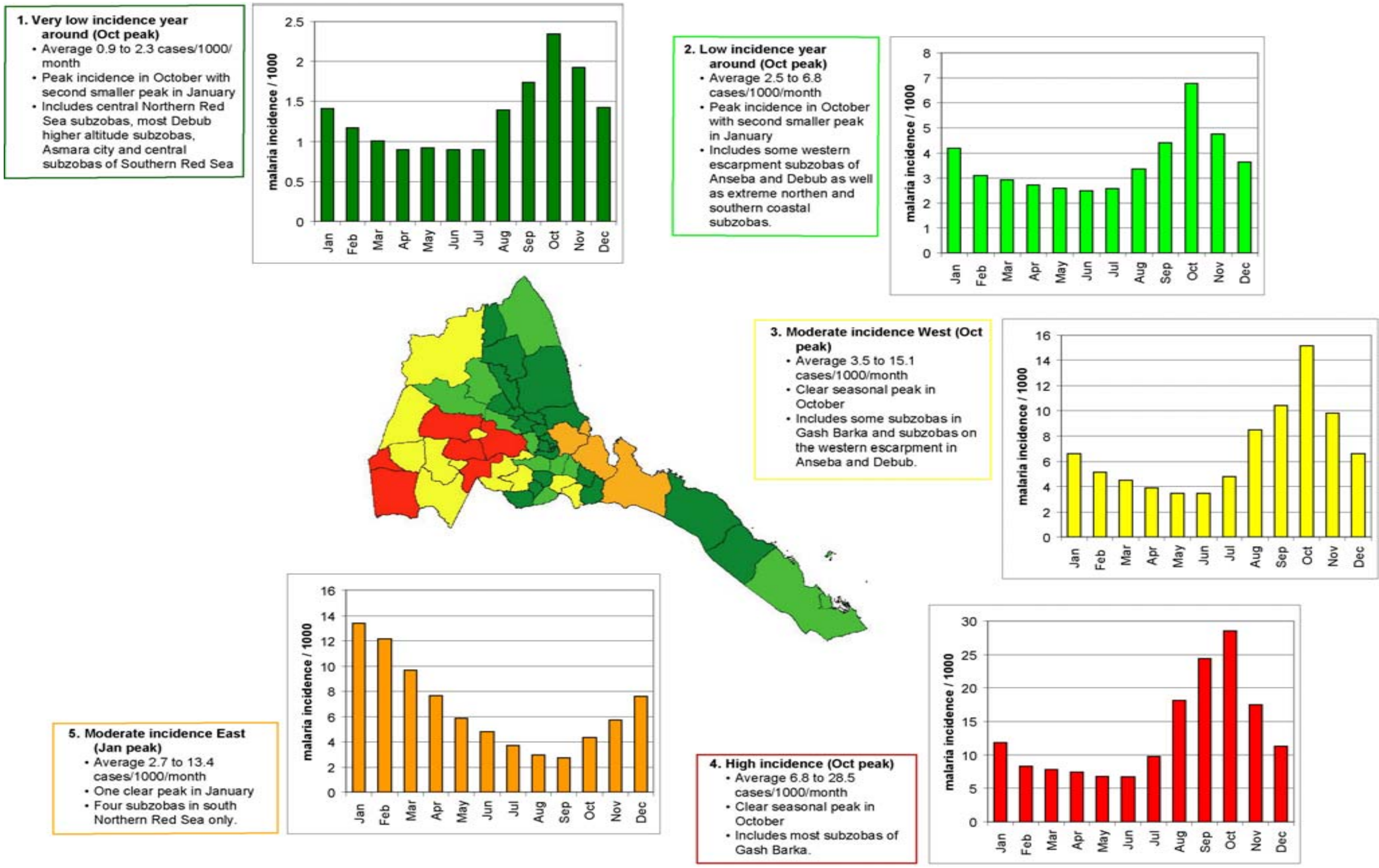

Figure 2: Map of Malaria incidence with sub-districts grouped into five clusters. Graphs show profile of malaria incidence within clusters.

3.2. Climate Forecast

Forecast products for precipitation, such as the one produced monthly by IRI, can be used for predicting rain for the following season (three months) (Figure 3). Analysis of rainfall in Eritrea shows high correlation coefficients (0.6–0.8) for several stations for the period October–December with ENSO (El Niño/Southern Oscillation) if 1997 data are included. (A strong El Niño event occurred in this period in 1997). However, correlation values dropped dramatically if 1997 data were not included, implying that good predictability in terms of rainfall could be achieved for Eritrea only during a strong El Niño event.

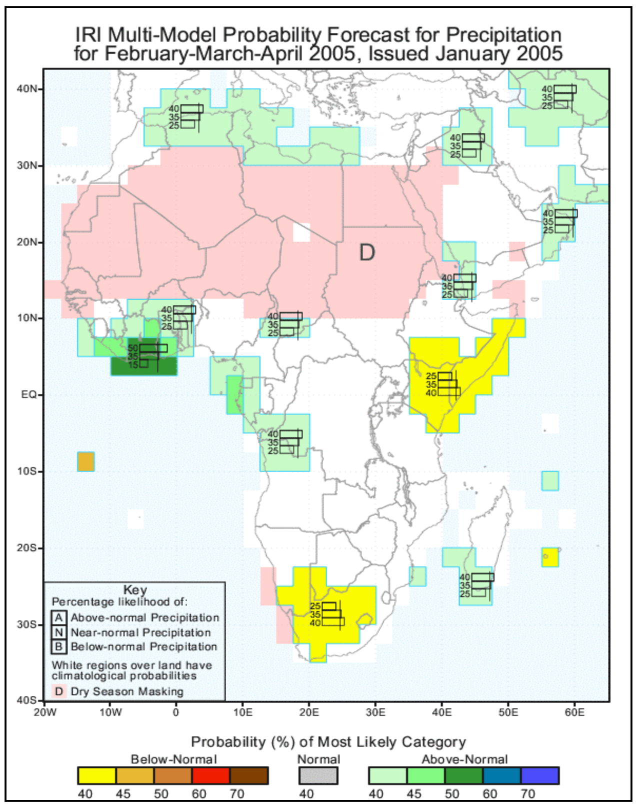

Figure 3: IRI Multi-Model Probability Forecast

3.3. Environmental Monitoring

Analysis of rainfall patterns using meteorological station data, rainfall estimated from satellite images, and malaria incidence indicated strong links between clinical malaria incidence and rainfall patterns across the country, with malaria incidence peaks lagging behind rainfall peaks by 2 to 3 months. Analysis of seasonal vegetation development in relation to malaria anomalies also showed high correlations in a large number of sub-districts in the northern part of Eritrea and along the coast, where grasses are the predominant species (Figure 4).

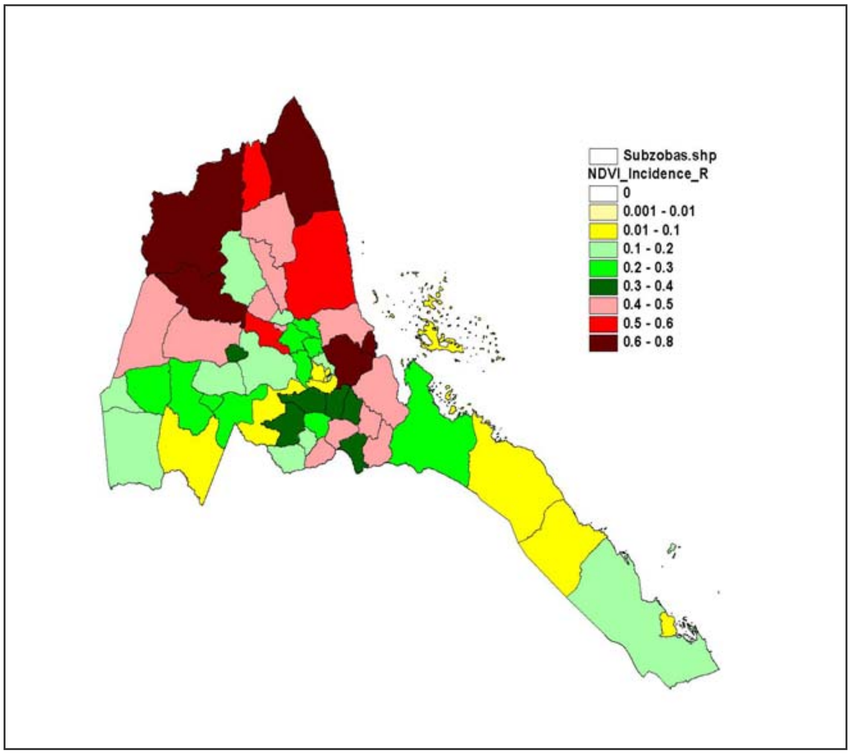

Figure 4: R^2 for significant stepwise regression between Normalized Difference Vegetation Index anomalies and concurrent malaria incidence anomalies

IRI has developed a Web-based interface that enables users to gain a broader contextual perspective of the current rainfall season by comparing it to previous seasons and climatological averages (Grover-Kopec *et al.,* 2005). The interface is in the IRI Data Library and takes the form of an online "clickable map" of Africa: http://iridl.ldeo.columbia.edu/maproom/.Regional/.Africa/.MEWS/. It displays the most recent decadal (10-day) rainfall map (Figure 5), over which national and district administrative boundaries and the epidemic risk zone can be layered. These visual features can be toggled on or off and the user can zoom in to any district for more clarity. Decadal rainfall can be spatially averaged over a variety of user-selected areas, including administrative districts and 11x11km, 33x33km, 55x55km, and 111x111km boxes. Upon the selection of this sampling area and a specific location of interest (by clicking on the map), four time-series graphs are automatically generated (Figure 6). These time-series graphs provide an analysis of recent rainfall with respect to that of recent seasons and the overall climatology. This system was used to analyze rainfall patterns in conjunction with malaria incidence data.

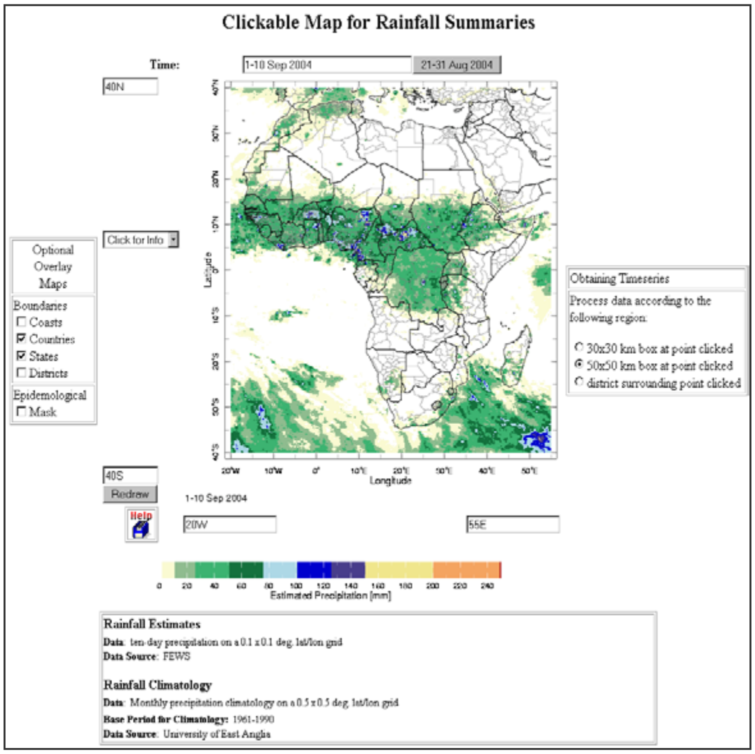

Figure 5: MEWS IRI “Clickable Map” for Rainfall Monitoring

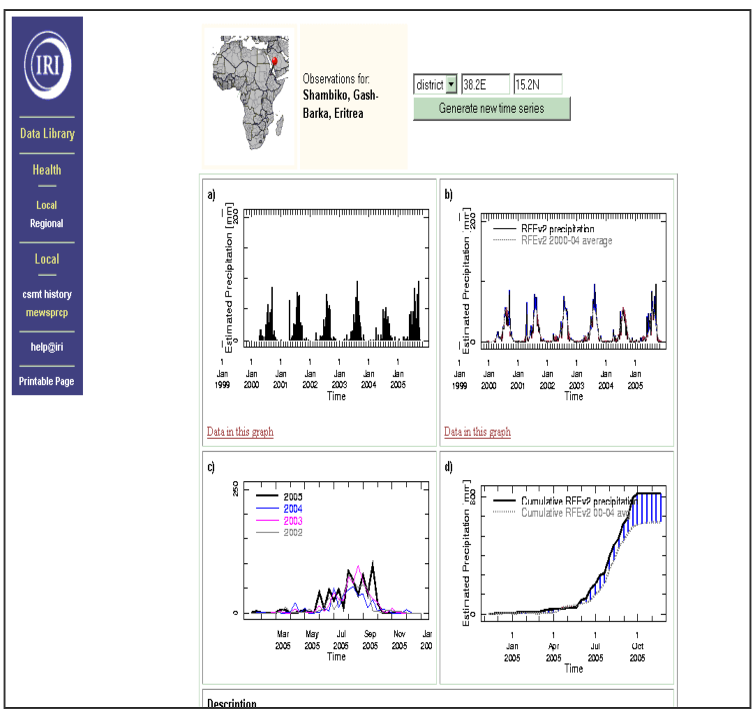

Figure 6: Summary information on current rainfall/seasonal development for location of interest (in this case: Habero, Anseba, Eritrea)

The presence of vegetation (which is used as a proxy for mosquito survival conditions in terms of humidity) is also monitored using satellite data from the Terra–Moderate Resolution Imaging Spectroradiometer (MODIS) at 250m spatial resolution. The images are provided via the IRI Data Library every 16 days to the NMCP and can automatically be integrated into a Geographical Information System (GIS) such as ESRI/ArcView® or WHO/HealthMapper (Figure 7).

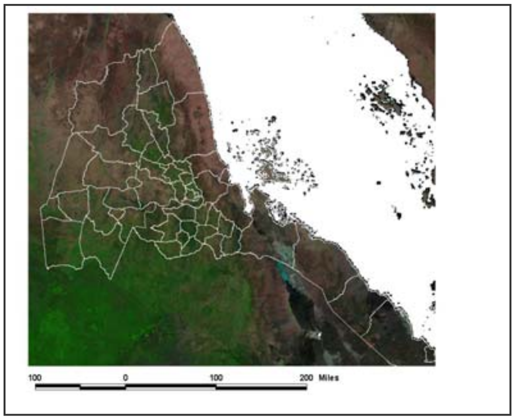

Figure 7: MODIS image showing vegetation in green, bare soil in brown, and bodies of water in blue.

3.4. Integrate and Deliver Malaria Early Warning System

Based on the stratification map and information on rainfall and vegetation provided by the satellite data, the MEWS was implemented in collaboration with the NMCP in Eritrea. Training on the use of the satellite images (rainfall, vegetation) and integration within a GIS was conducted with NMCP district and personnel coordinators (Figure 8).

Figure 8: Workshop on MEWS conducted in July 2005 at Asmara, Eritrea

Currently, the information on rainfall and vegetation issued from the satellite images is pre-processed within the IRI Data Library, then downloaded and analyzed at NMCP headquarters in Asmara. From Asmara, the information is sent to coordinators at the district levels in Eritrea.

4. CONCLUSIONS

MEWS based on the WHO framework are developed and implemented by IRI in different countries in Africa. The example of MEWS for Eritrea showed how a stratification map is created based on historical malaria incidence data to help decision makers identify where and when to implement malaria intervention programs. The IRI investigate the interaction between environmental factors (rainfall and vegetation) and malaria incidences. Monitoring rainfall and vegetation from remotely sensed images provides a tool for the decision makers to forecast where and when there will be increased risk of a malaria epidemic. The MEWS are developed and implemented in collaboration with the NMCP in countries.

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