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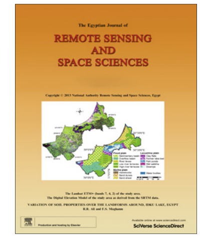

RESEARCH PAPER

Characterization of landscape features associated with mosquito breeding in urban Cairo using remote sensing

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Abstract Problems of mosquito vectors proliferation have been increasing in Cairo in conjunction with urbanization and industrialization where several anopheline and culicine species have been collected. The present study was carried out to characterize the landscape variables potentially associated with mosquito breeding in a subset of urban Cairo. The study compared the capabilities of two satellite sensors, namely Landsat TM5 and Ikonos; in such endeavor. The study area encompassed 18 urban districts of Cairo. Mosquito breeding habitats were characterized within the district level using integrated remote sensing and geographic information system (GIS) analyses. Different environmental variables derived from both satellite imageries were used to characterize landscapes of districts where mosquito breeding habitats occur. These variables include urbanization level, Land Use Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), wetness, and Band 2/Band 4 (B2/B4) ratios. The majority of mosquito breeding sites (93.5%) were found in slum areas. For both sensors, districts where breeding sites occurred were characterized by significantly higher mean of soil percentage and lower mean of majority wetness. At this level of characterization, Landsat TM5 would be adequate for the major identification of habitat areas. For targeting mosquito larval control however, Ikonos would provide better inputs as it allowed a better classification of small land cover classes including water.

1. Introduction

Vector-borne diseases are becoming one of the major public health problems associated with rapid urbanization in many tropical countries (Knudsen and Slooff, 1992). Cairo is among the mega cities of the world where its population rose from 6.1 million in 1975 to 16.5 in 2000 (2.7% growth rate); and reached 18 million in 2006 (CAPMAS, 2006). Problems of mosquito vectors proliferation have been increasing in Cairo in conjunction with urbanization and industrialization that took place in the second half of the last century (Ossman, 2001). In recent

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years, several mosquito species have been collected from urban Cairo, of which many are vectors of diseases (e.g. Abdel-Megeed et al., 2003; Morsy et al., 2004; Ammar et al., 2012).

One of the challenges facing health authorities in urban areas is locating and surveying breeding habitats of mosquitoes for control measures. Modern technologies such as Geographic Information Systems (GIS) and remote sensing have been progressively used by health authorities to assist in these operations (Beck et al., 2000). Satellite remote sensing is increasingly being applied to locate and characterize breeding habitats of a variety of vectors especially mosquitoes (e.g. Impoinvil et al., 2008; Severini et al., 2008). The availability of low-cost, medium-resolution imageries; such as Landsat Thematic Mapper (TM5), and of commercial imaging satellites; such as Ikonos and QuickBird, offer new opportunities to assess urban habitats for disease vectors by providing very high spatial resolutions appropriate for mapping urban variables that may indicate the presence of vector habitats (e.g. Jensen and Cowen, 1999; Rongnoparut et al., 2005; Mushinzimana et al., 2006; Jacob et al., 2006; Bogh et al., 2007).

The present study was carried out to evaluate the utility of two remote sensing sensors; namely Landsat TM5 and Ikonos; to characterize mosquito breeding habitats in urban Cairo.

2. Materials and methods

2.1. Study area

The present study was carried out in a subset of Cairo Governorate covering a total area of 135 km^2 (Upper Left: 31° 12′ 40.5″ E, 30° 05′ 07″ N-Lower Right: 31° 20′ 57.58″ E, 29° 59′ 14.76″ N) and including 18 districts. Annual rainfall is low with a long-term average of 25 mm/year. Daily air temperatures vary between 35 °C and 38 °C in summer and 10–20 °C in winter (Egyptian Meteorological Authority, 1996).

2.2. Mosquito breeding habitats

Data concerning mosquito breeding habitats (31 sites) encountered within this area were collected by the senior author of this manuscript during the period April–September 2005. During this period, most breeding habitats were visited twice. Breeding habitats positive for mosquitoes were geo-referenced using a hand-held GPS unit; and their type, mosquito species present and their surroundings were described. Collected mosquito larvae were transported to the laboratory where they were taxonomically identified using the keys of Harbach (1985), Harbach (1988) and Glick (1992).

2.3. GIS database

A GIS-ready layer of Cairo districts' boundaries was purchased scale 1:50000. The 18 districts of the study area were selected and converted into a shape file using Arc GIS to produce the district map. Geographic coordinates of mosquito breeding sites were also converted into GIS format and were represented by a-point coverage.

2.4. Remote sensing data acquisition

Images of the study area were obtained from two satellite sensors; Landsat TM5 and Ikonos satellites. The Landsat TM5 image was acquired on 12 July 2005 while the Ikonos scenes were acquired on 8 May 2003; as no suitable images (with no artifacts and low or no cloud cover) were commercially available for the similar dates.

The Landsat TM5 scene (Path/Row: 176/39) has a 30 m multispectral resolution. A subset of the scene for 135 km^2 study area was extracted from the image. The Ikonos image with 1 m panchromatic and 4 m multispectral resolution was comprised of two separate scenes. A mosaic of the two Ikonos scenes was produced using ERDAS (Earth Resources Data Analysis System) Imagine version 8.7. Both Landsat TM5 and Ikonos images were geo-referenced to a UTM projection (zone 36 North) with a WGS-84 datum using known ground control points collected in the field with hand-held GPS units.

2.5. Image analysis

Different environmental variables were used to indicate and identify mosquito breeding habitats. These variables include urbanization level, Land Use Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), wetness, and B2/B4 band ratios. All variables were derived from both Landsat TM5 and Ikonos imageries, except the urbanization level was generated from Ikonos merged imagery. Ikonos merged imagery at 1 m resolution multispectral was generated by merging 1 m resolution panchromatic image with the 4 m resolution multispectral bands.

2.5.1. Districts' urbanization level

The study area was stratified into two main strata namely; planned and slum using Ikonos imagery. According to this stratification, planned areas were characterized by a network of hierarchical roads, the presence of basic services, infrastructures, and green areas. Slum areas were characterized by irregular settlements, partial construction or uncompleted buildings, disorganized network of roads, extremely narrow streets with many dead ends, absence of services and infrastructures, crowding and high population density. Visual interpretation was performed on the merged data by digitizing and tracing different urban strata using ERDAS Imagine. The district map was overlaid onto the urban stratification map to produce the urbanization level map. According to the percentage of different strata within each district, the 18 districts were categorized into four urban categories as follows: planned ($\geqslant$75% planned), slum ($\geqslant$75% slum), planned with minor slum (60–75% planned) and slum with minor planned (60–75% slum).

2.5.2. Land use land cover (LULC) classification

Supervised classification was performed to cluster pixels in the image into four classes namely: water, vegetation, urban and soil. This was done by defining areas of interest (AOI) that represented each of the four land cover classes in the output image. The maximum likelihood classification was performed to assign each pixel in the image to the class that has the highest probability.

2.5.3. NDVI

NDVI is calculated as a ratio between measured reflectivity in the red (0.63–0.69 μm) and NIR (0.76–0.90 μm) portions. These two spectral bands were chosen because they are most affected by the absorption of chlorophyll in leafy green