Production of Risk Classification Map for the Area Vulnerable To Mosquito-Transmitted Diseases, Suez Canal Zone

Ahmed M. El-Zeiny[1], Asmaa M. El-Hefni[2] and Mohamed M. Sowilem[3]

[1]Researcher, Environmental Studies and Land Use Division, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt

[2]Environment Studies Specialist, Environmental Studies and Land Use Division, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt

[3]Researchers, Environmental Studies and Land Use Division, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt

[1] Corresponding Author: aelzeny@narss.sci.eg & narss.ahmed@gmail.com

Tel. Number: +201007737052

Abstract: *Suez Canal area is characterized by a unique nature therefore various species of mosquitoes are spread in the area. Present paper aims at mapping and classifying the area under environmental risk of mosquito proliferation and diseases transmission at Suez Canal Zone using Landsat OLI data and GIS. To fulfil this objective, 6 field trips in the period from Nov.2014 to Apr.2016, were conducted to collect mosquito larvae and characterize breeding sites. Six calibrated Landsat-8 images were processed to characterize mosquitoes breeding sites and therefore map the area under environmental risk of mosquito proliferation. Considering the degree of mosquito proliferation, the study area was categorized into four levels of risk; high risk, risk, vulnerable and non-infected. Results of surveys showed that the main vector of Filarasis (Culex pipiens) was the most abundant species in Suez Canal Zone. The produced risk map showed that the total high risk area occupies 59.16 km^2 (1 %), risk area 2026.37 km^2 (27 %), vulnerable 497.5 km^2 (7 %) and non-infected 4940.43 km^2 (65%) throughout Suez Canal Zone. Majority of the study area is located in the non-infected area which is concentrated in eastern and western deserts which are not inhabited. The high percent of the infected area is concentrated in several parts of Ismailia Governorate. The produced risk map is necessary requirement for decision makers to initiate mosquito control strategies and management programs. To assess the produced map, more than 120 different localities were visited. It could be concluded that Landsat-8 data and GIS techniques have proved high efficiency in mapping and classifying the area under risk of mosquito spread out particularly in inaccessible regions.*

Keywords: *mosquito, environmental risk, remote sensing, GIS, Suez Canal zone*

1. Introduction

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 as reported by the World Health Organization (Guruprasad *et al.,* 2014). Such diseases are Malaria, Lymphatic Filariasis, Yellow Fever, Encephalitis and Rift Valley Fever (Anosike *et al.,* 2007). 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, mosquitoes' ability to carry disease-causing pathogens, recurrent infection and diversity (Njabo *et al.,* 2013). Furthermore, mosquito bites can cause a substantial annoyance for humans and mammals. Severe annoyance can have adverse economic consequences (Connelly and Carlson, 2009).

Egypt is currently witnessing a number of mega projects, along the axis of Suez Canal, that aim to expand agricultural lands as well as logistics services, ease population pressures on the narrow Delta and create new job opportunities. These projects induce changes in land use/land cover which consequently have a great effect on the receiving environment and its biological components, including mosquito vectors of diseases. Such ecological disturbances may create suitable habitats for mosquito disease vectors allowing for their distribution into the project areas. All of these factors may generate health risks from emerging or re-emerging vector-borne diseases that would impact the integrity of development projects that ultimately aim for the prosperity of the Egyptian people (Hassan *et al.*, 1999; Hassan, 2001; Hassan and Onsi, 2004; Hassan *et al.*, 2004 and Abdel-Hamid *et al.*, 2011).

On the other hand, integration between remote sensing and geographical information systems (GIS) can be used as rapid and accurate tools for the determination of some environmental factors affecting mosquito's proliferation. Moreover, they could successfully be utilized to predict the habitat suitability, which can help in designing optimal mosquito vector control strategies based on precise spatial/temporal information database. Consequently, most of the developed countries are applying these systems to form their own policy levels to mitigate the mosquito problem. Furthermore, geospatial mapping offers the potential to identify larval habitats on a large geographic area that is difficult or impossible for using field survey. Remote sensing and GIS have greatly expanded opportunities for data collection, integration, analysis, modeling and map production (Hayes *et al.*, 1985; Washino and Wood, 1994; Hassan *et al.*, 2003; Hanafi-Bojd, 2012; Sowilem, 2014; El-Zeiny *et al.*, 2016).

There is a difficulty for accessing Suez Canal Zone for research studies as it requires special permissions which make it urgent to conduct more focused studies. Therefore, present study aims to utilize remotely sensed data, represented in Landsat images, and GIS techniques for detecting and classifying the area under environmental risk of mosquito proliferation at Suez Canal Zone.

2. Materials and Methods

2.1. Studied Area and Field Survey

The study area, representing in the western bank of the Suez Canal from Port Said on the northern extremity to Suez, includes three governorates; Port Said, Ismailia and Suez. It occupies an area of 7523.008 km^2 and lies between latitude 29 ^{o} 30' N to 31 ^{o} 30' N and longitude 32 ^{o} 10' E to 32 ^{o} 40' E. It is bordered from the north by Mediterranean Sea, west and south by eastern desert, and from the northern east by a part Sinai Peninsula. The direction of strong winds (wind speed over 10 m s^{-1}) is generally between 240 and 360° from North at Port Said (about 65% of the time), and between 330 and 360° from North at Suez (about 50% of the time) (Abril and Abdel-Aal, 2000; El-Zeiny *et al.*, 2016).

Initially, mosquito reproduction is successful only if larval habitats stay stagnant for a period equivalent to development of immature stages (Barros *et al.*, 2011). Therefore, seepage from the Suez Canal as well as some irrigation and drainage branches accounted from most of the breeding sites positive for mosquitoes' larvae. During the study period (i.e. 2014-2016), more than 120 different localities were surveyed and monitored along Suez Canal Area, from Port Said Governorate to El-Ain El-Sokhna (i.e. South of Suez Governorate) as shown in Figure 1. From these sites, mosquitoes larvae were collected by dipping, using small ladle with a wooden handle, from small stagnant water bodies including; irrigated fields, drainage canals, sewage, sabkha land, cesspools, cesspits and from seepage areas. A total number of six field trips were mainly carried out to identify the characteristics of mosquito breeding sites as well as to ascertain the results obtained.

2.2. Satellite Imageries Acquisition, Processing and GIS Analyses

Space-borne multispectral Landsat8-OLI images were freely acquired from http://glovis.usgs.gov/. Six different time series images were downloaded and used in this study, covering the period 2014-2016 (Nov. 2014, Jan. 2015, Apr. 2015, Oct. 2015, Feb. 2016 and Apr. 2016). The study area is located within two different scenes (i.e. path 176, rows 38 and 39) and downloaded as raw data (i.e. digital number; DN). Before the data were analyzed, it was necessary perform pre-processing to normalize the data as well as to remove atmospheric effects and noise. For this purpose, ENVI V5.1 was used. A georeferenced mosaic was obtained and resized to crop the study area. To determine the best predictor of habitat type; Normalized difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI) and Land surface temperature (LST) were calculated according to Liang (2004) and Duran (2015).

Based on the corresponding values of NDVI, NDMI and LST at mosquito proliferation sites, these parameters were used as input criteria in a weighted overlay GIS model to predict mosquito breeding habitat in the whole Suez Canal zone (El-Zeiny *et al.*, 2016). The predicted area was then classified considering the risk level into 4 classes. Class 1: High risk area represents mosquito habitat prediction at urban areas where urbanization facilitates the proliferation of different mosquito species that most often transmit pathogens to humans. Class 2: Risk area, a radius of two kilometers around the urban area served to determine the areas at risk of mosquito proliferation. Class 3: Vulnerable areas represent the areas which are environmentally suitable for mosquito breeding. Class 4: Non-infected which represent the area secured from mosquito borne-diseases.

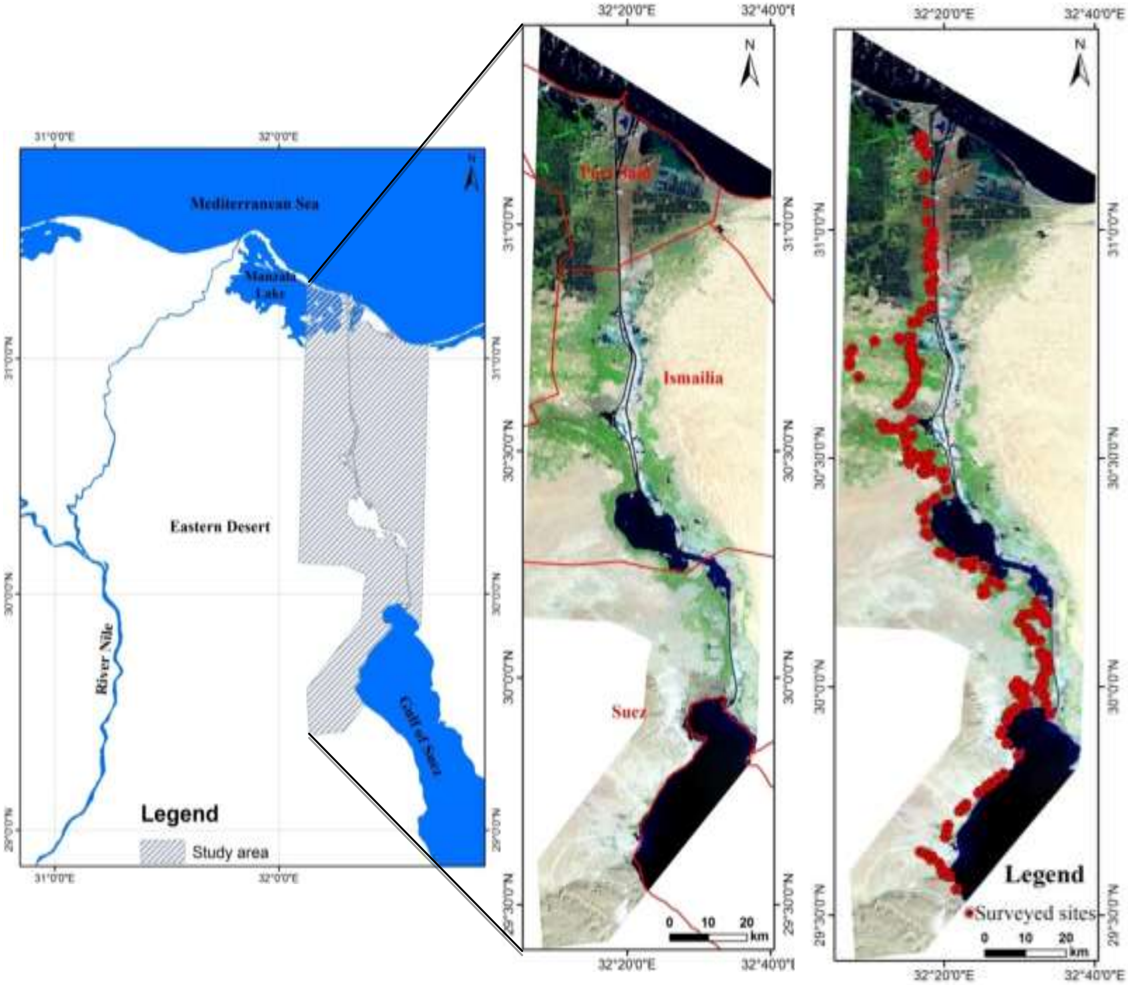

Fig. 1: Location map of the study area, right image represents surveyed sites

3. Results and discussions

3.1. Mosquito larval abundance, medical importance and habitat characteristics

Survey showed that *Culex pipiens* was the most abundant species in the study area (65.22%) and widespread in most localities which are similar to the previous observations of El-Said and Kenawy (1983), Bahgat *et al.*, (2004) and Abdel-Hamid *et al.* (2011). *Ochlerotatus detritus*, *Culex perexiguus*, *Culex pusillus* and *Culiseta longiareolata* recorded 13.86 %, 10.59 %, 7.2 % and 1.32 % respectively. *Anopheles tenebrosus* and *Ochlerotatus caspius* reported relatively same abundance; 0.69 % and 0.68 %, respectively. In Egypt, Culicine mosquitoes mainly *Cx. pipiens* and *Cx. perexiguus* are the main vector disease of human filariasis (Gad *et al.*, 1987). *Oc. caspius* has been incriminated to transmit Rift valley fever virus during 1977 & 1993 epidemics (Gad *et al.*, 1987; Turell *et al.*, 1996).

Mosquitoes prefer an environment with certain resources (food, shelter, favorable temperature and suitable humidity) in sufficient quantity and at appropriate time for survival and development (Romoser and Stoffolano, 1998). Corresponding levels of NDVI, NDMI and LST at mosquito breeding sites were utilized to represent the environmental characteristics of mosquito habitat at Suez Canal Zone. NDVI at mosquito breeding sites was located within 0.1-0.22 which confirms the importance of vegetation, even sparse, for mosquito breeding, as shelter and feeding source, where most sites recorded positive values of NDVI (El-Zeiny *et al.*, 2016. The type of vegetation which surrounds the breeding sites provides potential resting, sugar feeding supplies for adult mosquitoes and protection from climatic conditions. It may also be necessary in determining the abundance of mosquitoes related with the breeding site (Beck *et al*., 1994). Mean values of NDMI, at mosquito proliferation sites, recorded positive values (0.01 – 0.07) which indicates the necessary of moisture for mosquito breeding. Optimum temperature for mosquito proliferation usually range from 27 to 37 ºC however it could survive at temperature 40 ºC or more as reported in Suez Canal zone at Oct. 2015. Temperature has an effect on both the vector and the parasite. For the vector, it affects the juvenile stages (egg, larvae, pupae) development rates, the length of the gonotrophic cycle and survivorship of both juvenile and adult stages with an optimal temperature and upper and lower lethal boundaries. For the parasite, it effects the extrinsic incubation period (Lactin *et al.*, 1995).

3.2. Risk area prediction and classification

Based on the previous characteristics, area vulnerable to environmental hazard of mosquito proliferation was predicted. The predicted area was categorized into four different classes; high risk, risk, vulnerable area and non-predicted to mosquito breeding according to risk degree of disease transmission. Prediction at residential areas represents class 1 which is the highly subjected areas to mosquito proliferation and spread of transmitted diseases. Zones around the infected residential area represent class 2, which is the area at risk of mosquito proliferation but lower in hazard than class 1. On the other hand, areas that are environmentally and climatically suitable for mosquito breeding represent class 3 which are the areas vulnerable to mosquito breeding and infection probability (Figure 2). Class 4 is the rest area which is considered the non-infected zone where there’s no possibility of mosquito breeding and/or transmitted diseases due to the inappropriate conditions to mosquito breeding. A risk area classification map was generated which have categorized the area of study in relation with hazards of mosquito breeding and vector-borne disease. This map is considered the first developed map for Suez Canal Zone which has been created based on 2 years of work (Figure 2). The total high risk area, throughout Suez Canal Zone, occupies 59.16 km^2 (1 %), risk area 2026.37 km^2 (27 %), vulnerable 497.5 km^2 (7 %) and non-infected 4940.43 km^2 (65%). Majority of the study area is located in the non-infected area which is concentrated in eastern and western deserts which are not inhabited. The high percent of the infected area is concentrated in several parts of Ismailia Governorate. Actually, such map is very necessary for decision makers. It could help to initiate mosquito control strategies and management programs starting by the high risk area and ending by the vulnerable area. Furthermore, geographic locations of the expected area are well defined which facilitate the reachability to the infected sites. To ascertain the produced map and test the accuracy of the obtained classes, more than 120 different sites were visited. The overall accuracy of the risk area classification map reached more than 80 % in predicting the area under environmental risk of mosquito proliferation.

4. Conclusion

In this study, space-borne technology integrated with field surveys were used to detect the area under risk of mosquito proliferation at Suez Canal Zone. GIS environment was successfully employed for classifying the area under risk of mosquito proliferation and diseases transmission. Landsat images (OLI) were processed to characterize mosquito breeding sites which were then employed to define and detect mosquito habitats. NDVI, NDMI and LST were selected to describe the environmental characteristics of mosquito breeding habitats. The study produced, for the first time, a classified image for the area under environmental risk of mosquito proliferation. At Suez canal Zone, four main levels of risk to mosquito breeding were identified; high risk area 59.16 km^2 (1 %), risk area 2026.37 km^2 (27 %), vulnerable 497.5 km^2 (7 %) and non-infected 4940.43 km^2 (65%). The study concluded that Landsat data and GIS techniques have provided the necessary information and/or tools for mosquito proliferation studies. Also they could successfully be utilized for producing and classifying the mosquito risk areas at a large scale which is not possible by conventional methods.

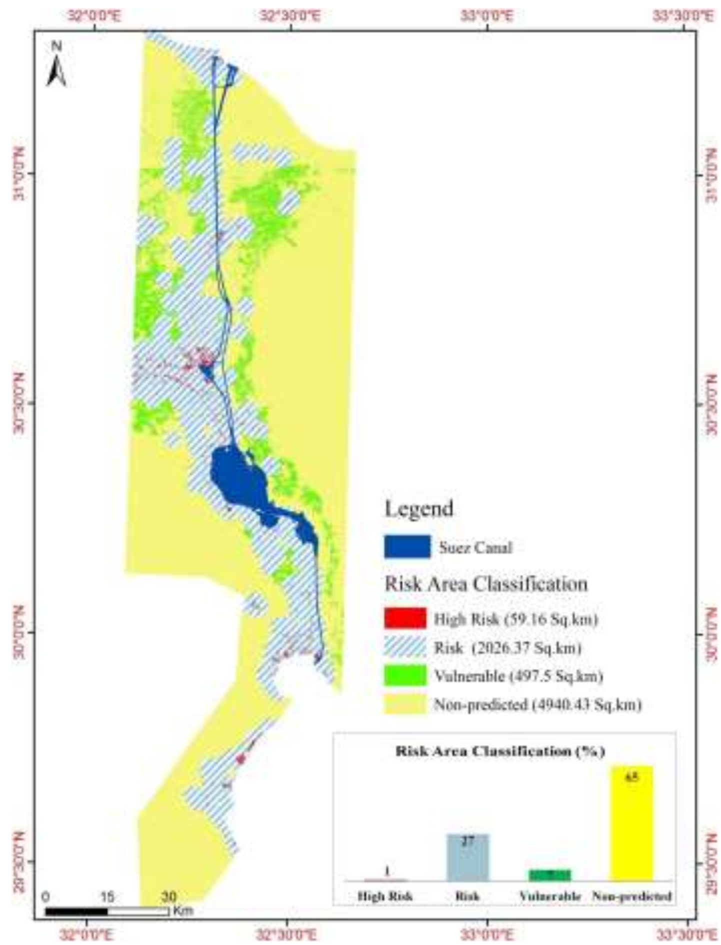

Fig. 2: Risk Area Classification map for Mosquito Proliferation

5. Acknowledgment

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