DEVELOP Project Uses Satellite Data to Help Control Malaria in Zanzibar

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Introduction

According to a 2013 study published by the World Health Organization (WHO[1]), across the globe malaria is considered endemic in 104 countries and territories, with some 3.4 billion people—and children, especially—at risk of the disease.

Given these facts, there is increasing consensus that the practical policy option for dealing with malaria is to pursue a global policy of progressive elimination and aggressive control in high-burden areas, potentially leading to its eventual eradication. Some African countries have chosen this path and are already developing malaria control and elimination strategies along with *aid delivery roadmaps*, plans to effectively target and distribute resources and to prevent malaria from being reintroduced into regions where control strategies have been successful.

New strategies to eradicate malaria require understanding how interventions affect the transmission of the disease across different geographic areas, in varying climates, and where detailed land-surface processes affect vector[2] population dynamics and behavior. Climate variability and change at multiple spatial and temporal scales are among the most important factors in the transmission of malaria. A key problem in collecting appropriate data is that, owing to a lack of much needed resources, and consequently the infrastructure necessary to acquire and process such data, it is often difficult to collect the *in situ* meteorological and ecological data needed to establish links between environmental factors and the spread of vector-borne diseases.

Some of these problems can be overcome by using Earth-observing satellite data to fill these "data voids." The remainder of this article describes a project conducted under the auspices of NASA's DEVELOP Program[3] in which data from the International Space Station (ISS) SERVIR[4] Environmental Research and Visualization system (ISERV) camera are being compared with data from the Landsat 5 satellite to determine which data product produced the best results for classifying land cover on the island of Zanzibar. The results will be applied to help predict the occurrence of and/or track the spread of future malaria outbreaks in this area.

Study Area: Zanzibar

Zanzibar is located off the coast of Tanzania, in Southeast Africa. The island contains numerous lush forests and mangroves housing a plethora of rare species of flora and fauna. Its picturesque beaches and striking landscapes have propelled tourism to be a major economic driver in the country. Unfortunately, some of those eye-catching landscapes can provide fertile breeding grounds for mosquitoes; therefore, periodic outbreaks of malaria have been problematic for Zanzibar.

Currently, Zanzibar employs several malaria control methods, such as insecticide-treated nets, indoor-residual spraying, and a *combination therapy* based on the use of artemisinin (derived from the sweet wormwood plant) along with some other treatment modality. The combination approach is necessary because malarial parasites in this area appear to be becoming drug-resistant and WHO has explicitly discouraged *monotherapy*—i.e., using artemisinin alone.

Important Satellite Data: Landsat and ISERV

Since a key factor in predicting where malaria outbreaks are likely to happen is knowledge of the land surface, land imagery from satellite remote sensing can be a valuable tool. In this study, a series of images taken by the ISERV camera system were used in concert with a single image from the Thematic Mapper (TM) onboard Landsat 5 to identify which product better classified land cover for Zanzibar, where malaria transmission is still present.

Landsat Image

The Landsat image chosen for the classification was a Landsat 5 image from July 1, 2009, obtained from

[1] The WHO *World malaria report 2013* is available for download at *www.who.int/malaria/publications/world_malaria_report_2013/report/en.*

[2] A *vector* is any agent that carries and transmits pathogens to another organism.

[3] The NASA DEVELOP National Program fosters an interdisciplinary research environment where applied science research projects are conducted under the guidance of NASA and partner science advisors. For more information, visit *develop.larc.nasa.gov/about.html.*

[4] SERVIR is a joint NASA and U.S. Agency for International Development effort that provides analyses and applications from space-based, remotely sensed information to help developing nations in decision-making processes that address natural disasters, climate change, and other environmental threats. SERVIR is an acronym meaning "to serve" in Spanish.

the 2010 Global Land Survey—shown on the left in **Figure 1**. This particular image was chosen because it was the only image from Landsat 5, 7, or 8 that did not have cloud cover over the island. Unfortunately, because the image was obtained from Landsat 5, panchromatic sharpening could not be used (since the panchromatic band was not available until Landsat 7) to enhance the resolution of the image for classification purposes. Despite this limitation, however, the resolution of the Landsat image was an eminently useful 30 m (~98 ft).

ISERV Images

The ISERV images chosen for the classification comparison were acquired from NASA's Global Hydrology Resource Center[5]. Unlike the Landsat image, the ISERV images were only able to cover the northern portion of the island due to the camera's smaller viewing area, but they had a higher spatial resolution of approximately 3 m (~10 ft). Despite the reduced aerial coverage, the area covered in the ISERV images contained various land cover types, so it was still a viable candidate for the comparative analysis. As explained in the next section, the image on the right in Figure 1 shows the area covered by all of the mosaicked ISERV images that were used in this study.

Classifying and Reclassifying the Data

The land-cover determination for the Landsat data was done using an *Iso-Cluster analysis*—an unsupervised classification tool in the *ArcMap* geographic information system (GIS). To complete the classification, the ISERV scenes were mosaicked in *ENVI*, a commercial platform for advanced image processing and geospatial analysis. After that, another unsupervised classification was performed, this time, to classify the mosaicked scene. Both the Landsat image and the mosaicked ISERV images were classified with many different parameters such as the number of classes, minimum class size, and differing sample intervals for the classes. The ideal classifications were selected by visually comparing the results of the classifications with a ground-truth map and *in situ* photos.

After the various classifications were performed on the images, the maps with the classifications that were most similar to the ground-truth map were chosen and then reclassified based on the ground-truth map. Certain land cover types (e.g., forest) in the reclassified images were originally spread over numerous classes and were subsequently combined to match the ground truth map as best as was practicable.

As shown in Figure 1, the Landsat 5 image outperformed the ISERV images in differentiating between the various land cover classes. The Landsat classification was able to adequately classify brush and shrub areas, forest, urban areas, mangrove swamps, and sugarcane and rice fields. One of the limitations found when using the Landsat 5 classification was that it would sometimes incorporate high-reflectance areas (such as coastlines) into the same class as urban areas.

[5] For more on the Center, visit *earthdata.nasa.gov/about/daacs/global-hydrology-resource-center-ghrc-daac*.

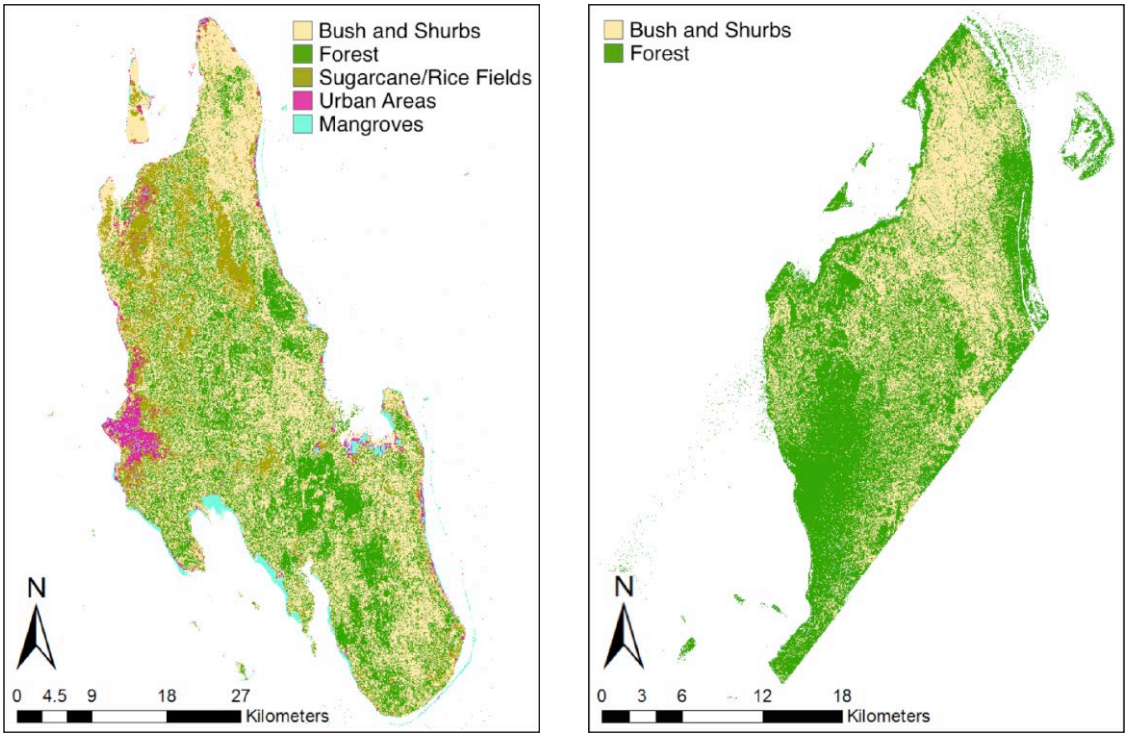

Figure 1. Finalized classification maps using an Iso-cluster unsupervised classification analysis on a Landsat 5 Thematic Mapper image [*left*] and on a set of mosaicked ISERV images [*right*]. Note the scales of these maps are different; the ISERV images only covered the northern portion of the island but had much greater spatial resolution than Landsat 5. **Image credit**: Jerrod Lessel

The ISERV images generally were not able to differentiate between the various land-cover classes. The image classes had a tendency to overlap after reclassification; consequently, distinct regions were not apparent. The only classes that could be viewed as similar to the ground-truth map were the brush/shrubs class and the forest class, and these classes tended to overextend into other classes (such as urban areas and sugarcane/rice fields). A beneficial result from the ISERV classification was that it was able to identify some high-spatial-resolution features such as roads—as shown in **Figure 2**.

The Best of Both Worlds

Each of the final maps were compared with *in situ* field photos to further verify that the classes were properly differentiated—with results as shown in **Figure 3**.

The combination of using the overall land-cover classes from Landsat alongside the higher-spatial-resolution classifications from ISERV will prove useful in tracking the spread of malaria throughout Zanzibar and better identify fertile breeding grounds for the mosquitoes that transmit the disease. The Zanzibar Malaria Control

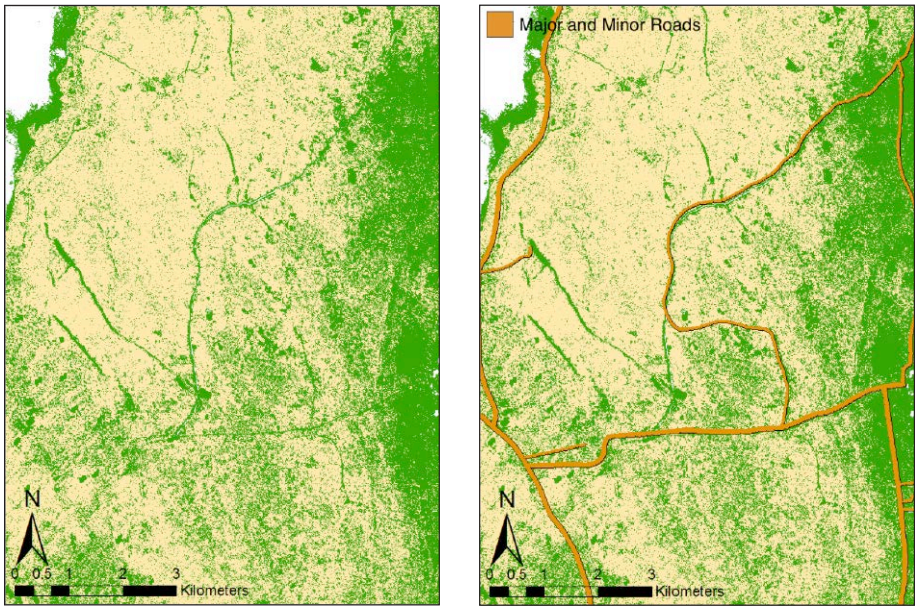

Figure 2. While ISERV in general was not as effective at classifying the land cover as Landsaat 5, the higher resolution allowed for some smaller scale features, e.g., roads, to be identified. Shown here is a zoomed-in portion of the classified ISERV image from Figure 1 [*left*] overlaid with a major and minor roads shapefile [*right*]. **Image credit**: Jerrod Lessel

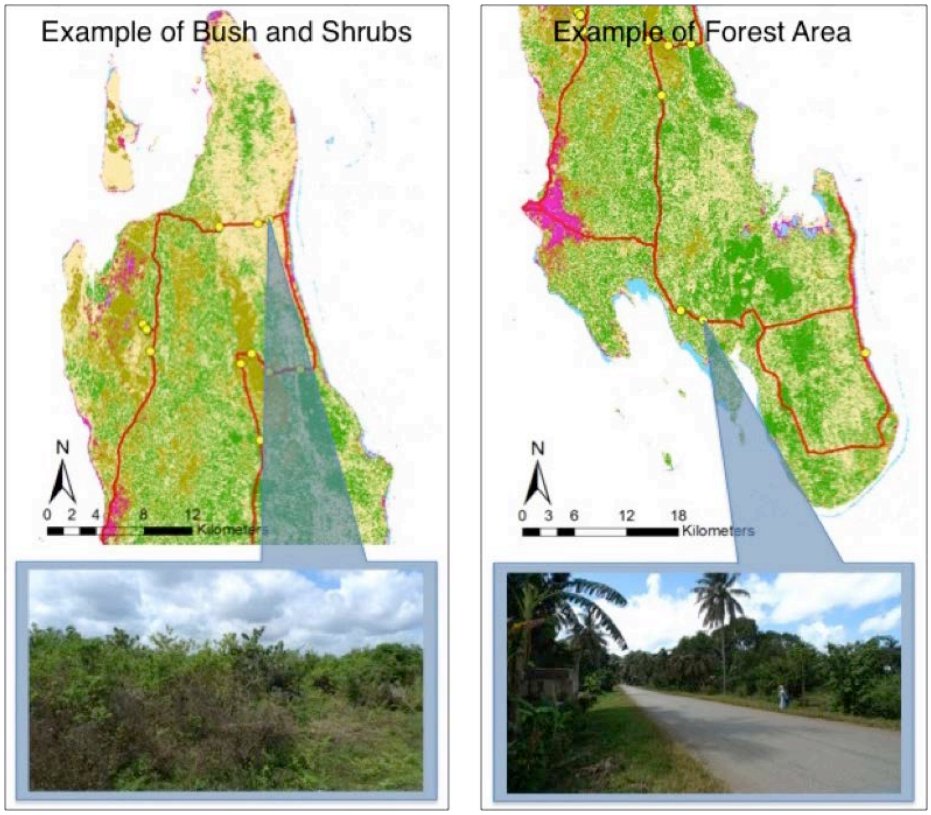

Figure 3. The final Landsat 5 classification map was validated against *in situ* field photos. Each map [*top*] shows where the photograph below it was obtained (yellow boxes). The photographs are examples of two of the land cover types used in the study (listed on Figure 1): an area classified as *brush and shrubs* [*bottom left*] and an area classified *forest* [*bottom right*]. The red line on each of the maps shows the path the researcher in the field took during his time on the island. **Photo credits:** Pietro Ceccato

Program (ZMCP) will be able to use these products and combine them with their own malaria data to help track the distribution and spread of malaria.

Conclusion

A key factor in predicting where malaria outbreaks are likely to happen is knowledge of the land surface. This article has described a NASA DEVELOP study to test the effectiveness of using land classifications from satellite remote sensing as a means to help control the spread of malaria in Zanzibar. The study used both a Landsat 5 image and a series of mosaicked ISERV images, and the results revealed benefits with respect to the classification from both types of images. The Landsat 5 image was able to accurately classify the brush/shrubs, forest, urban areas, mangroves, and sugarcane/rice fields land cover classes. While the ISERV images were not able to differentiate between the various land cover classes nearly as well, they were able to classify high spatial resolution features such as roads that the Landsat 5 image could not detect. One of the main benefits of using remotely sensed products such as the ones used in the methodology described in this study is that the maps can be updated to include additional *layers*, e.g., ecosystem conditions and urban growth change. Hence there are opportunities to expand this study in the future. Using this methodology and the maps created, the ZMCP can more accurately track how malaria responds to these changing ecosystem conditions and urban growth in an effort to eradicate malaria on Zanzibar. ■

In Memoriam

Angelita "Angie" Castro Kelly, the first woman to become a NASA Mission Operations Manager (MOM), passed away on June 7, 2015, at the age of 72.

Angie served as Earth Observing System Constellation Team Manager and played an active role in guiding the Earth science Morning and Afternoon Constellations from concept to reality. As the constellation mission manager she conducted numerous Mission Operations Working Group meetings for constellation members, where she brought together diverse groups of engineers and scientists from the U.S., the U.K., Netherlands, France, Japan, and Argentina. The continuing success of these two Earth science constellations is a testament to her leadership. In addition, Angie served as the Science Interface Manager and was the liaison between ESMO and the instrument teams for Terra, Aqua, and Aura.

She once said, "I'm the first woman MOM, so I cracked the ceiling. Before me, all the MOMs—which is kind of funny—were men[1]." Angie joined the Earth Science Data and Information System (ESDIS) team in 1990, which later became known as the Earth Science Mission Operations Office (ESMO). In her role as EOS MOM, she developed early mission operations concepts for many of the EOS missions now in orbit. Before becoming EOS MOM, Angie had a career in manned space flight. She was the project manager for the highly successful Space Shuttle/Spacelab Data Processing Facility, which she helped develop. She learned how to work with science data users to understand their requirements as she negotiated agreements with NASA's Johnson Space Center, NASA's Marshall Space Flight Center, and NASA's international partners in Germany and Japan.

Born in Isabela province in the Philippines in 1942, she grew up in Sampaloc, Manila, graduating with a bachelor's degree in Mathematics and Physics at the University of Santo Tomas (UST). She later finished her master's degree in physics at the University of Maryland. Kelly reaped numerous awards in her distinguished career, including the *NASA Exceptional Achievement* and *Exceptional Service Medals*, the *Goddard Space Flight Center Exceptional Service Award*, the *Manned Flight Program Launch Honoree Award*, the *Goddard Space Flight Center Exceptional Performance Award*, and the unique *Astronauts' Manned Flight "Snoopy" Award*.

The Earth Observer staff extends its condolences to Angie's family and her NASA colleagues as we all mourn her loss.

[1] From Kelly's interview in *The Great Ilocanos* interview series (2012) which can be viewed at *www.youtube.com/watch?v=IH-zJwhYtWc*.