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Research Paper

Geospatial techniques for environmental modeling of mosquito breeding habitats at Suez Canal Zone, Egypt

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ABSTRACT

Egypt is currently witnessing a number of mega projects, along the axis of Suez Canal, which consequently have a great effect on environment and its biological components including mosquito vectors of diseases. This study is an attempt to explore the use and efficiency of integrated remote sensing-GIS techniques and field surveys for detection of mosquito breeding habitats at Suez Canal Zone. Remote sensing and field surveys provided the necessary verified ground truth information to the present study. A corrected Landsat8 image, acquired in Jan. 2015, was utilized to produce NDVI, NDMI and LST to identify environmental variables associated with mosquitoes breeding habitats. Concurrently, a GIS model was developed to predict probable mosquito habitats and areas under environmental risk of diseases transmission. Results revealed that *Culex pipiens* and *Ochlerotatus detritus* are the most abundant species in Suez Canal Zone recording total number of 362 larvae (51.86%) and 244 larvae (34.96%), respectively. The model predicted that Ismailia is the most subjected Suez Canal Governorate to mosquito borne diseases. It recorded the maximum levels of high risk, risk and vulnerable areas to mosquito proliferation; 6.06 km^2 (64.26%), 954.65 km^2 (54.58%) and 152.87 km^2 (80.09%), respectively. The developed prediction model achieved an accuracy of 80.95% and increased to 100% at sites where predicted larval habitats were ascertained by *in-situ* checks.

1. Introduction

Egypt is currently witnessing a number of mega projects, along the axis of Suez Canal, that aim to expand agricultural lands and logistics services in addition to ease population pressures on contracted Delta. These projects induce changes in land use/land cover which consequently have a great effect on environment and its biological components including mosquito vector of diseases (Abdel-Hamid et al., 2011). Such environmental disturbances may provide suitable habitats for mosquito vectors allowing their wider distribution into and around the project areas. All of these factors may cause health risks from emerging or re-emerging vector-borne diseases that would have impacts on the integrity of development projects aiming for the prosperity of Egyptians (Hassan et al., 1999, 2004; Hassan, 2001; Hassan and Onsi, 2004; Abdel-Hamid et al., 2011). The Suez Canal Zone is characterized by the distinguished energetic and environmental nature; therefore various mosquito species are spread in and around the area. Urban extension, dissimilar urban areas, existence of rural and desert areas consequently lead to the diversity of mosquito habitats (Martens and Hall, 2000).

Mosquitoes have a greater importance in terms of major public health problems. Approximately one million people died because of mosquito-borne diseases and about 247 million people become ill in tropical and subtropical areas of the world in 2006, as reported by the World Health Organization (WHO, 2008). The number of deaths was estimated to be decreased in 2009 to 781,000 (WHO, 2010). Different mosquito species belonging to genera *Culex*, *Aedes* and *Anopheles* serves as significant vectors of several serious diseases (Weaver and Reisen, 2010; Kilpatrick, 2011). This is arisen as a result of their abundance, ability for mosquitoes to carry disease-causing pathogens, recurrent infection and diversity (Njabo et al., 2013). Moreover, mosquito bites may cause a significant nuisance for mammals and humans which may have adverse economic consequences (Connelly and Carlson, 2009).

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Mosquitoes were irregularly surveyed starting from 1903 in Suez Canal Zone and continued till 1981 (Kenawy, 1988). Such surveys were followed by different investigators (i.e. El-Said and Kenawy, 1983; Harbach et al., 1988; Cope et al., 1995; Abdel-Hamid et al., 2011 and Abdel-Hamid et al., 2013; Ammar et al., 2012). According to these surveys, twenty-nine mosquito species belong to five genera (i.e. *Culex, Anopheles, Culiseta, Aedes* and *Uranotaenia*) have been encountered in the different parts of Egypt (Tawfick, 1990; Morsy et al., 2003). Twelve of these species were reported in Ismailia Governorate/Canal Zone (El-Said and kenawy, 1983; Harbach et al., 1988; kenawy and El-Said, 1990; Morsy et al., 1990; Bahgat et al., 2004).

Suez Canal Zone has an old history of vector borne diseases where about one third of the Suez Canal population was infected by malaria (Halawani and Shawarby, 1957). In 1936, very high malaria indices were detected in Ismailia governorate (Barber and Rice, 1937). Between 1982 and 1991, malaria was reported in 7 governorates including Port Said and Suez (Hassan et al., 2003). By the end of 1998 till now, no local cases were reported in the following years (kenawy, 2015). However, the risk of subsequent localized outbreaks of malaria cases exists due to infection of local anopheline mosquitoes by imported cases mainly from Sudan and Africa (Hassan et al., 2003). Moreover, Ismailia populations were infected by Rift Valley Fever virus (Ghoneim and Woods, 1983) with reported outbreaks among humans over the past four decades (Drake et al., 2013).

Integration between remote sensing and geographical information system (GIS) can be used as fast and powerful tools for determination of some environmental factors affecting proliferation of mosquitoes (Sowilem, 2014). Moreover, GIS tools could successfully be utilized to predict the habitat appropriateness, which can help in designing optimal mosquito vector control strategies based on precise spatial/temporal information database (Agarwal et al., 2012). Consequently, most of the developed countries are applying these systems to develop their own levels of policy to mitigate mosquito problems. Furthermore, geospatial mapping by using remote sensing offers the potential to identify larval habitats on a large geographic area that is difficult or impossible using field surveys. Globally, several studies have successfully utilized geospatial techniques (remote sensing and GIS) in environmental studies of mosquito (Hayes et al., 1985; Washino and Wood, 1994; Dale et al., 1998; Hay et al., 1998; Hassan et al., 2003; Li et al., 2006; Palaniyandi and Mariappan, 2012; Hanafi-Bojd et al., 2012; Palaniyandi, 2014, 2015).

Finally, the information about spatial distribution of mosquito species is still unavailable within the study area because of the local travelling difficulty to access this area for research. Even now, conducting field research, near the Suez Canal, often requires special permissions therefore urgent needs for more focused studies are arisen. The main objective of this research is to model the spatial distribution of probable mosquito breeding sites, including non-surveyed and inaccessible areas, at Suez Canal zone by integrating limited field surveys and laboratory identifications of larval mosquito species with remote sensing and GIS techniques.

2. Material and methods

2.1. Study area

The Suez Canal is situated in the northeast of Egypt and extends from Port Said, in the North, to Port Taufiq, near Suez, in the South. Extreme borders of the Canal lie between latitude 29° 5′ N to 31° 10′ N and longitude 32° 18′ E to 32° 35′ E. It connects the Mediterranean Sea at North to the Suez Gulf at South and thus to the Red Sea, as shown in Fig. 1. It is 165 km long and passes through an area of substantial agriculture, industrial and tourism activity. The canal cut through three different lakes; Manzala Lake in the north, Temsah Lake in the middle and Bitter Lakes in the south. The study area is located along the Suez Canal from Port Said, on the northern extremity, to Suez Governorate including the three Suez Canal governorates; Port Said, Ismailia and Suez. The area under investigation occupies 7445.87 km^2 and lies between latitude 29° 30′ N to 31° 30′ N and longitude 32° 10′ E to 32° 40′ E. It is bordered from the north by Mediterranean Sea, west and south by eastern desert, and from the northern east by Sinai Peninsula.

2.2. Survey of mosquito breeding habitats

Initially, mosquito reproduction is successful only if larval habitats stay stagnant for a period equivalent to development of immature stages (Barros et al., 2011). Sites surveyed throughout Suez Canal area included; seepage from the Suez Canal, some irrigation and drainage canals, sewage, cesspools, sabkha land and water logged areas (Table 1, Fig. 2). First field trip was conducted during January 2015, where a number of 31 different localities were surveyed. The survey covered the region from Port Said Governorate to El-Ain El-Sokhna (i.e. South of Suez Governorate). Mosquito larvae were collected using a small ladle (10.5 cm diameter with 90 cm wooden handle). Collected larvae were placed in labeled glass vials containing a fixative solution (70% Ethyl Alcohol) and transported to the laboratory for identification using the Keys of Harbach (1988) and Glick (1992). Procedures and precautions in larval collection were done according to World Health Organization (1975). Surveyed sites were geo-referenced using a hand-held Global Positioning System device (GPS, Magellan 320-USA).

The first field trip was conducted for the purpose of collecting mosquito larvae and identifying the environmental characteristics of mosquito breeding sites (habitat). Based on these characteristics, a cartographic model was built to predict mosquito breeding habitats in the whole study area including the non-surveyed sites. Another field trip was conducted in February 2016 in order to validate the predicted area and ascertain efficiency of the generated model in identifying mosquito breeding habitats. In the second field trip a number of 42 different sites, located within the predicted area, were surveyed.

2.3. Satellite sensor and image preprocessing

Space-borne multispectral Landsat8-OLI image, dated 29th January 2015, was freely downloaded from http://glovis.usgs.gov/. The study area is located in two scenes (path 176, rows 38 and 39) and acquired as raw data (Digital Number, DN). Initially, radiometric calibration and atmospheric correction were applied for each scene separately to correct radiometric errors and spectral distortions in the image, using ENVI V5.1. A georeferenced mosaic was produced, at which the study area was cropped. Finally, water bodies defined as non-stagnant (e.g. Suez Canal) were clipped because they represent non-suitable sites for mosquito breeding as mentioned previously.

2.4. Estimation of NDVI, NDMI and LST

To determine the preferable predictor of mosquito breeding habitats; Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI) and Land surface Temperature (LST) were calculated at mosquito breeding sites. First studied index is NDVI which responds to variations in chlorophyll content, green biomass and canopy water stress. It is important in predicting surface characteristics when the vegetation cover is not too