Swiss TPH

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Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse

Associated Institute of the University of Basel

Spatial-temporal distribution of entomological inoculation rates in Manhica DSS, Mozambique

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Outline

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- Objectives
- Methodology
- Modelling
- Results
- Discussion
- Acknowledgement

Introduction

- Malaria is still a primary cause of both morbidity and mortality in Mozambique especially among the children and pregnant women
- Almost 100% of the population lives in a high transmission zones and are at risk of infection
- It is responsible for 60% of paediatric admissions and 23% of all in-hospital deaths
- The disease is predominantly caused by plasmodium falciparium, transmission is perennial with a seasonal peak in the rainy season (November-April)

Introduction cont..

- Since 1940s, the country has been applying WHO recommended tools (IRS,ITN and provision of treatment using ACT)
- According 2009 WHO report, the country has registered a decline in overall malaria case except for children
- The relationship between malaria mortality and levels of transmission is still unclear

- EIR, one of the recommended indices for measuring transimission levels in areas of high intensity
- In 2002, INDEPTH initiated the MTIMBA project with the aim of assembling a database that can be used to address malaria transmission and mortality relationship

Objectives

General Objective: develop statistical methods for analysing large DSS data in order to examine the relationship between mortality and malaria transmission

Specific objectives:-

- **to** identify environmental predictors for EIR
- to establish the relationship between EIR and various predictors
- to produce spatially explicit and season specific estimates of EIR

Methodology

Study site:

- Maniac DSS is located in southern Mozambique (at 25°24'S and 32°48'E)
- It has the natural catchment population of the District hospital
- DSS is situated in fertile lower lands and an escarpment of moderate height
- The area has two distinct seasons , warm (Nov and April) and a cool

DSS data: it is collected at very large number of households repeatedly over time, and thus they are correlated in space (***spatial***) and time (***temporal***).

- Common exposures (climatic), may influence mortality similarly in households of the same geographical area, introducing spatial correlation in mortality and malaria transmission

Entomological data

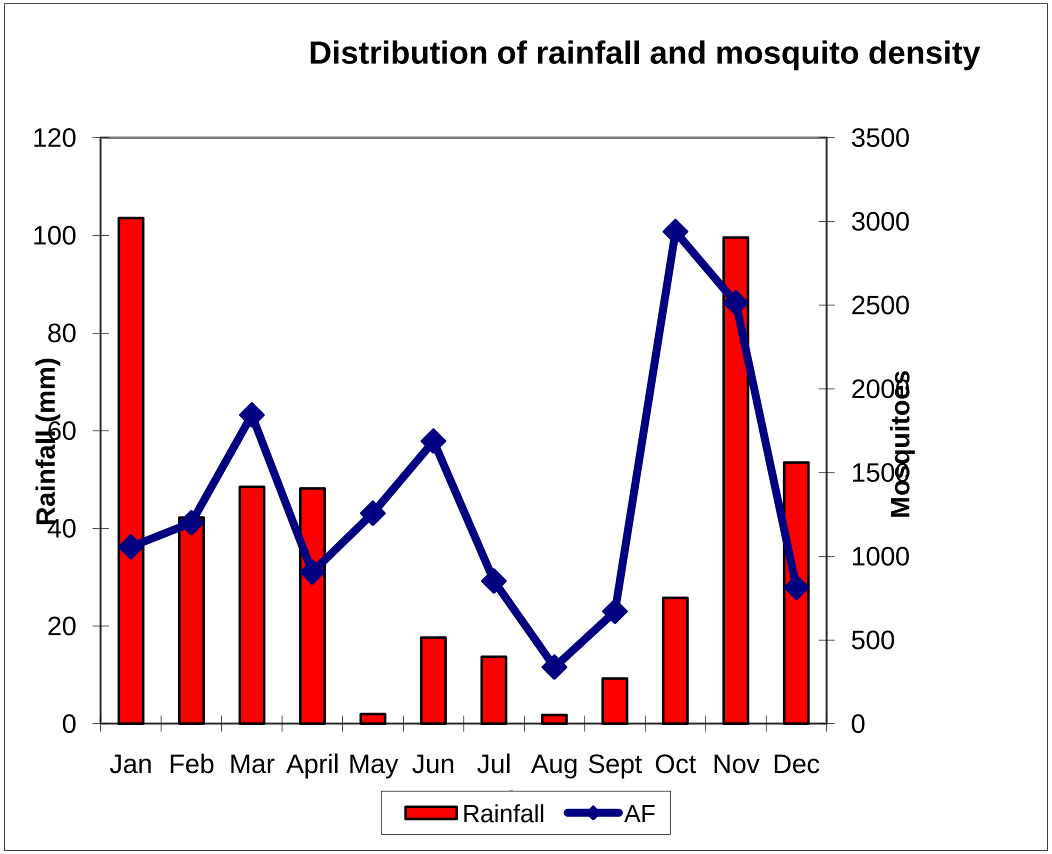
- Entomological data were collected from randomly selected compounds using both LTC and HBC
- LTC were performed overnight/over 2 consecutive nights
- HBC were carried out monthly for calibration purposes against LTC
- Mosquito catches were performed between 6.00pm to 6.00am
- LTC anopheles mosquitoes were tested for plasmodium falciparium using ELISA

Environmental data

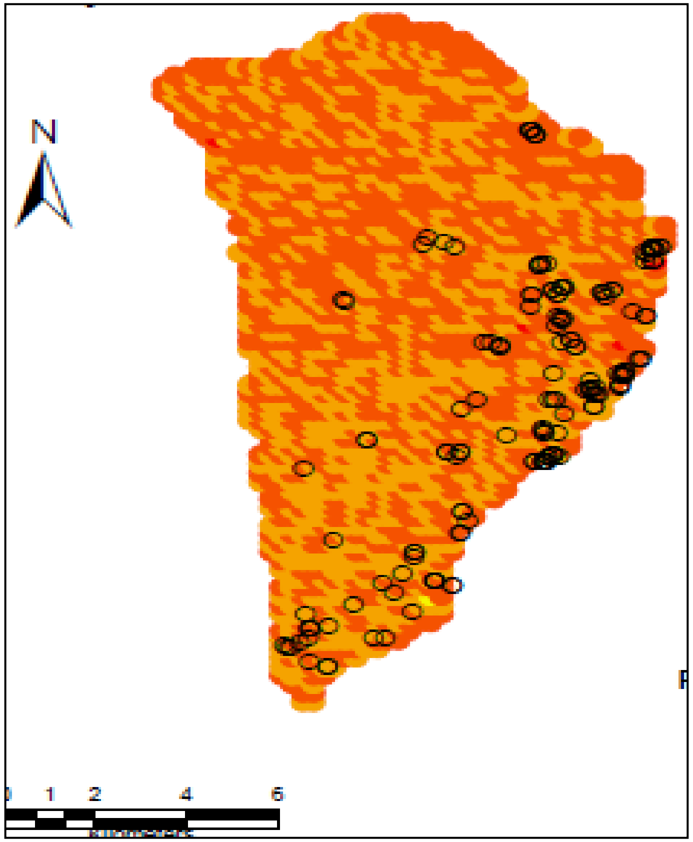
Predictor	Spatial Resolution	Temporal Resolution	Source
Day land surface temperature (Day LST)	1 km²	8 days	**MODIS**
Night land surface temperature (N**ight LST)**	1 km²	8 days	**MODIS**
Normalized difference vegetation index (NDVI)	250 m²	16 days	**MODIS**
Enhanced Vegetation Index (EVI)	250 m²	16 days	**MODIS**
Rainfall estimate (RFE)	8 km²	Dekadal	**ADDS**
Elevation/Altitude	1 km²	-	**USGS**
Nearest distance to water bodies (rivers and wetlands)	-	**-**	**Manhica DSS**

Spatio-temporal distribution

Temporal distribution



Spatial distribution



Spatio-temporal models

- Classical regression models assume independence of events which is not the case all the time
- Spatio-temporal data are correlated in space and time
- Ignoring correlation leads to under estimation of the standard error and overestimation of covariates' significance
- Spatial models incorporate spatial correlation
- Spatial models can be used to predict outcomes at new locations

Model fit

Logistic regression model

$$Y_{it} \sim Bn \;\; N_{it}, P_{it}$$

Where N_{it} number of tested mosquitoes

P_{it} sporozoite rate

$$\log it(P_{it}) = X_{it}^{\;T} \beta + f(t)$$

Where $f(t) = \varphi_1 \cos\left(\frac{2\pi t}{T}\right) + \varphi_2 \sin\left(\frac{2\pi t}{T}\right)$, the seasonality function

β Regression parameters

Spatio-temporal Logistic regression model

$$\log it(P_{it}) = X_{it}^{T}\beta + f(t) + \phi_i + \in_t$$

Where $\phi_1,\ldots\ldots\ldots,\phi_{n-1,}\phi_n \sim MVN(0,\Sigma)$

$\Sigma_{ij} = \sigma^2 \exp\ -\rho d_{ij}$ and $\rho > 0$

σ^2 Spatial variance

d_{ij} distance between locations i and j

ρ the correlation parameter

$$\in_t \sim AR(1)$$

Model fit (2)

Negative Binomial model for count data

$$Y_{it} \sim NB\left(p, r\right)$$

Where r dispersion parameter

P Probability of success

$$P = \frac{r}{r+\mu}$$

$$\log(\mu_{it}) = X_{it}^{T}\beta + f(t)$$

Where $f(t) = \varphi_1 \cos\left(\frac{2\pi t}{T}\right) + \varphi_2 \sin\left(\frac{2\pi t}{T}\right)$, the seasonality function

β Regression parameters

Spatio-temporal negative binomial

$$\log(\mu_{it}) = X_{it}^{T}\beta + f(t) + \phi_i + \in_t$$

Where $\phi_1, \ldots\ldots\ldots, \phi_{n-1,} \phi_n \sim MVN(0, \Sigma)$

$\Sigma_{ij} = \sigma^2 \exp\ -\rho d_{ij}$ and $\rho > 0$

σ^2 Spatial variance

d_{ij} distance between locations i and j

ρ the correlation parameter

$\in_t \sim AR(1)$ (temporal term)

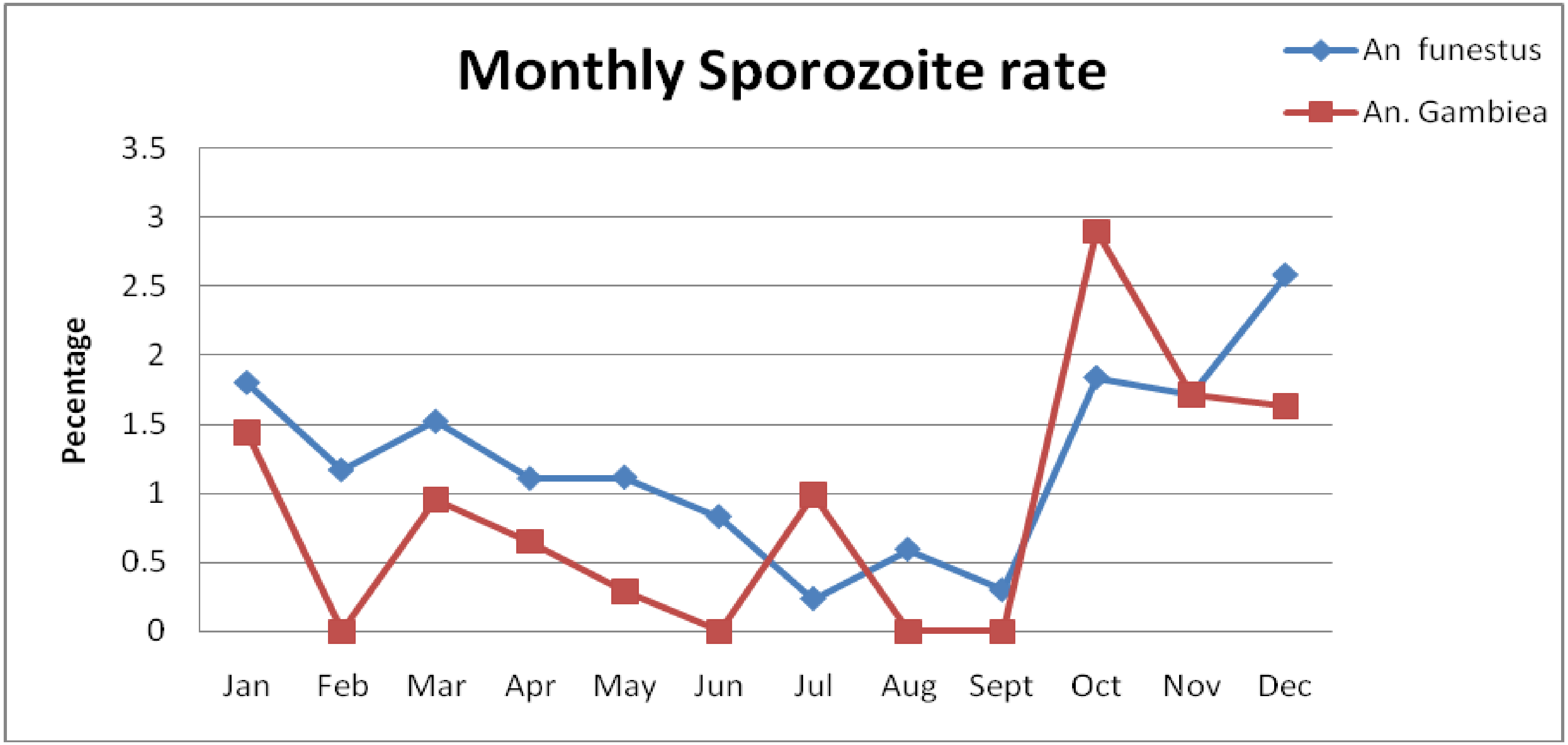
Data Analysis

- Lag time analysis was used in order to account for elapsing time of environmental factors on SR and MBR
- Seasonality was accounted for using dry/wet binary variable or a mixture of trigonometric functions
- Bayesian method and Markov chain Monte Carlo simulation were used to estimate model parameters.
- Due to large number of locations, the spatial process was estimated using a subset
- Analysis was performed using Stata ver 10, OpenBUGS and R softwares

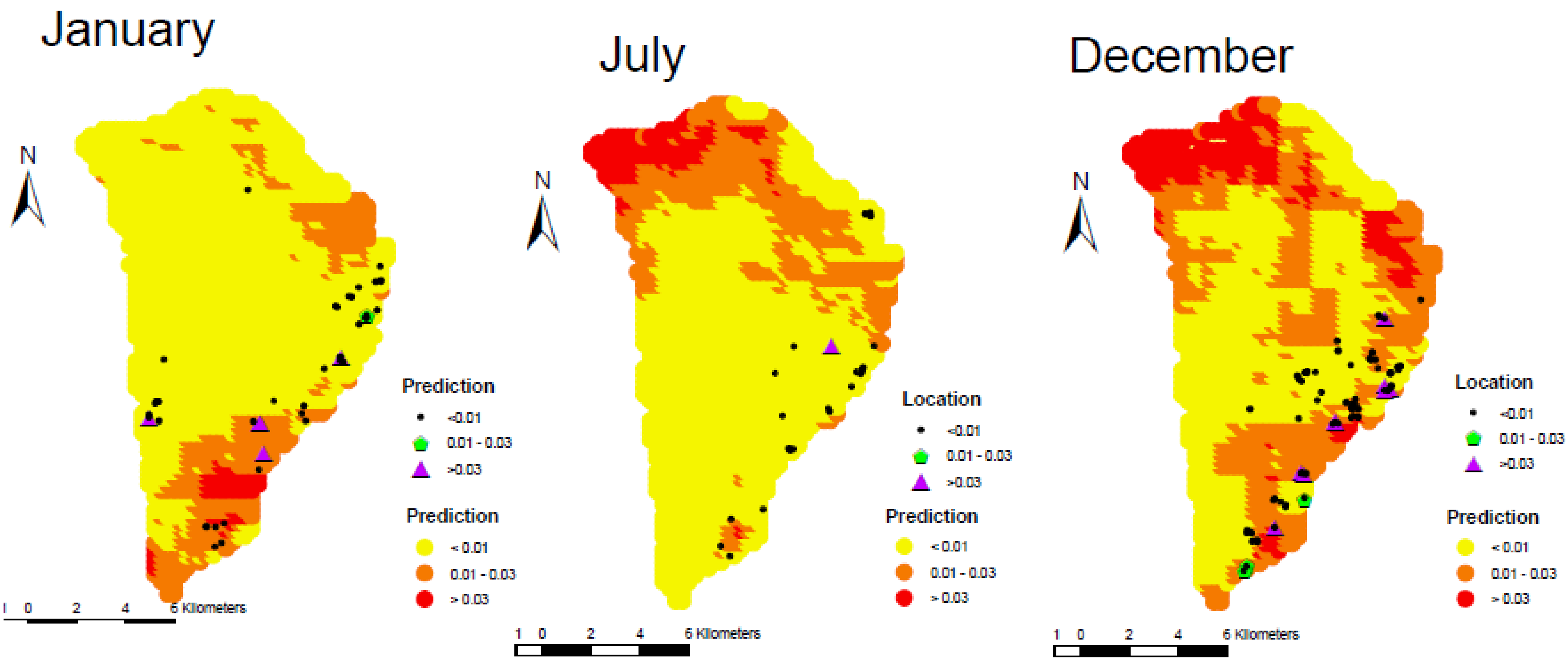
Results

- Total number of An. funestus was 16078 (85%)
- Total number of An. gambiea was 2845 (15%)
- Overall sporozoite rate for AF was 1.4% and 1.1% (AG)

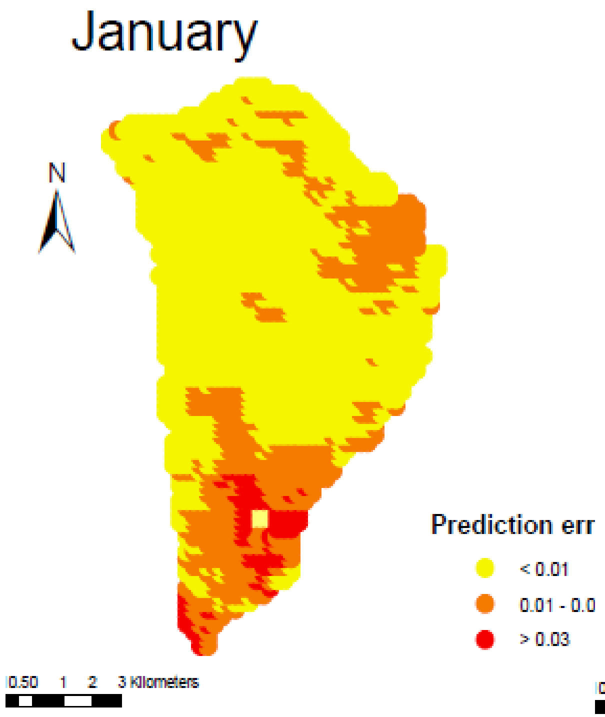
Observed sporozoite rates

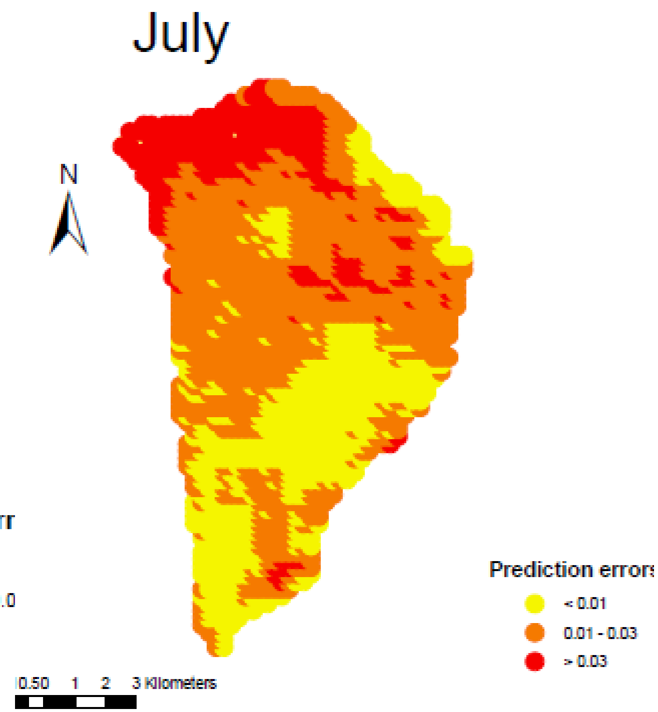


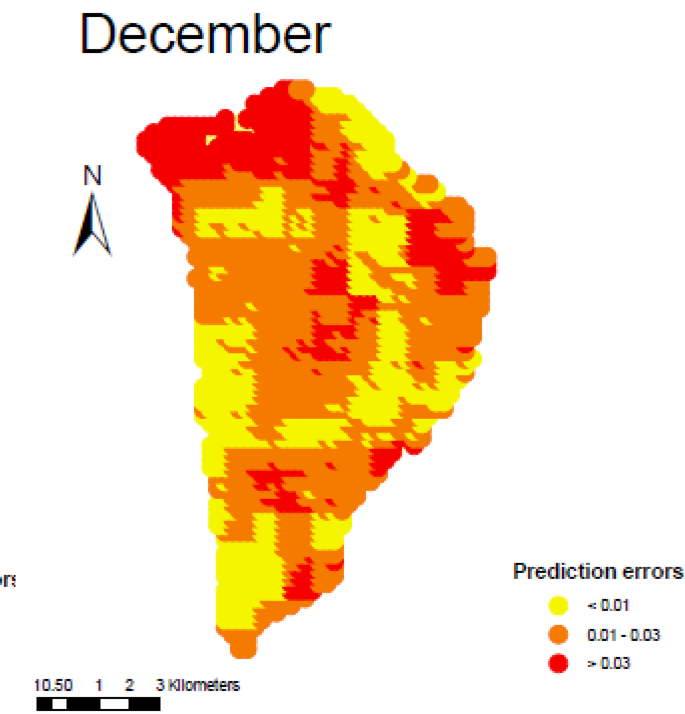
Predicted SR using ZIB model (AG)



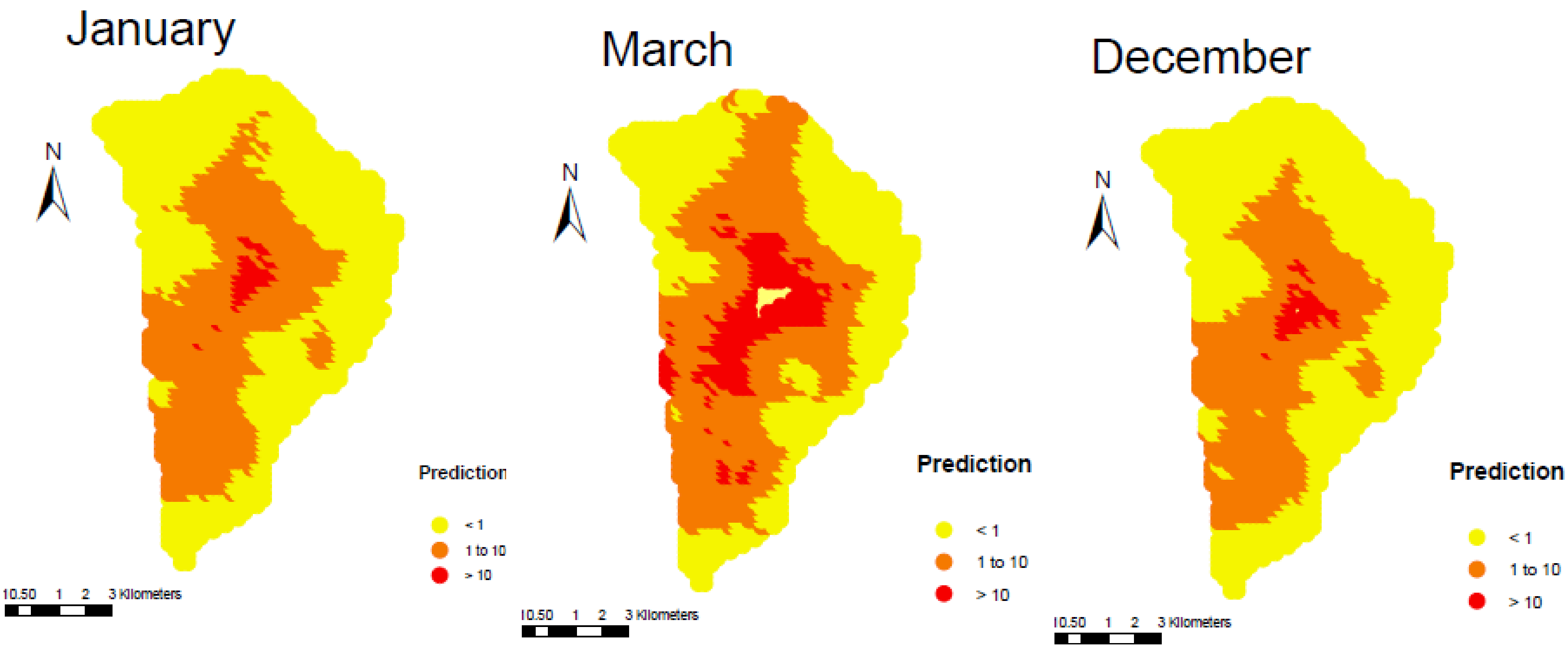
Prediction errors for SR using ZIB model



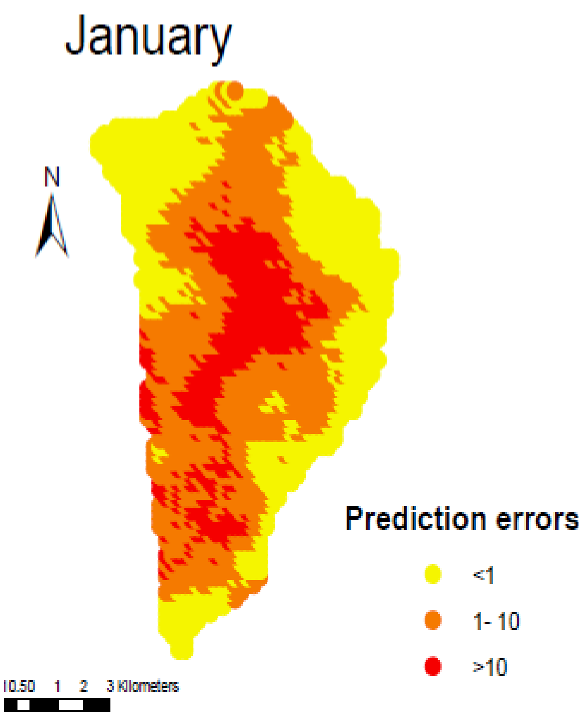


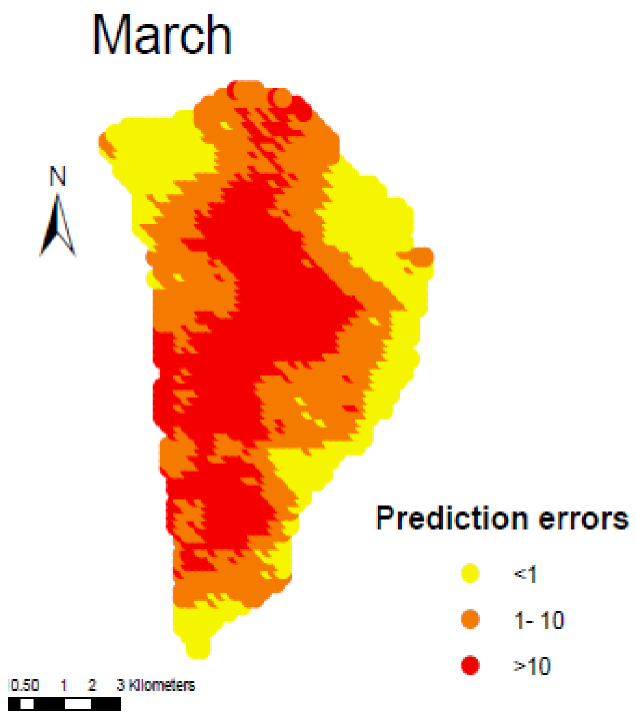


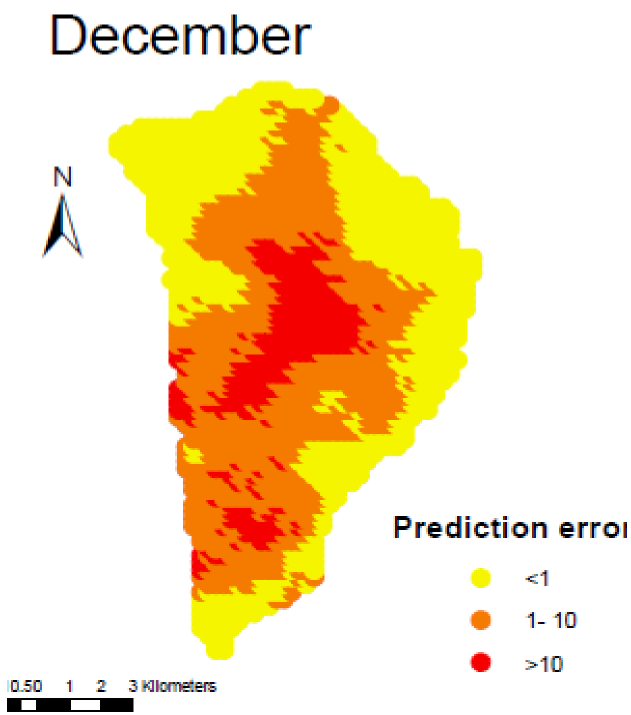
Predicted mosquito density using ZINB (AG)



Prediction errors for Density using ZIB model







Discussion

- Accurate maps are essential tools needed in establishing the effectiveness of malaria control innervations
- Malaria transmission in sub-Saharan Africa is heterogeneous and environmentally driven. Application of spatio-temporal models is a necessary measure for developing early warning sign for a particular country.
- Entomological data is very sparse making statistical analysis complicated

Acknowledgement

Swiss Tropical Institute

PD Dr. Penelope Vounatsou

Prof. Dr. Thomas Smith

MTIMBA Site PIs

1. Dr. Salim Abdulla
2. Dr. Kayla Laserson
3. Dr. Ariel Nhacolo
4. Dr. Seth Owusu-Agyei
5. Dr. Diadier Diallo

Financial Institutions

- Swiss National Foundation
- MIM/TDR, RBM and WHO-AFRO
- Other funding agencies for the network & sites

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THANK YOU !!!!