Review of remotely sensed data products for disease mapping and epidemiologygy

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Outline

- Background: why are we interested?
  - Applications in disease mapping
  - Geostatistical modeling
  - Remotely sensed data convenience
  - Advances in technology

- Examples of applications in epidemiology
  - Disease vector distributions
  - Modeling examples

- Remotely sensed data products review
  - Review findings
  - Problems
  - Conclusions way forward

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Background

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Disease applications: remotely sensed data, geostatistics and GIS

- Geostatistical methods combining remote sensing (RS) techniques and geographic information systems (GIS) remain effective in estimating spatial and temporal effects of environmental determinants on disease outcomes.
- Geostatistics allow production of model-based maps which are used to predict outcomes at unsampled geographic locations
- In case of disease control programmes this aids and support targeted control

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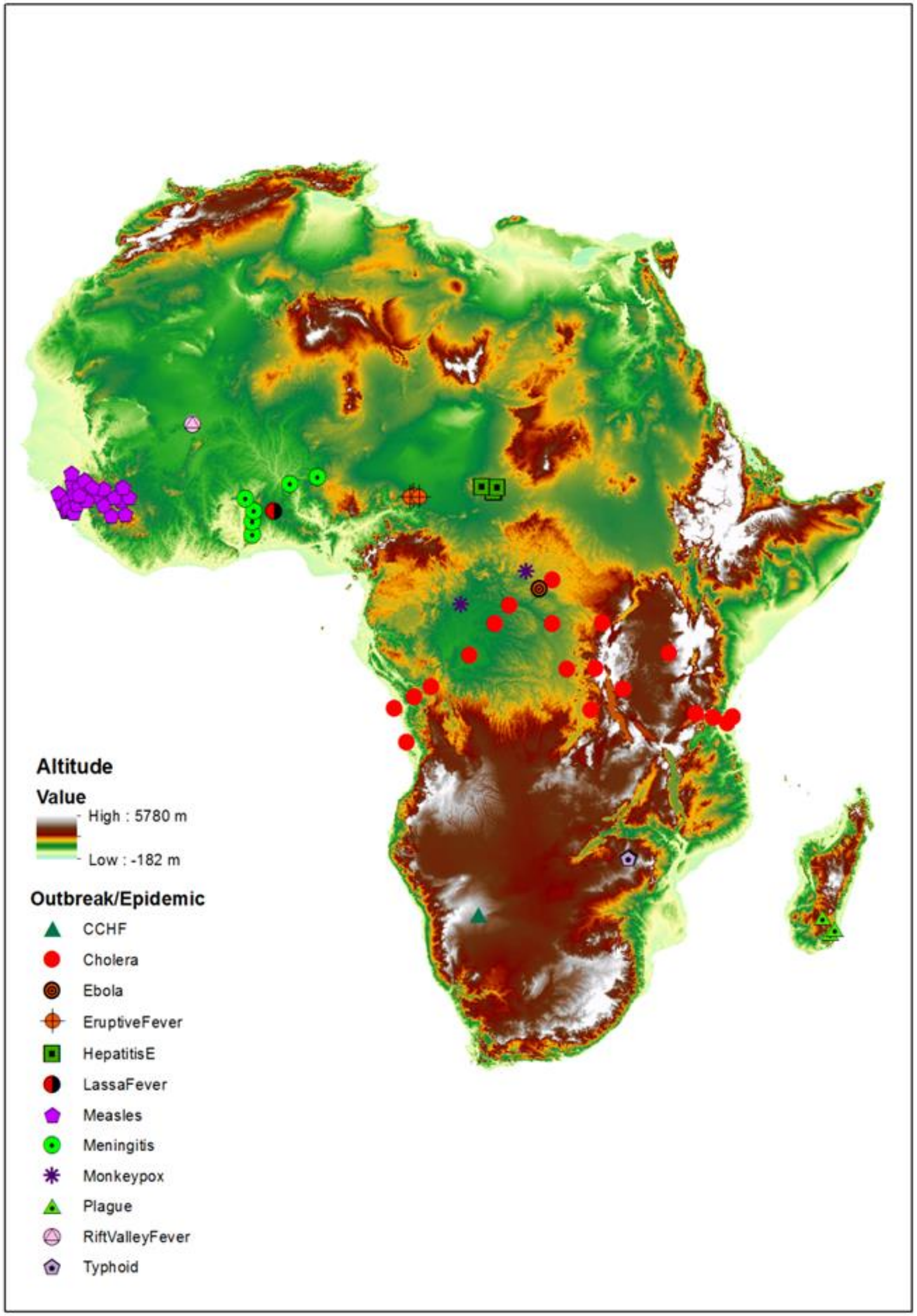
Altitude
Value
High : 5780 m
Low : -182 m
Outbreak/Epidemic
CCHF
Cholera
Ebola
EruptiveFever
HepatitisE
LassaFever
Measles
Meningitis
Monkeypox
Plague
RiftValleyFever
Typhoid

Geostatistical modelling in disease mapping

- Often, epidemics occur with quasi-regular cycles and are predictable with a reasonable degree of precision
- Meaning they could be preventable, if control programmes are adequately informed and prepared
- Geostatistical modeling is applied to improve our understanding and predictability of such epidemics

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Convenience of remotely sensed data

- Advantages of using RS data products is its
  - Near real-time availability for rapid assessment of at risk areas
  - Allows prediction of disease distributions, especially in inaccessible areas with poor ground measurement meteorological station networks that may also lack baseline data
  - Directly feeds into algorithms and models that attempt to create smooth/continuos climatic surfaces where ground measuremnt coverage is poor

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Relevance of technological advances

- The increase in the launch of higher resolution satellites and advances in processing techniques+ Computational power have enabled wider adoption of RS data
- Large datasets that were previously difficult to handle and to process can now be efficiently processed and results obtained within reasonable time frames

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Examples of applications in epidemiology

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Disease vector distributions

- Vector borne diseases such as malaria, are highly sensitive to changing temperatures, precipitation and altitude (RS products)
- Which affect vector breeding habits
  - For instance, stagnant pools of water make the physical environment more suitable for vector to oviposit and hatch
- These conditions determine epidemic situations

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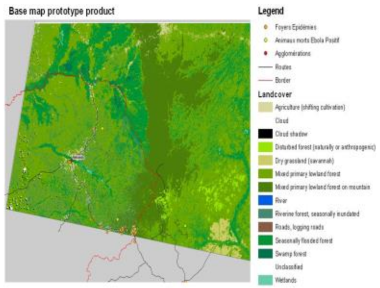
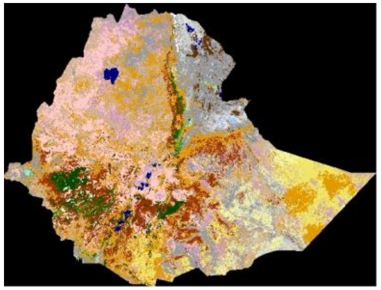
Examples:
RS products for Epidemiology

EO in Epidemiology

Vegetation Maps



Medium Resolution
Land Cover/Use Maps



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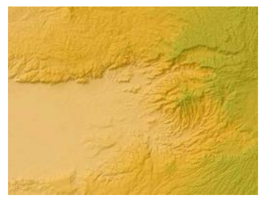
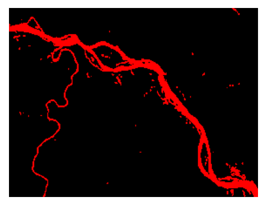
Examples:
RS products for Epidemiology

- EO in Epidemiology

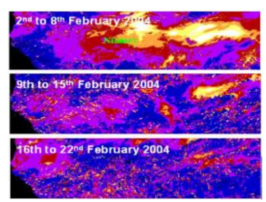
Digital Elevation Maps



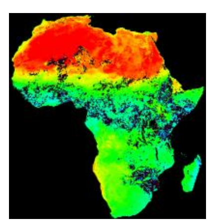

Water Body Maps




Wind Blown Dust Maps



Land Surface
Temperature Maps

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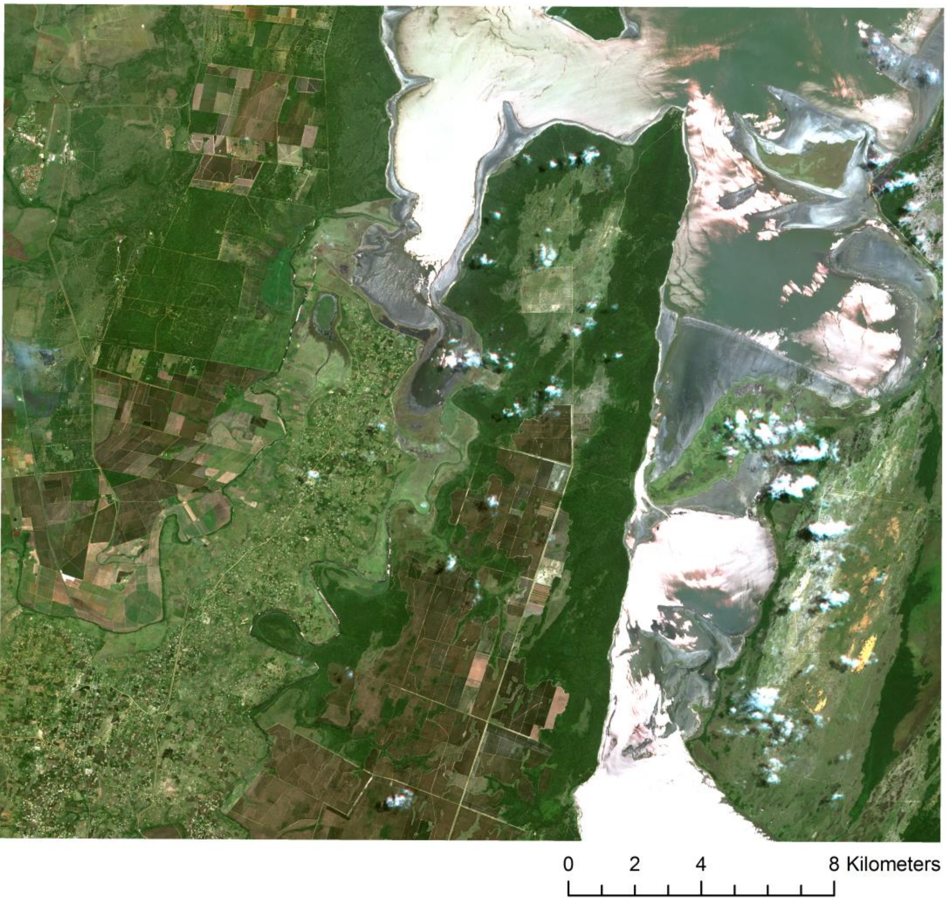
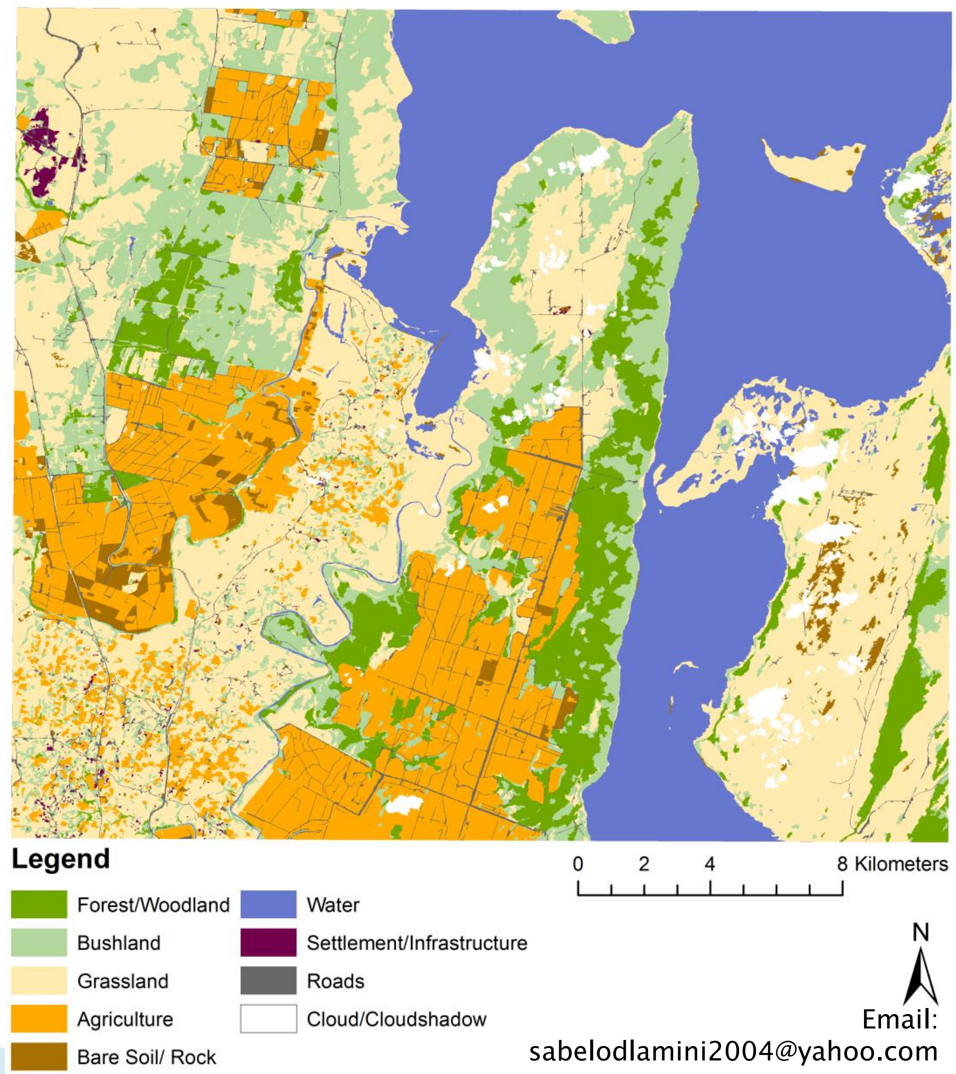
Example Land Cover Classification

RapidEye 09/10/2011



Land Cover Classification



(c) RapidEye (2011), provided under EC/ESA GSC-DA

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Applications in modeling: Negative binomial model fitted in WinBUGS

Let Y_i be the average number of malaria cases at a given location s= $i,\ldots.n$

with likelihood Y_i ~dnegbin(P_i, r)

where P_i is the proportion of malaria cases in a defined location and r is the dispersion parameter and $\mu_i = r\frac{1-p}{p}$ while $\sigma_i^2 = r(1-p)p^{-2}$. The model was written as: $Logit(\mu_i) = logit(Popu_i) + \beta_0 + \beta_1 X_i \ldots\ldots \beta_{12} X_i + \varepsilon_i,$ where μ_i is the number of malaria cases in each location and β are the regression coefficients, X are the model covariates and ε are spatial/temporal random effects. The distributed lag model was restricted to a polynomial function of power 2 which was formulated as follows:

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Applications in modeling: Polynomial function

Distributed lag model restricted to a polynomial function of power 2 could be formulated as follows:

$$\beta_i = \sum_{k=0}^{2} a_k \, i^k$$

Where k is the categorical variable for the covariate corresponding to β_i coefficient and a is the intercept for locations $i \ldots . n$. The model describes the relationship between an independent value of X_i and the corresponding dependent mean Y_i. This is summarized as $E(y|x)$. The model gives the expected μ_i of malaria cases given the corresponding value of each categorical variable at location s.

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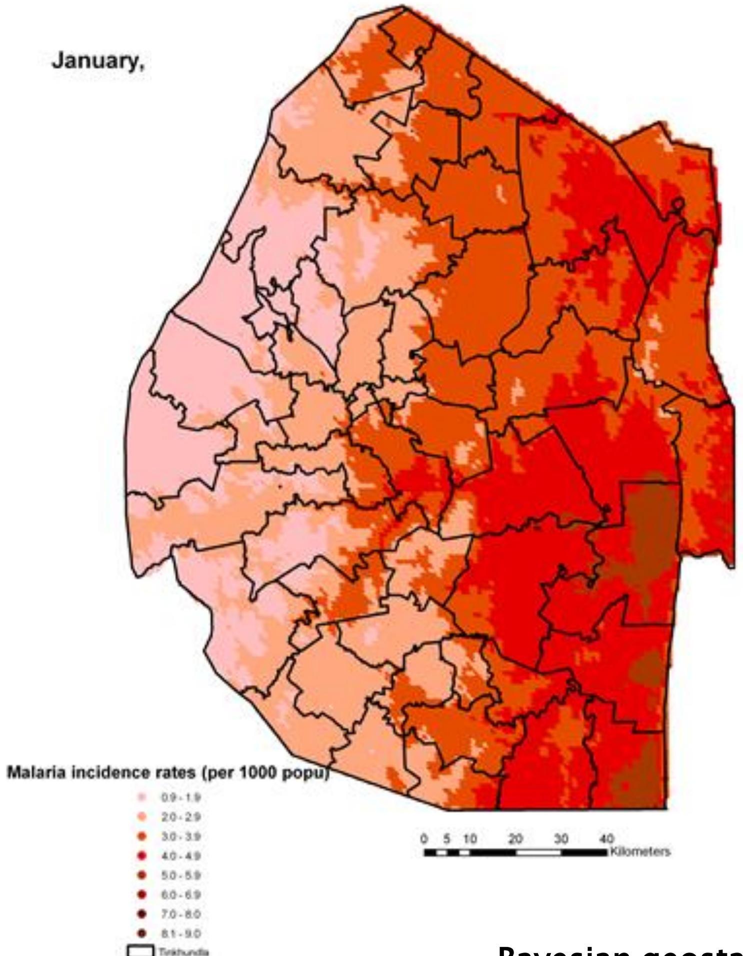
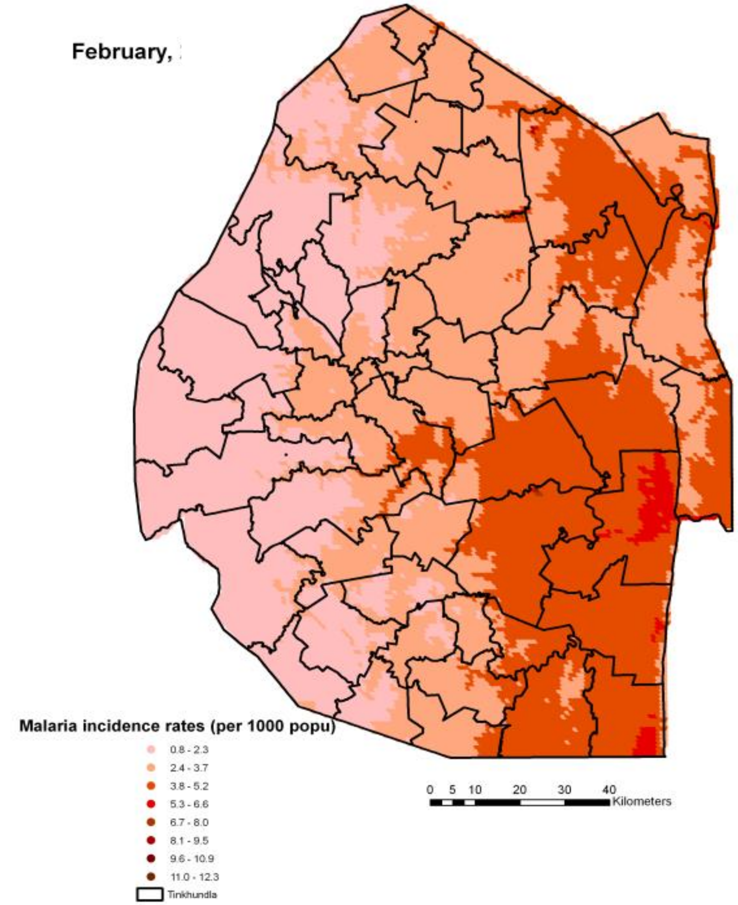
Monthly forecast of malaria incidence rates





Bayesian geostatistical modeling to assess spatio-temporal variations and elapsing time for malaria incidence risk in Eswatini

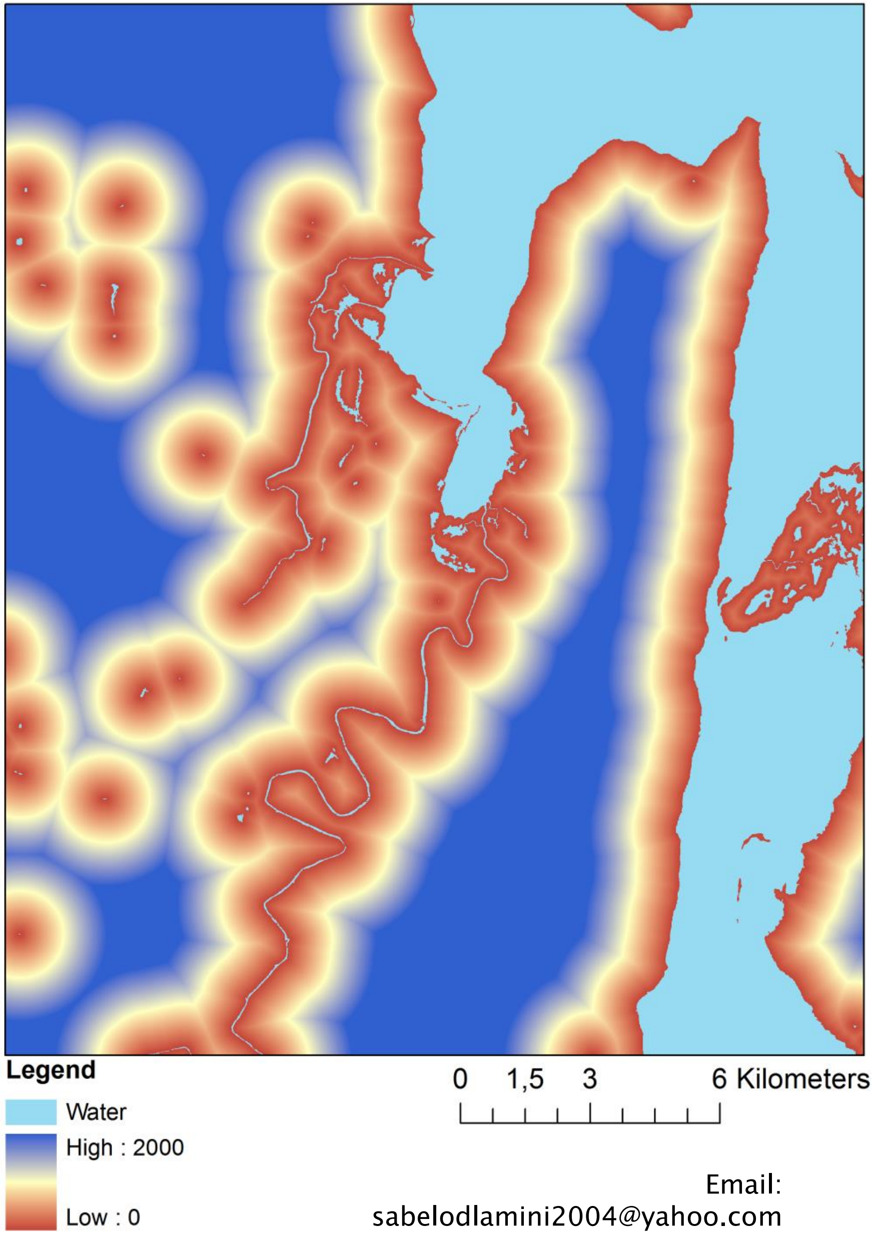
Sabelo Nick Dlamini*[1], and Sizwe Mabaso[1]
[1]University of Eswatini, Kwaluseni Camous, Matsapha, Eswatini

Under Review: Parasites and vectors journal

Example: some model outputs

- Water Body Mapping
- Distance to water assessment

Distance to water [m]



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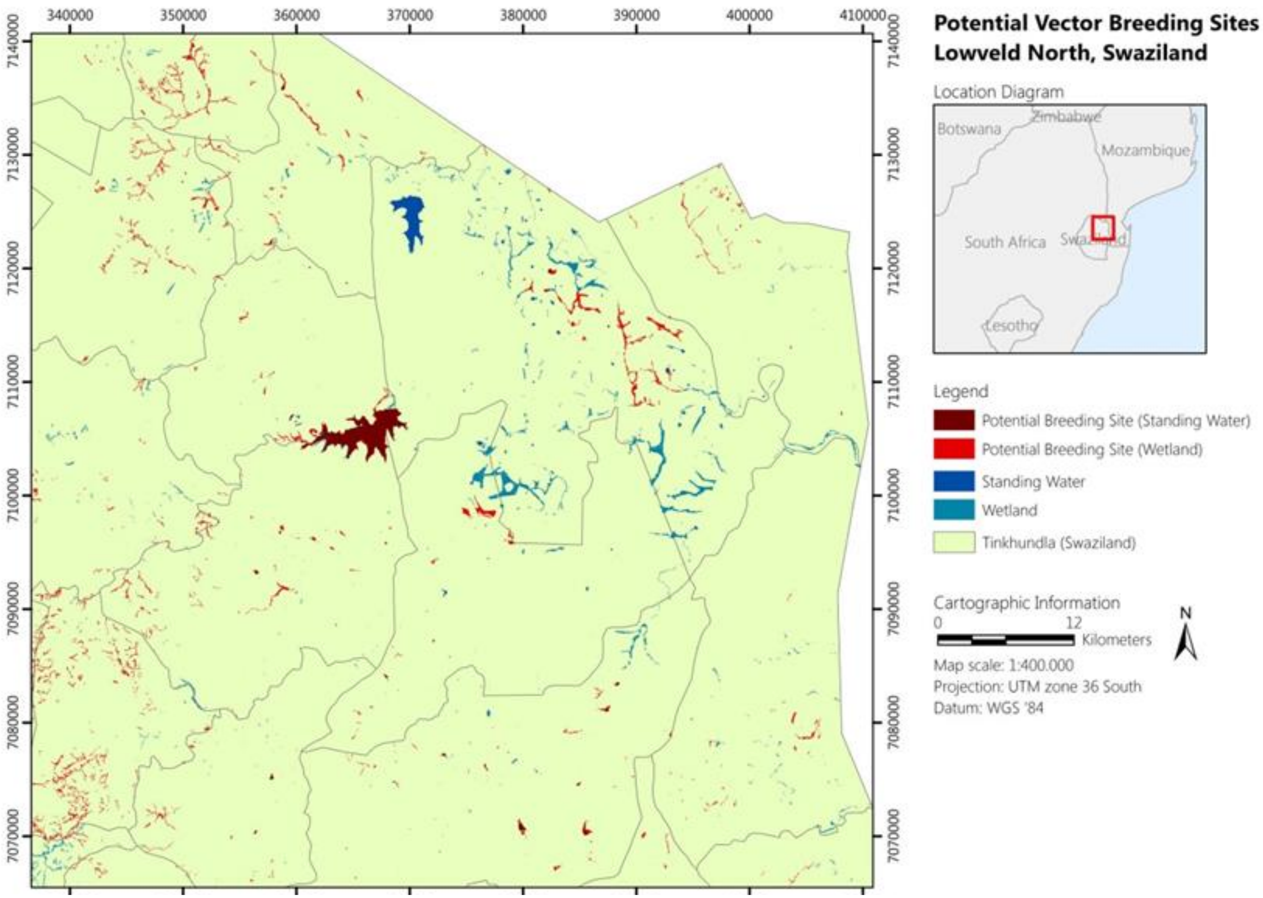
Potential vector breeding sites classification of the malaria-endemic area covered by 5-m resolution RapidEye data (northern part of the Lowveld)



Assessing the relationship between environmental factors and malaria vector breeding sites in Swaziland using multi-scale remotely sensed data

Sabelo Nick Dlamini,[1,2] Jonas Franke,[3] Penelope Vounatsou[1,2]

[1]Swiss Tropical and Public Health Institute, Basel; [2]University of Basel, Switzerland; [3]Remote Sensing Solutions GmbH, Baierbrunn, Germany

Geospatial Health Journal

So what?

- Evidently RS products greatly support disease mapping distributions
- Very high to high resolution remotely sensed (RS) data products remains of interest to disease mapping studies
- Although high costs had been a barrier for most end users- there are changes already taking place in RS landscape- DRONES
  - May have implications on future pricing

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Remotely sensed data products review

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Review of remotely sensed data

- We conducted an online review to find out what RS data products were accessible for disease mapping and epidemiology
- Purpose was:
  - To document RS data products for disease mapping
  - To propose new products that could be incorporated in disease mapping studies
  - Need for information availability on the type of data products obtainable from satellite imagery in order to facilitate access and utilization

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RS review findings

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Review findings

Need for Information Bulletin

- National Aeronautics and Space Administration (NASA) monthly bulletin called Spacewarn was launched in 1991 (http://nssdc.gsfc.nasa.gov/spacewarn/) to raise awareness about newly launched satellites and their missions to the general public.
- Unfortunately, this bulletin was discontinued with the last issue available until July 2011– how about products?

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Review findings

- Little effort made to inventorize existing and potential RS data products that could be used in disease mapping and epidemiology
- Space activity (satellite launches, landuse/cover observations) has increased
- Information on the type of RS data products obtainable from these missions is somewhat elusive.

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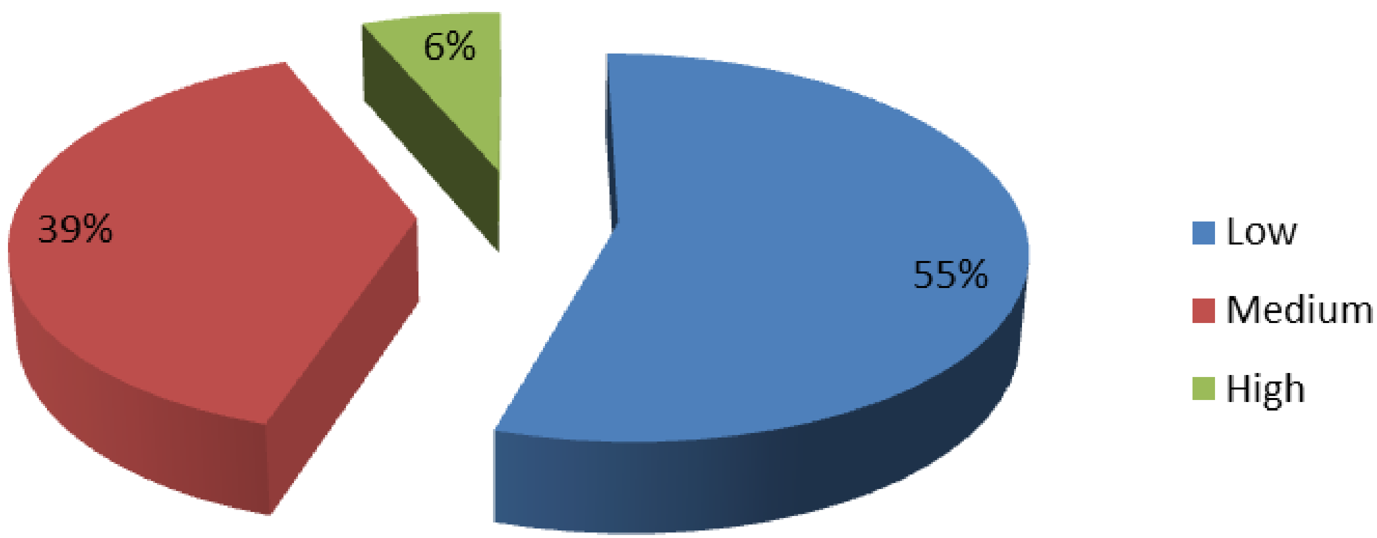
Review findings: distribution of spatial resolutions of remote sensing sensors and products



Review of remotely sensed data products for disease mapping and epidemiology
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In Review: Remote Sensing Journal: Society and Environment

Review findings cont.

- Present documentation of RS data products from satellites imagery is ad-hoc, incomplete and characterized by duplication and redundancy between access websites
- E.g MODIS products were found across access sources such as Copernicus (Sentinel Scientific Data Hub), USGS Earth Explorer, NASA Earth Data among others.
  - (Host, supply agency or middleman?)
  - Good descriptions but direct download not found?
  - magnified resolutions!!!

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Review findings cont.

- ESA comprised of 58 already launched missions and about 18 planned launches from year 2018 to 2028 while for NASA missions we found about 200
  - Launches are faithfully recorded but there is little info on the resultant products for end users
- We found various inexhaustive data download ftp sites managed by both remote sensing agencies and private web bloggers who enthusiastically follow remote sensing issues

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Review findings cont.

- For instance, such websites included NASA Goddard Space Flight Center found on https://www.nasa.gov/goddard, Copernicus Open Access Hub) previously known as Sentinels Scientific Data Hub (https://scihub.copernicus.eu/), Observing Systems Capability Analysis and Review Tool (OSCAR), including NORAD Catalog (http://satellitedebris.net/Database/), and Global Visualization Viewer (GLOVIS) among others.
- (although they may look few but when looking for some products and you are not sure who has it as it is made mention of across agencies but you can not really trace it to a supply agency e.g NDWI, soil moisture)
- When you get products via a middleman its authenticity may be in doubt

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Modeling problems

- Alignment in time – e.g daily LST against dekadal rainfall or even 8/16 days NDVI
- Indices like LST do not directly measure ambient air temperature, critical consideration in vector dispersal
- Not easy to know continuous or sustained acquisition programme from once-off project specific products
  - End of RS data products supply not known

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Outputs of the review

- We prepared a catalogue of indices from ecological studies that could be used as covariates/predictors in disease mapping and epidemiology studies
- Remotely sensed data products related to climate, meteorology, land use/cover, cartography and urban mapping were explored as potential indices for disease mapping and epidemiology

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Conculsions

- There remains a substantial amount of work to be conducted on the evaluation and validation of some of the indices presented in this study
- Synergies between remote sensing experts and epidemiologists could be useful in the uptake and testing of new RS products as well as some of the RS data products presented in this catalogue

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Conclusions cont.

- Development of indices that are sensitive to vector conditions or take into account the climatic conducive environments of disease causing vectors could be useful for epidemiologists
- Need to identify and define RS data products in terms of their characteristics and formats as this relates to the decision to select data products for any analysis

Why?

  - The characteristics and formats of RS data products as well as availability of handling software for interoperability still determine their accessibility and utilization by end users

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Siyabonga
Merci
Danke schön
Thank you:

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