Quantifying Weather and Climate Impacts on Health in Developing Countries (QWeCI)

Science Talk

Landsat derived environmental metric for mapping mosquitoes breeding habitats in Nkomazi district, South Africa

QWeCI is funded by the European Commission's Seventh Framework Research Programme under the grant agreement 243964

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SEVENTH FRAMEWORK PROGRAMME

UNIVERSITEIT VAN PRETORIA
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Introduction

- The use of remotely sensed data to describe, investigate and predict the spatial and temporal patterns of the transmission and prevalence of vector-borne diseases has been demonstrated for about two decades.
- A common aim in the use of remotely sensed data is to be able to define and identify environmental parameters that are associated with malaria occurrences.
- The spatial and temporal distribution as well as the abundance of mosquito is strongly determined by the environmental conditions and this can as well be remotely observed.
- Temperature, vegetation, humidity and precipitation have been shown to significantly influence the development and the survival of mosquito.
- For significant reduction of the incidence, prevalence of malaria and a good cost-effective measure of control practices a reliable mapping of the spatial distribution of mosquito breeding habitats is crucial.

Introduction

- The use of geospatial technology by using geographic information system (GIS) integrated with remote sensing (RS) provides the possibility of identifying breeding habitats on a large area basis to an extent that is difficult or impossible using conventional ground survey

- Thomson et al., 1997 indicated that a positive relationship exist between NDVI and rainfall amount and availability of the vector. Also, Nualchawee *et al.*, 1997 studied the relationship between vegetation cover and incidences of malaria using Landsat image.

- However, a review of these works revealed that most of the works are done in East and West Africa but none has been done in South of Africa. Although, Martin *et al.,* 2001, in collaboration with the South African Medical Research Council developed a GIS based Malaria Information System, the use of remote sensing was not included.

Method……. Data Sets

Landsat Image

- A summer Cloud free Landsat Thematic Mapper (TM) image of date 1998/02/07 of path/row 168/078 was downloaded from the Global Land Cover Facility.
- Spectral band 2 (0.52 - 0.60), 3(0.63 - 0.69 µm), 4(0.76 - 0.90 µm), 5(1.55 - 1.75 µm) and 6(10.4 - 12.5 µm) of the image was considered for this study
- All have a spatial resolution of 30 m except for thermal band 6 which is 60m.

NDVI

- The normalized difference vegetation index (NDVI) and the normalized difference water index (NDWI) are popular two vegetation indices that can be derived from satellite images, which can be used as indicators for mapping mosquitoes habitat.
- The NDVI is a measure of the amount and greenness of vegetation at the surface.

NDWI

- The Normalized Difference Vegetation Index (NDWI) is developed to isolate non-water and water features.

Method……. Data Sets

LST

- Temperature has been proven to be one of the major indicators for the development and survival of the vector.
- In relation to the *Anopheles* species for example, *P. vivax,* has duration of about 10 days at 25 ° C, while it is 8 to 14 days for *P. falciparum* and 18 to 20 days for *P. ovale* and *P. malariae* at 25 ° C.
- In *P. falciparum* the larvae can withstand rather low temperatures, but do not complete their development at temperatures below 10 to 13 ° C and no appreciable development takes place until a temperature reaches 18 to 23 ° C.
- Therefore, a slight increase in temperature or temperature below 16 ° C negatively impacts the development of the parasite.
- Land surface temperature (LST) can be estimated from the thermal band of thermal infrared (IR) sensors.

Aim and Objectives, Study Area

Aim and Objectives

- The major aim of this study is to determine the potential breeding habitats of *Plasmodium Falciparum* using environmental metric parameters derived from Landsat TM imagery in the Nkomazi district of Mpumalanga province in an effort to develop a means for forecasting and predicting risk of exposure to Malaria.
- The objectives of this work include identification of breeding habitats of mosquito and create a risk map to provide reliable information for adequate malaria control measure.

Study Area

- Nkomazi district municipal of about 3254.041 Km^2 is located eastern part of Mpumalanga province of South Africa.
- The Eastern half is situated in the subtropical low altitude known as the Lowveld/Bushveld, dominanted by the savanna habitat as a result of its closeness to the warm Indian Ocean and latitude.
- The Kruger National Park is located in this region.

Study Area

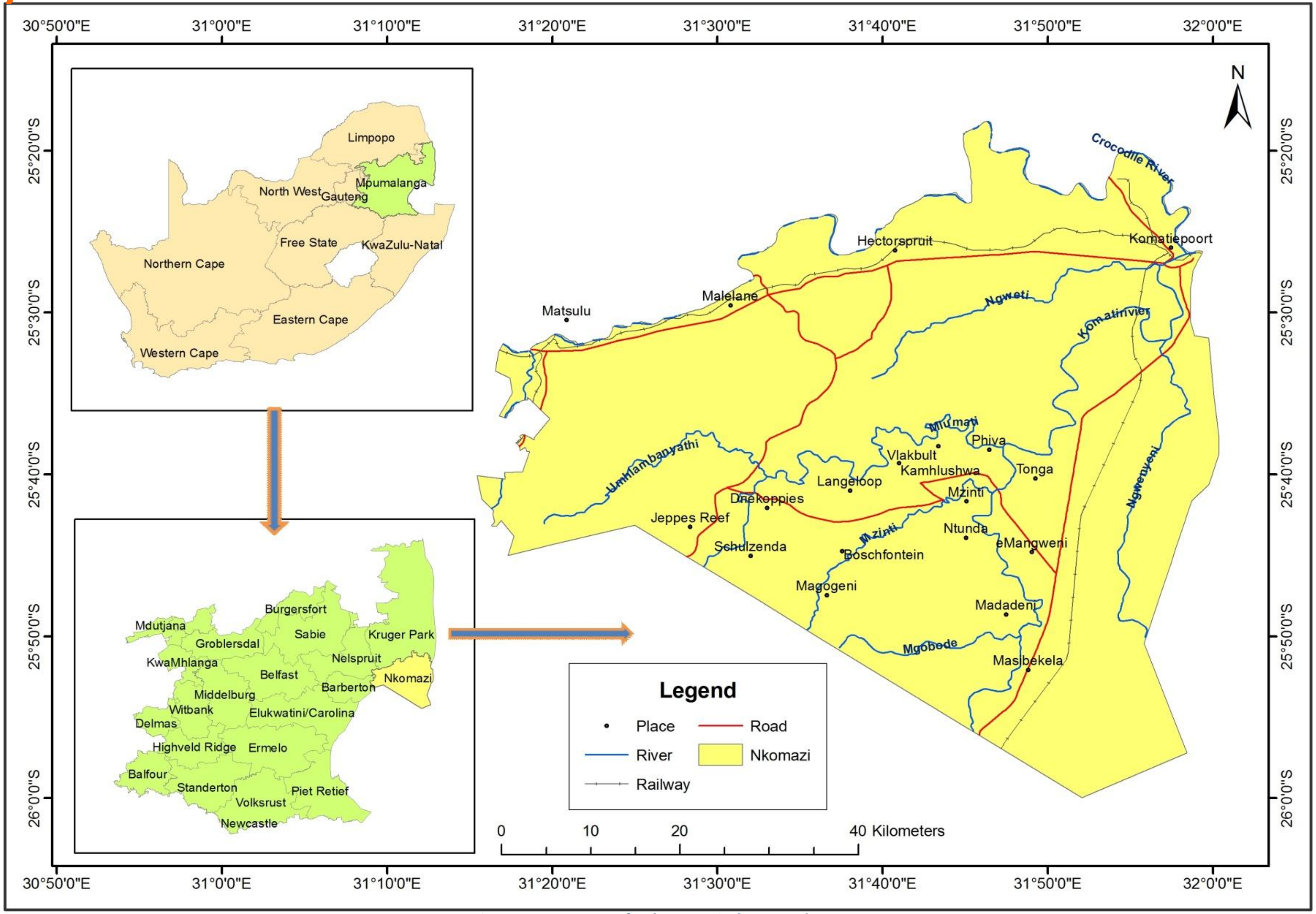


Figure 1: Map of Nkomazi the study Area

Data Analysis

Landsat image

- All the bands were defined in Universal Transverse Mercator (UTM) projection. Erdas imagine 9.1 software was used for image processing.
- The TM+ image is USGS L1-T products that have been processed for radiometric, geometric and terrain corrections.
- Visual inspection was performed to ascertain that the pixels are well aligned.
- The area of interest (AOI) of 3254.041 Km^2 was subsequently extracted. See figure 1.
- Equation 1 and 2, using the spatial modeler of Erdas imagine were used to convert the digital numbers (DN) of the involving bands (2, 3, 4 and 5) to radiance and thereafter to exoatmospheric reflectance respectively (Gyanesh *et al.,* 2009).
- The DN of band 6 (thermal) was also converted to radiance and equation 3 was used to derive the Brightness Temperature (BT) also known as the LST.

Data Analysis

Conversion of Digital Number to Radiance

- $$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{Qcalmax - Qcalmin}\right)(Qcal - Qcalmin) + LMIN_\lambda$$ Equation 1
- *Where*

  L_λ = Spectral radiance at the sensor's aperture [W/(m^2 sr µm)], $LMAX_\lambda$ = the spectral radiance that is scaled to QCALMAX [W/(m^2 sr µm)], $LMIN_\lambda$ = the spectral radiance that is scaled to QCALMIN [W/(m^2 sr µm)], **Qcal** = Quantized calibrated pixel value [DN], ***Qcalmax*** = the maximum quantized calibrated pixel value (corresponding to $LMAX_\lambda$) in DN = 255, ***Qcalmin*** = the minimum quantized calibrated pixel value (corresponding to $LMIN_\lambda$) in DN

Conversion of Radiance to Reflectance

- $$\rho = \frac{\pi * L_\lambda * d^2}{ESUN * Cos\Theta_s}$$ Equation 2
- *Where:*

  ρ = Unit less planetary reflectance, L_λ = Spectral radiance at the sensor's aperture from equation 1, d = Earth-Sun distance in astronomical units, **ESUN** = Mean solar exoatmospheric irradiances, Θ_s = Solar zenith angle in degrees provided in the Meta file

NDVI Calculation

- $$\text{NDVI} = \frac{\rho NIR - \rho RED}{\rho NIR + \rho RED}$$ Equation 3
- *where*
  - ρRED *and* ρNIR correspond to the reflectance measured in band 3 (0.63–0.69 µm) and band 4 (0.77 – 0.90 µm) respectively (Rouse *et al.,* 1974). See figure 2a and b.

NDWI Calculation

- $$\text{NDWI} = \frac{\rho^{Green} - \rho^{SWIR}}{\rho^{Green} + \rho^{SWIR}}$$ Equation 4
- *where*

  ρGreen and ρSWIR correspond to the reflectance measured in band 2 (0.52 - 0.60 µm) and band 5 (1.55 - 1.75 µm) respectively (Xu, 2006).

Data Analysis........

- *LST Calculation*
- $$T = \frac{K2}{\text{In}\left(\frac{K1}{L_\lambda}+1\right)}$$ Equation 5
- *where*
  - T equals to the black body temperature, K1 and K2 are constants and correspond to the spectral radiance (Gyanesh *et al.*, 2009).
- The NDVI, ranges from -1 to +1, for this study threshold of
- **0 = No Vegetation, 0.7–0.9 = Dense/healthy vegetation, 0.5-0.6 = Sparse/not healthy vegetation, 0.2-0.4 = Built up, ≤ 0.1 = Dry bare soil and ≤ -0.257 = water.**
- Generally, water typically has an **NDVI less than 0, bare soil between 0 and 0.1 and vegetation >0.1** (Holben, 1986).
- From the above, threshold of > 0.35 was set to distinguish vegetation from other feature: therefore **0.35 ≥ NDVIvegetation = larva haitat.**
- Similarly, for MNDWI it can be stated that; **1 ≥ MNDWIwater ≥ threshold > MNDWImoist soil > 0 ≥ MNDWInon-water ≥ -1, therefore 1 ≥ MNDWIwater = larva habitat.**
- A threshold of 0.3 was set to distinguish water from moist soil.
- In summary, the ranges of MNDWI correspond with features (Figure. 5a) as following: **MNDWI < 0: non-water, 0 ≤ MNDWI < 0.3: moist soil, 0.3 ≤ MNDWI ≤ 1: water.**

Data Analysis……..

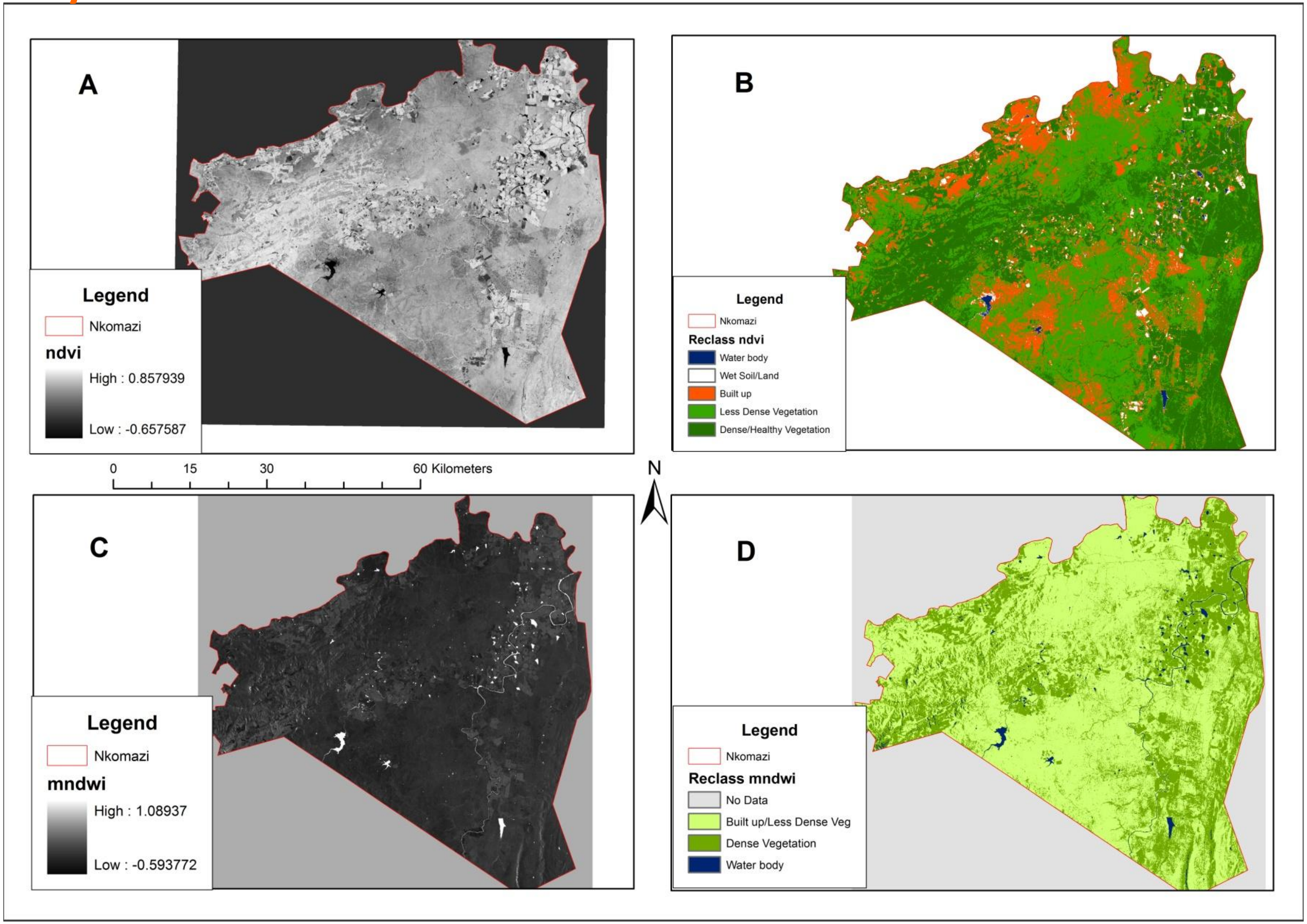


Figure 2: (A) ndvi, (B) Reclass ndvi, (C) mndwi (D) Reclass mndwi

Data Analysis……..

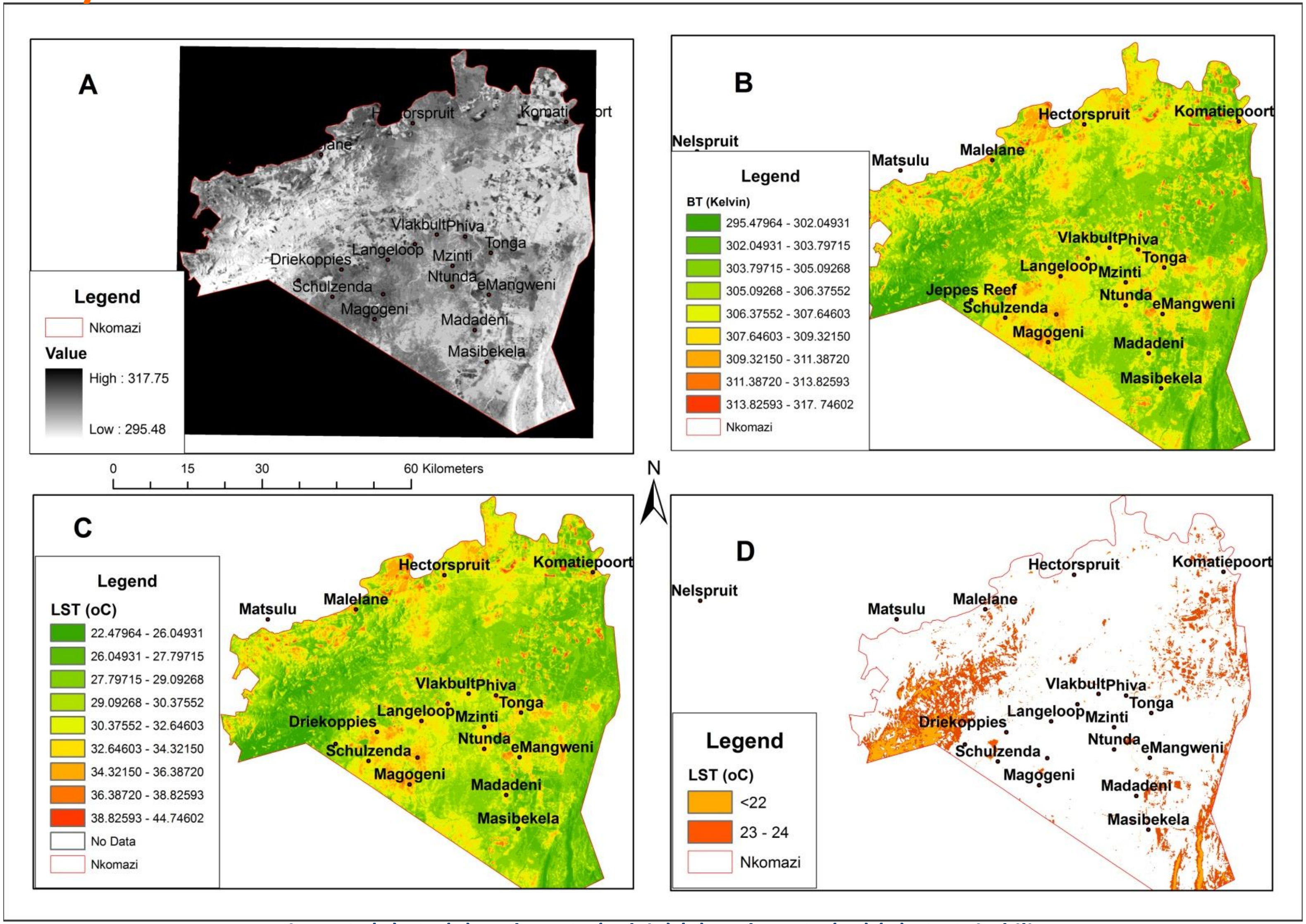


Figure 3: (A) LST (B) Reclass LST (Kelvin) (C) Reclass LST (oC) (D) LST Suitability Map

Data Analysis…….. Buffering

Buffering

- A buffer is referred to as a polygon or area that encompasses a feature or phenomenon within a fixed distance of the spatial feature. In this study, two buffer zones were created.
- The rivers and other water bodies were buffered at 1.5 miles and 2 miles representing areas of high risk and low risk respectively.
- The selection of the flight range is according to research carried out by West Nile Virus on vector-borne diseases titled ''Notes on important species of mosquitoes'' available on http://www.cdc.gov/ncidod/dvbid/westnile/resources/mos_p22_p44.pdf. ''Normally, most adults of *P. falciparum;* (the dominant species in the study area) fly not more than one-half mile from their larval habitat and only a small percentage fly farther than one mile''.
- This was done to determine the possible area or population at risk of mosquito bites and consequently being exposed to malaria infection. The buffer zones were created using ArcGIS as shown in figure 4b and d.

Data Analysis………

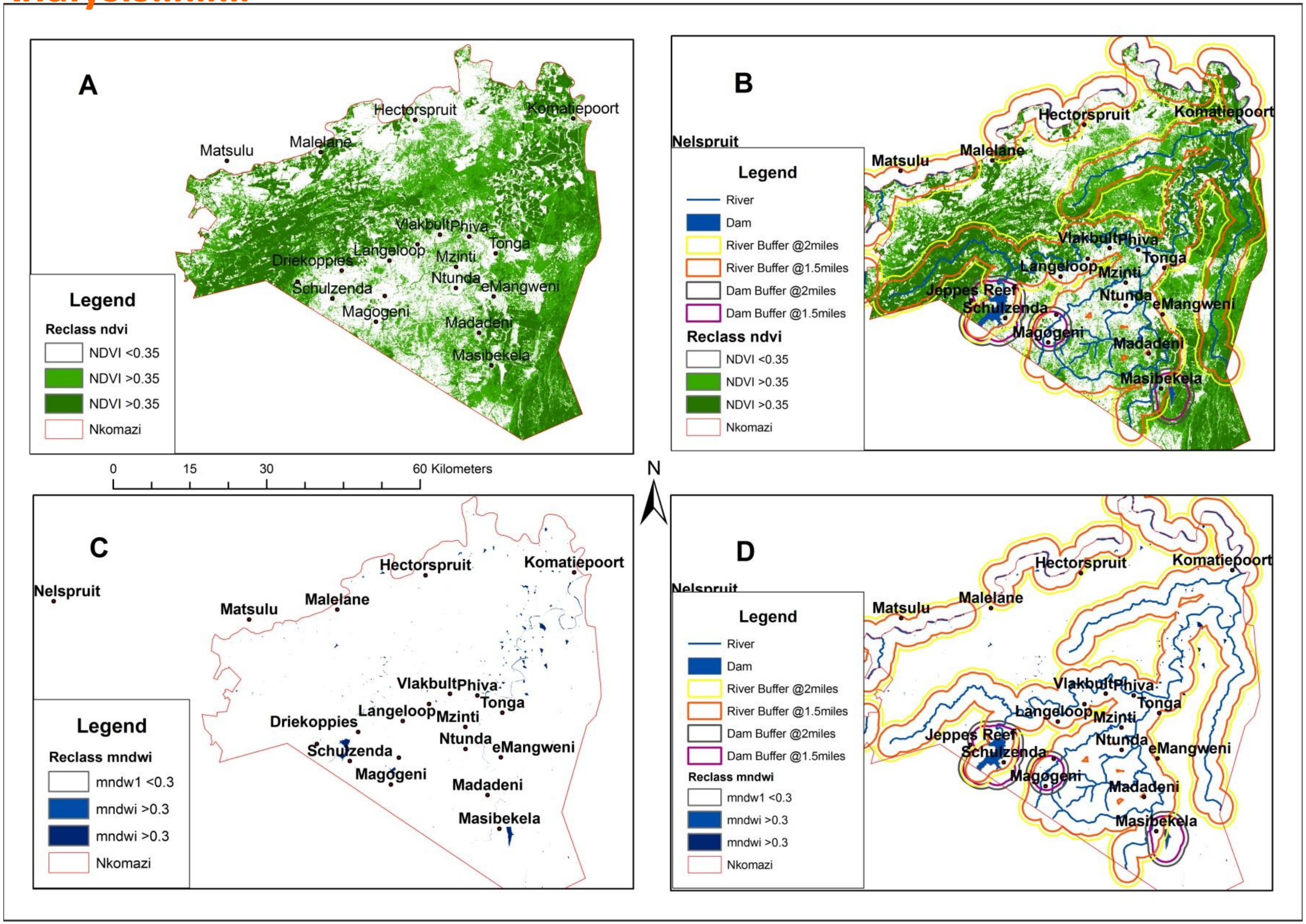


Figure 4: (A) Suitability map of ndvi, (B) Risk map in relation to ndvi, (C) Suitability of mndwi (D) Risk map in relation to mndwi

Result

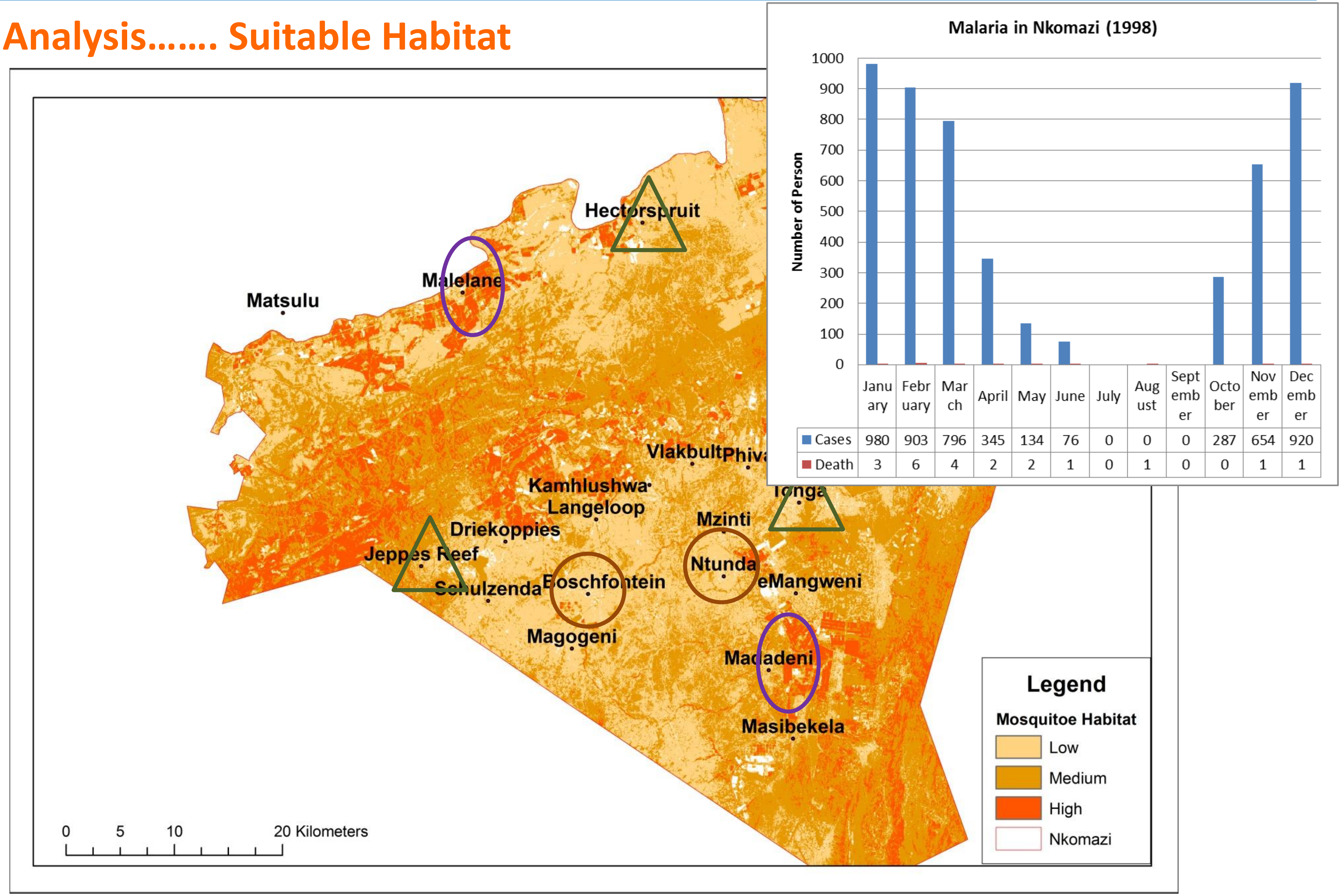
Suitable Breeding Habitats

- The breeding habitats is categorised into 3 classes namely; high, medium and low areas. Using the expression

- **0.3 ≥ MNDWI ∩ 0.35 ≥NDVI ∩ ≥22 ≤24 = Suitable Breeding Habitats.**

- The high areas include Komatiepoort, Malelane, Madadeni; medium include Tonga, Jeppes Reef, Masibekela and the Low areas include Langeloop, Ntunda and Driekoppies as shown in figure 5.

Data Analysis…… Suitable Habitat



	January	February	March	April	May	June	July	August	September	October	November	December
Cases	980	903	796	345	134	76	0	0	0	287	654	920
Death	3	6	4	2	2	1	0	1	0	0	1	1

Figure 5: Risk map of the study area

Result and Conclusion

- This study demonstrated the usefulness of NDVI, NDWI and LST as derived from satellite image for mapping mosquito's habitat in Nkomazi where malaria is endemic.
- The analysis shows a good correlation between NDVI and LST and between NDWI and LST to detect potential breeding sites for the vector.
- The regression coefficient of 0.79 between NDVI and LST and a very close regression coefficient of 0.80 between NDWI and LST indicated that these environmental parameters are reliable,
- It was therefore deduced that areas with NDVI of about 0.35 and above, LST of about 22-24 ^{0}C are mostly suitable breeding habitats
- and population within 1.5 miles of the suitable sites are at higher risk than population at 2 miles away, illustrated in figure 4b and d.
- The correlation analysis between the two indexes, LST and clinical data shows that they are well correlated.

Result and Conclusion

- This is related to why there is more number of malaria caused deaths during the summer months (October and March) as shown in the clinical records as against the winter season when favourable conditions for the vector to breed is rarely met.
- The production of risk maps could more dynamic if the relationship between the determining factors of malaria transmission (the environmental, climatic and social; population and immigration) are properly combined in model with the biology of the mosquitoes and the epidemiology of the disease.
- Also the availability of continuous remotely sensed or meteorological data must be guaranteed.
- Therefore, the main end result should be to implement an operational system; Malaria Early Warning System (MEWS) that will integrate all parameters both climatic and environmental to facilitate prediction, forecasting and real time monitoring of incidences.

Acknowledgement and References

Acknowledgement

- This study was funded by the EU project QWeCI (Quantifying Weather and Climate Impacts on health in developing countries; funded by the European Commission's Seventh Framework Research Programme under the grant agreement 243964)."

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