SUMMARY PAPER

ArcGIS and the fight against malaria:
Using GIS and remote sensing to compare malaria control interventions in Tanzania

Application for the 2017 Esri Young Scholar Award

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1. GOALS

1.1. Background

Malaria intervention methods have averted an estimated 663 million clinical malaria cases between 2000 and 2015, with insecticide-treated mosquito nets (ITNs) claiming 68% of the contribution [1]. Yet, the global malaria burden remains high, with 212 million estimated malaria cases worldwide and 429,000 estimated deaths in 2015 [2]. *Anopheles* mosquitoes, the exclusive vector of malaria parasites [3], are the primary focus of these malaria prevention initiatives. Indoor residual spraying (IRS) is the second major control tool and, unlike the more widely-used ITNs, is applied largely in targeted areas only, where insecticide is sprayed on indoor surfaces [4]. The World Health Organization has implemented various global malaria reduction and elimination milestones for 2030, but adequate funding for these targets is lacking [2]. How might GIS help malaria control efforts better target at-risk populations?

1.2. What led to this project?

During my Master's degree, I compared spatial patterns in ITN ownership across the United Republic of Tanzania (hereafter Tanzania) in Africa (Figure 1a) with *Anopheles* mosquito distributions [5]. I chose Tanzania as my study region because malaria remains the leading cause of morbidity and mortality in the country, particularly in children under the age of five [6]. Also, Tanzania was one of the first African countries to implement rigorous ITN and IRS strategies [7, 8]. I hypothesized that if ITN ownership were optimized to target most at-risk areas, ownership would increase with increasing mosquito habitat suitability. However, my results suggested the opposite was true [5].

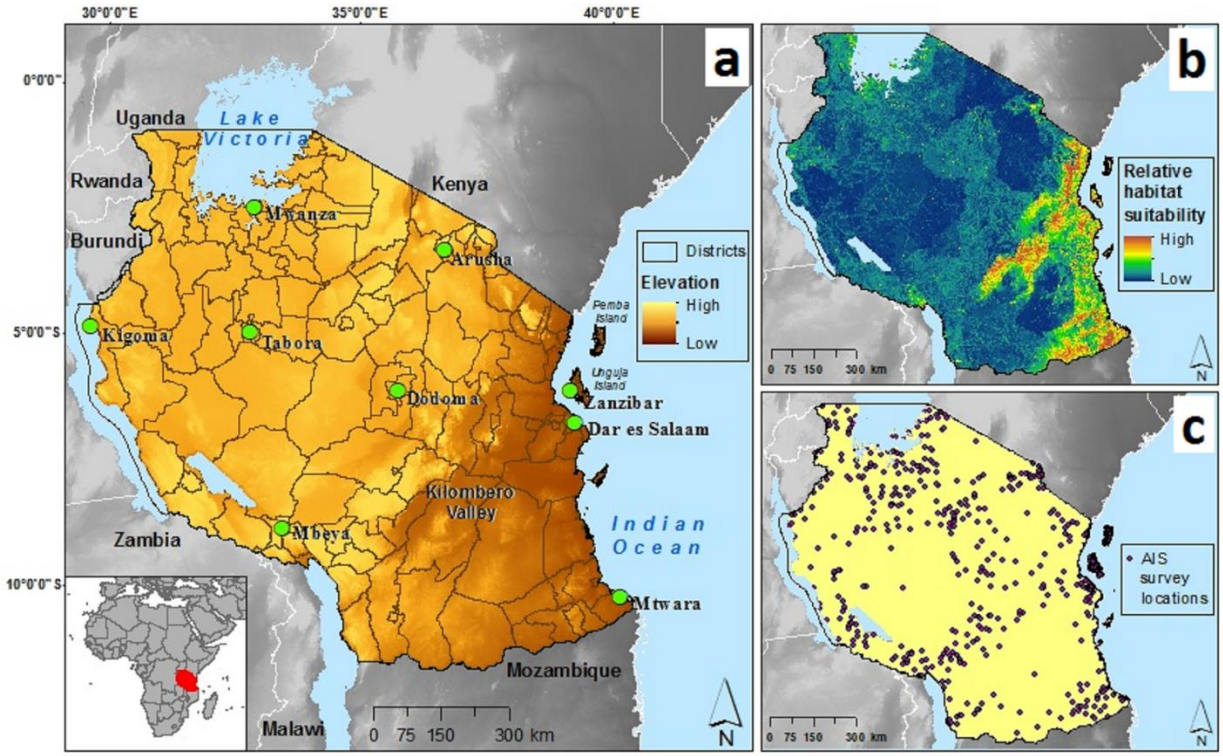

Figure 1. a) Map of Tanzania, b) *Anopheles* habitat suitability map created by Maxent, and c) the survey locations provided by the AIDS Indicator Survey (AIS).

1.3. What am I aiming to accomplish?

For this year's Esri Young Scholar Award, I present my findings from the project extending from my Master's degree. Instead of looking at general ITN ownership, I focused on ITN use amongst children under the age of five [6]. I also analyzed IRS coverage across the country. Since IRS is not distributed countrywide but targets only northern Tanzania and the islands, does IRS coverage target at-risk areas better than ITN coverage? This project is unique because GIS analyses have never before been conducted to compare ITN and IRS use with mosquito distributions anywhere in the world.

2. METHODS

First, using the Maxent program (Version 3.3.3k) [9], a species distribution model was constructed relating *Anopheles* mosquito occurrences for 1999–2003 to environmental observations. The output was an *Anopheles* habitat suitability map (Figure 1b). This time period was chosen because it preceded countrywide malaria control efforts that may have affected mosquito distributions [10]. I used ArcMap 10.3.1 to prepare these environmental records for input into Maxent.

Second, I used the R-ArcGIS bridge to create 2011-2012 layers of ITN and IRS coverage with georeferenced data across Tanzania supplied from the AIDS Indicator Survey (AIS) (Figure 1c) [11]. I made buffer zones around each survey location, since the AIS randomly displaces urban locations by up to 1 km and rural locations by up to 5 km for privacy reasons, but does not allow the displaced coordinate to pass district boundaries (Figure 2).

Third, I looked at three variables: 1) the average number of children under the age of five using an ITN the night before the survey was conducted, 2) the proportion of children under the age of five using an ITN the previous night (i.e. no children = 0; ≥ 1 child = 1), and 3) the proportion of dwellings that had been sprayed for mosquitoes in the 12 months prior to the survey (i.e. no spraying = 0; spraying = 1). I correlated the resulting buffer areas of ITN and IRS use to the underlying mosquito habitat suitability map.

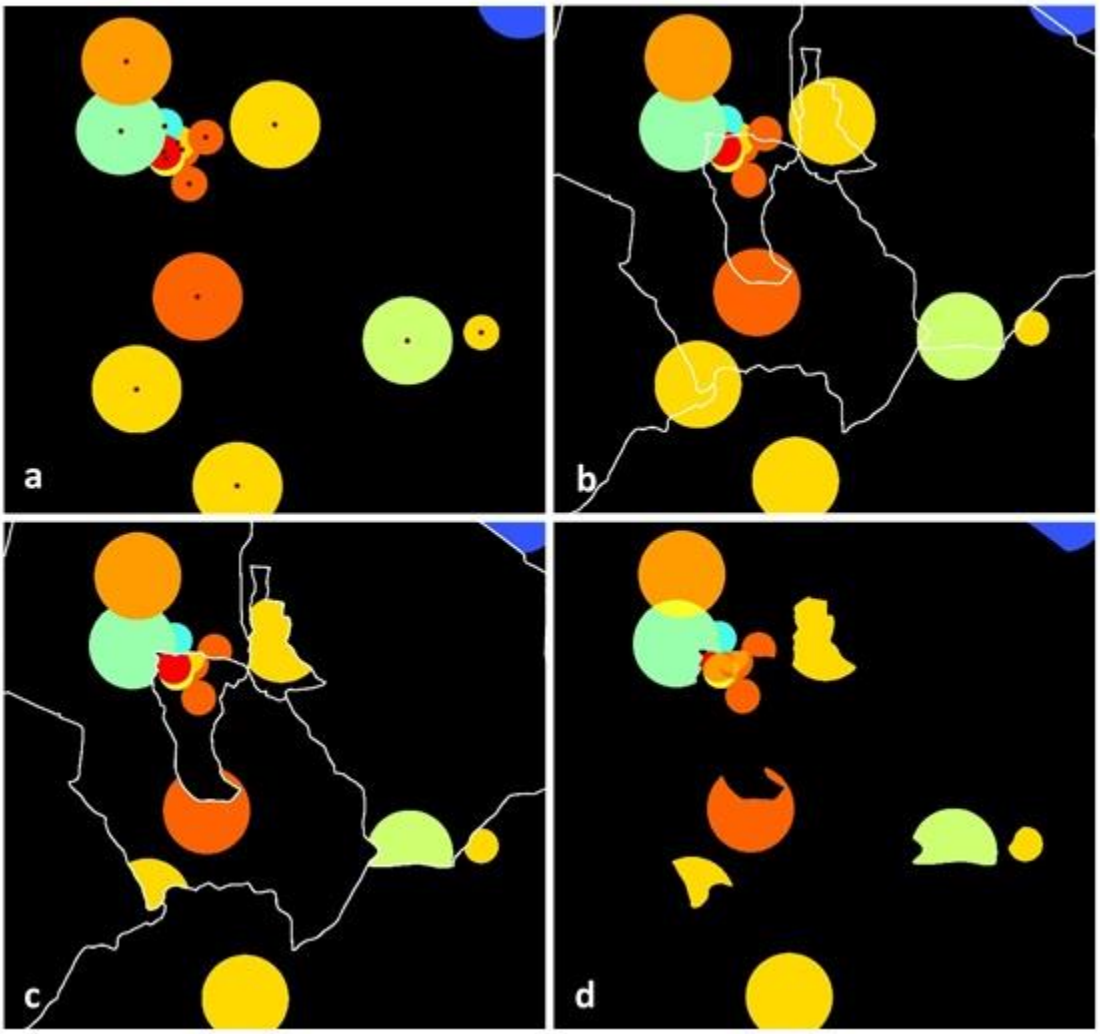

Figure 2. An example of the buffer clipping process. a) The original buffer zones around survey locations, b) the district boundaries, c) where buffers were clipped along district lines, and d) the final buffer layer used for the analysis.

3. RESULTS AND CONCLUSIONS

3.1. What I found

My results were consistent with previous findings on ITN ownership [5], with the average number, and proportion, of children under five using an ITN the previous night showing

weak but significant negative correlations with mosquito habitat suitability based on Ordinary Least Squares (OLS) regression (R^2 = 0.079 and R^2 = 0.087, respectively). IRS applications showed a relatively strong significant positive correlation with mosquito habitat suitability (R^2 = 0.319). Quantile regression analysis, which looked at the populations within the lowest and highest 10% of ITN or IRS use (i.e. 0.1 and 0.9 quantiles, respectively), also showed these significant trends (Figure 3).

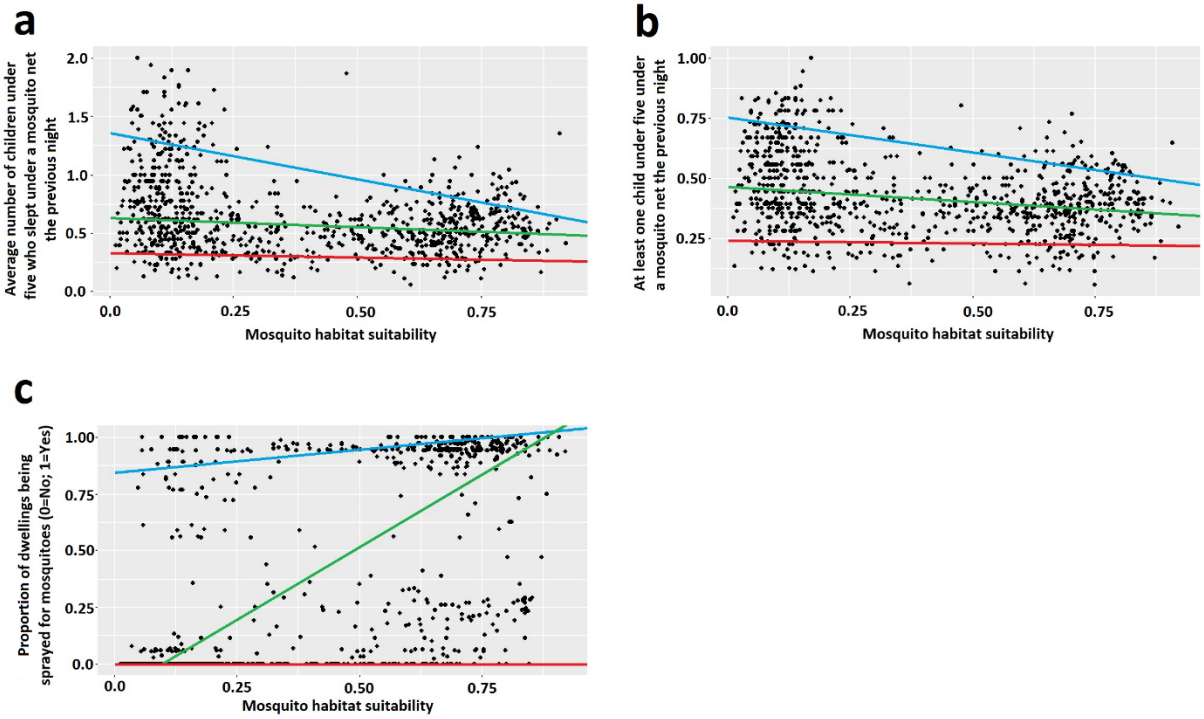

Figure 3. Scatterplots representing the OLS regression line (green) and corresponding 0.1 (red) and 0.9 (blue) quantile regression lines for a) the average number and b) proportion of children under five who slept under an ITN, and c) the proportion of dwellings sprayed for mosquitoes in the last 12 months, all as a function of *Anopheles* habitat suitability in Tanzania.

3.2. Are these results unexpected?

I did not expect these results because ITNs are the top method of malaria control worldwide [1]. IRS use is particularly limited because it is more intensive to apply and is currently decreasing in Tanzania because of the need to switch to more expensive insecticides due to mosquito resistance [12]. Yet, despite its more limited use, IRS managed to target areas with higher mosquito habitat suitability, while ITN use amongst children under five decreased with increasing habitat suitability.

3.3. What's next?

I accomplished my goal to compare ITN and IRS coverages in Tanzania and discovered that IRS coverage appears to target at-risk areas better than ITN use at the countrywide scale. However, since IRS appears to be localized to certain regions of Tanzania, I would like to focus future work on local scales of Tanzania. Do ITN and IRS coverages still target mosquito habitats the same way at local scales? These analyses provide a crucial GIS perspective to help countries allocate limited control resources and meet malaria elimination deadlines.

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