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The Use of Radar Remote Sensing for Identifying Environmental Factors Associated with Malaria Risk in Coastal Kenya

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ABSTRACT - Malaria remains one of the greatest killers of human beings, particularly in the developing world. The World Health Organization has estimated that over one million cases of Malaria are reported each year, with more than 80% of these found in Sub-Saharan Africa. The anopheline mosquito transmits malaria, and breeds in areas of shallow surface water that are suitable to the mosquito and parasite development. These environmental factors can be detected with satellite imagery, which provide high spatial and temporal coverage of most of the earth's surface. The combined use of remote sensing and GIS provides a strong tool for monitoring environmental conditions that are conducive to malaria, and mapping the disease risk to human populations.

Since many vector-borne diseases such as malaria are prevalent in tropical areas, persistent cloud cover often presents a challenge to remote sensing operations. Radar remote sensing has the capability of penetrating clouds, providing a solution to the cloud-cover problem often experienced with optical satellite remote sensing. This research investigates the use of RADARSAT-1 data for monitoring and mapping malaria risk in coastal Kenya. An object-oriented approach to image classification is taken in order to circumvent some of the limitations of traditional pixel-based classification of radar imagery. GIS routines are used to assess how classified land cover variables relate to the presence and abundance of malaria-carrying mosquitoes and their proximity to populated areas, in order to generate a malaria risk map.

I. STUDY AREA

The study site is located along the eastern coastal plain for Kenya, near the town of Mombasa, where malaria is a severe health concern. The environment consists of a mix of indigenous forest, grassland savanna, mangrove swamps, and wetland vegetation. Agriculture plantations (mainly coconut, sisal and cashews) are also found along the coast. The ground elevation ranges from sea level to approximately 400 metres above sea-level (ASL) and there are several small rivers that flow from the highlands to the Indian Ocean.

Mosquito larval habitats in this area are diverse and change with the season. During the dry season, some rivers and streams become completely dry, while others have reduced flow and numerous isolated, residual pools of water in the main riverbed. Portions of mangrove swamps stay permanently flooded throughout the whole year. Seasonal swamps are also present and some are used for rice cultivation during the rainy season. These land cover types are particularly conducive to mosquito breeding.

II. DATA

The focus of this research is on the usefulness of RADARSAT-1 data for monitoring and mapping malaria in coastal Kenya. Four multi-temporal standard mode ascending pass scenes were acquired, with a nominal spatial resolution of 25m and swath coverage of 100 km^2.

The RADARSAT-1 images were acquired for both the dry season (20/03/1999 and 09/03/2001) and for the wet season (11/10/2001 and 4/11/2001). In this region of Kenya, March marks the end of the dry season with average monthly rainfall of 60 mm. The October 2001 and November 2001 images were both acquired during the short annual rainy season, with average monthly rainfalls of 90.2 mm and 96.4 mm respectively (www.worldclimate.com).

Six main land cover classes were identified for this study: water, forest type 1, forest type 2, agriculture, grassland, wetland and urban areas. Forest type 1 consists mainly of indigenous trees and rain forest, and forest type 2 consists mainly of mangrove forest. For each class, 7-12 ground truth areas were identified and used as training sites in the image classification routine.

III. METHODOLOGY

Images were processed, geo-corrected, registered, filtered and enhanced, in order to obtain useful input images for the image classification. Speckle reduction was done with an adaptive filter, to smooth the data while preserving edges. Texture analysis was also carried out on the original images to extract information about the variations in image tone.

Image analysis was performed using *eCognition* software - a classification analysis package that uses an object-based approach rather than the traditional pixel-based routine. Image data is classified based on parcels of pixels known as 'objects' that are created using a segmentation routine, which separates significantly contrasted adjacent regions in an image based on image brightness values, and extracts the homogeneous regions as individual objects [1].

Following segmentation, a classification was performed using the multi-temporal filtered and texture analysis images as input. A standard nearest neighbour classification was performed based on user-specified training objects. The resulting classification was validated with test sites.

Classified polygons were extracted as GIS layers for use in the malaria risk map generation procedure. The premise for assessing areas at risk of malaria infection is based on the maximum distance a malaria-carrying mosquito can travel from its breeding ground to infect human hosts. For this study, a two-kilometre buffer zone around the classified larval breeding grounds was used [2] [3], and the wetland class was considered to be most conducive to larval breeding [4] [5] [6] [7]. With this information, a risk map was generated to show the populated areas that lie within the two-kilometre buffer zone around the wetland areas.

IV. RESULTS

The resulting classification was assessed at 85.5% overall accuracy. Figure 1 shows the classification results for the populated areas. The town of Mombasa (island in south part of image) is clearly identified as populated, smaller villages found in the middle part of the image. The bright radar backscatter response and textural information allowed for accurate classification of the populated areas, at 93.2%.

Classified as wetlands are shown in figure 2. The accuracy for this class was found to be 65.3%, with significant confusion found between the wetland and forest type 1 classes. Forest type 1 (mangrove forests), are characterised by flooded areas with emergent vegetation. For this reason, backscattering characteristics, as well as textural information are similar to wetlands. Due to the similarities in environmental conditions, both landscape variables may be considered as high risk in terms of malaria breeding sites.

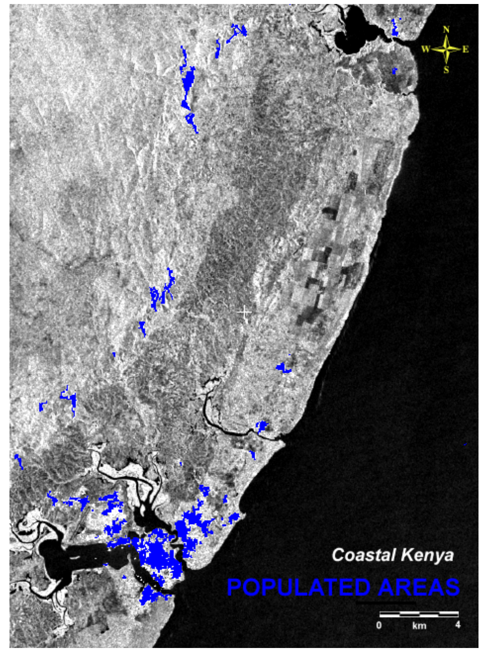

Figure 1 Map of populated areas in the coastal Kenya study site

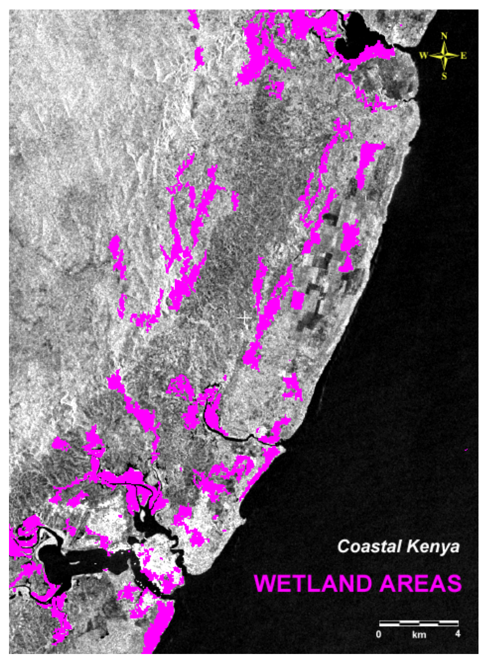

Figure 2 Map of wetland areas in coastal Kenya study site

A radius of two kilometres around the wetland objects served to determine the areas where malaria-carrying mosquitoes may be present. A buffering algorithm was used to produce the results seen in figure 3.

A final step identified populated areas that fall within the two-kilometre radius of the wetland areas. Figure 4 shows the results of this routine – a map of populated areas at risk of malaria.

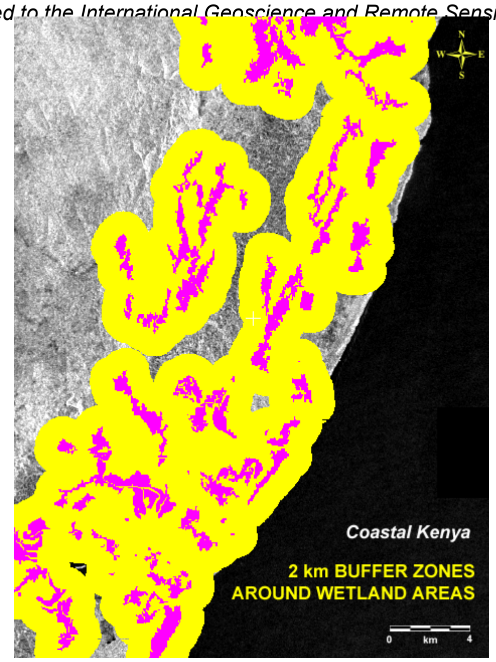

Figure 3 Map of 2 km. buffer zones around wetland areas.

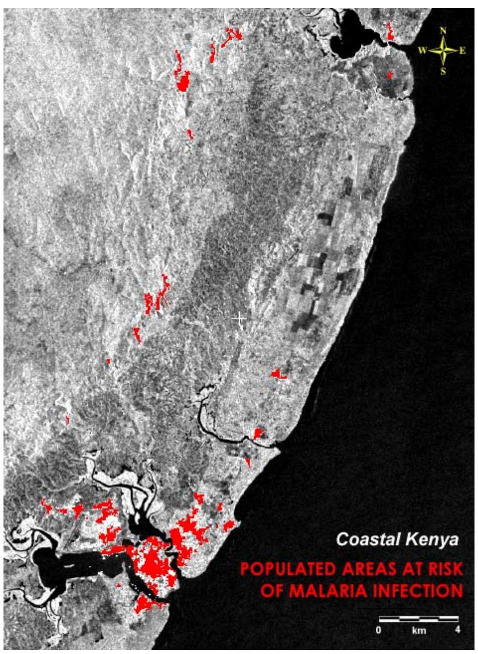

Figure 4 Map of populated areas at risk of malaria in coastal Kenya

98.6% accuracy was achieved for water targets as the dominant scattering mechanism (specular reflection) produces a consistently dark tone. The large areas of grassland savannah in the highlands of the study site are relatively homogeneous and were classified with 97.3% accuracy. More complex targets such as wetlands and forests were classified between 60-75% accuracy. Agriculture targets produced an accuracy of only 53.8%, due to the different tones and textures from various crop types and growth stages.

V. CONCLUSIONS

This study demonstrates the methodology of using SAR images for identification of land cover variables that may be associated with malaria-carrying mosquito breeding. The use of *eCognition* software demonstrated the importance of object-oriented classification for SAR data, which allows for quantification of surface patterns that are not adequately done with per-pixel approaches [8] [9]. The use of RADARSAT-1 imagery in this research filled a gap where no cloud-free optical satellite data were available. This, as well as SAR's sensitivity to surface geometry and target moisture conditions, is the main advantages of SAR data for disease monitoring applications.

Many tropical areas like the Kenya coast face a serious and growing problem relating to environmental health. There is a strong need for an operational disease surveillance tool in these areas. This research demonstrates how SAR remote sensing could play a critical role in addressing this need.

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