The Malaria Distribution case study
Interactive PPDAC Report

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1. Introduction

This paper focuses on actively preventing human-based malaria outbreaks in Africa using a special anti-mosquito product. Though still a serious issue globally, health authorities assert that ninety percent of all malaria-related deaths actually occur in Africa. This makes the continent a natural spatial-temporal focus for efforts to prevent regular outbreaks of this mosquito-spread disease.

Unlike a tsunami or similar random event, research shows that malaria outbreaks often occur predictably when certain broad conditions are met simultaneously, creating a malarial "hot zone":

- High temperatures, common in Africa, but not usually found in mountainous areas.
- Rainfalls over 100 mm per month for an area that experienced a 'sub-100 mm' amount the month before.
- High population density within these vulnerable areas.

To prevent outbreaks, this paper supposes that a special bedding net has been developed by a pharmaceutical company intended to retard mosquito breeding. A coordinated distribution effort is proposed to get a supply of nets to vulnerable areas at the right time. Issues of concern are the fact that the net is effective for one month, requiring right before a favourable outbreak month, and that only one area per month can receive a load. Our concerns are: Where, and on which month, will the nets be delivered? How will they be delivered? How does the project make sure that no deliveries are duplicated?

2. Plan

The cartographic goal of this project was to create a final "travel" map showing where and when the anti-malarial nets were to be distributed. This involved a multi-map visualization process using ArcGIS Model Builder, beginning with a map showing areas of high population density. This was followed by a map showing those areas climatically favourable to a malaria outbreak, overlapped onto the first map to show areas where an outbreak was likely to occur (both high and low population areas), as well as areas with a low likelihood. The next map added in the months when the rainy season would probably begin, followed by a focused final map showing a hexagon-based travel plan highlighting the exact area, month and airport used for the net supply drop.

3. Data

The data for our final map consisted of both raster and vector data. All the provided 'raster' data sources related directly to the three main factors that make an area vulnerable to malaria, with useful themes of elevation (related to temperature), rainfall annual/monthly means, and African population densities. The 'vector' datasets we chose to use, provided within a file geodatabase, included AfCountryBoundary (for reference) and HexagonalZones_Africa (for the final map). We also used an outside dataset showing all official airports in Africa.

We chose not to use any of the three water-themed datasets, since we felt this data was not needed, nor the cities or regional datasets, since they added nothing of value to the crucial "population-density" factor. The Roads dataset was also unnecessary, since our concern was focused on airport-centric distribution on a large continent, rather than the means by which the nets would be distributed afterward.

4. Analysis

We first defined areas where the population faces a high risk of contracting malaria, assuming that outbreaks required temperatures (height below class 7), rainfalls (more than 400 mm/year) and population densities (above 70 person/Km2). An “average annual rainfall” raster and a “heights” raster are reclassified [1] [2] to define vulnerable areas, after which critical rainfall areas and critical temperature areas are aggregated [3] and reclassified [4] to only show areas where these two climatic factors co-occur. The result is combined [6] with a reclassified [5] raster presenting population densities above 70 person/Km2 (based on ‘65 person/Km2’ average population density for Africa). After reclassification [7], the raster matches malaria-likely areas to densely populated areas. Two countries (Madagascar, South Africa) were excluded by extracting [9] raster values that do not overlap the country polygons.

We then looked at the time factor, since outbreaks occur in the month when the rainy season starts (as mentioned earlier). Rainfall rasters for each month were clipped [10] to the malaria risk study area raster to show rainfall values only in these areas. The monthly rainfall rasters are reclassified [11] to show areas where rainfall totals are below (value 0) or above (value 1) 100 mm. To define where and in which month the rainy season starts, twelve rasters are created by calculating [12] the value of the previous month plus the value of the current minus the previous (for example: January + February - January).

A travel plan was created, based on air travel (due to large distances) and a limit on one hex zone per month. To focus efforts, the population density raster is reclassified [13] to show only areas with the highest densities (above class 11). The population density raster values then multiplicate [14] the twelve “rainy season starting months” raster. This shows months and areas where outbreak risk is higher. The outbreak risk average value for each hex zone is computed by a zonal statistic operation [15]. The twelve rasters’ values were converted [16] into integer datatype to extract [17] the four hexagons with the highest malaria outbreaks risk for each month. This manual operation determines the four highest values for each raster. Finally, the values were sorted and presented in graphic form in the interactive map.

A manual selection of hexagons with the highest values for each month gives us the correct hexagon, since those with highest population densities often over-represent the malaria outbreak risk in comparison with lower density hexagons. Therefore, if mosquito nets have have already been distributed in a hexagon, no additional new supplies will be distributed in the same hexagon for the next 12 months, so that distribution is “passed down” to a hexagon with the next lower value. A world airport vector dataset was then clipped [18] to provide airports, and displayed in the interactive map along with the travel itinerary.

5. Conclusion

Malaria is still a serious health threat in many parts of Africa, and GIS technology and skills are obviously well-suited to investigating the logistical possibilities of fighting such serious issues. This project clearly illustrated how careful spatial-temporal analysis, using appropriate data and optimized GIS software, can be used to produce a useful and time-sensitive cartographic tool. Our multi-step ‘predictive approach’ clearly allowed us to fulfill the primary goal of choosing where, when and how the specialized nets would be distributed, with the ultimate aim of maximizing the prevention of catastrophic outbreaks.

Analysis Workflow

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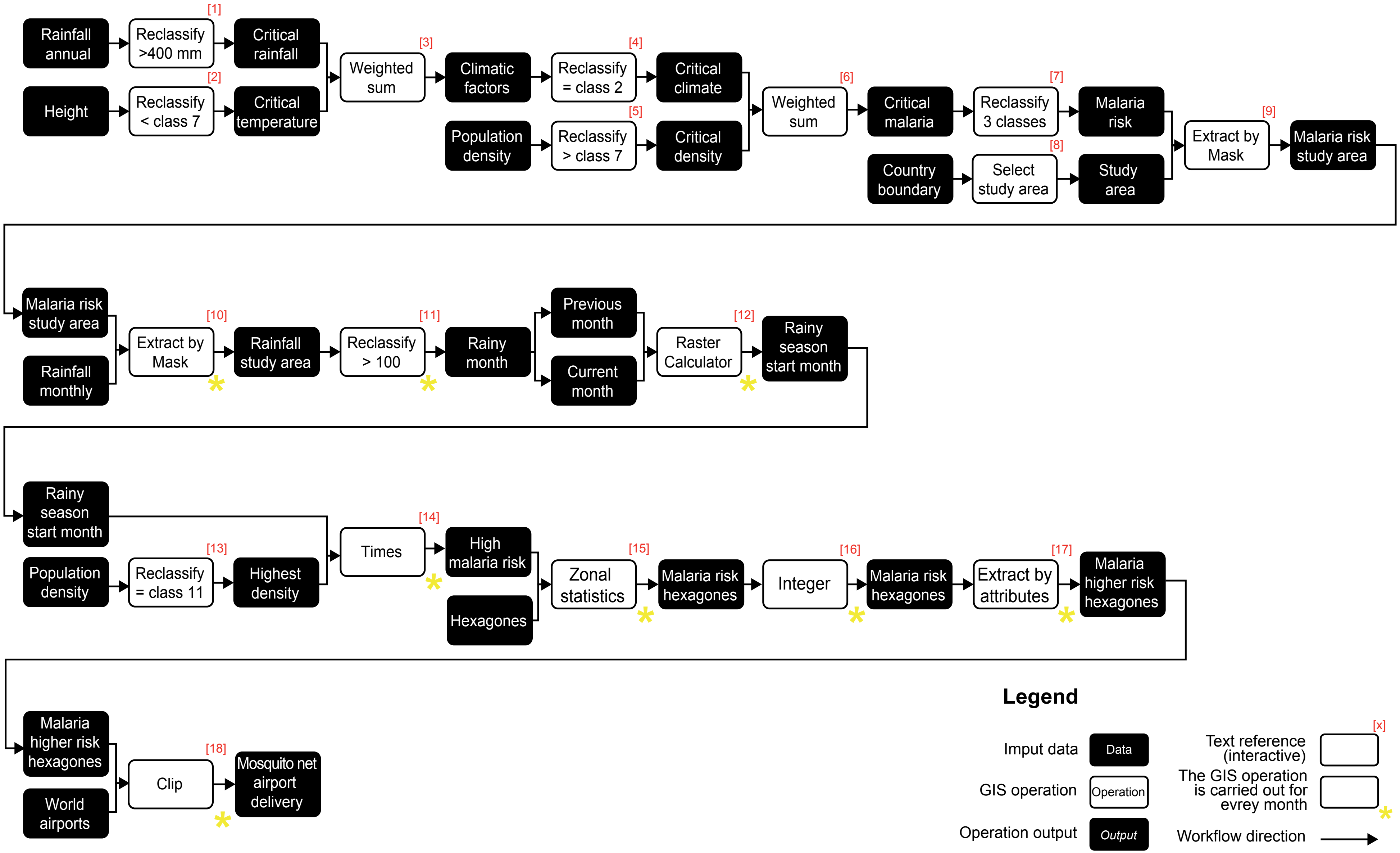

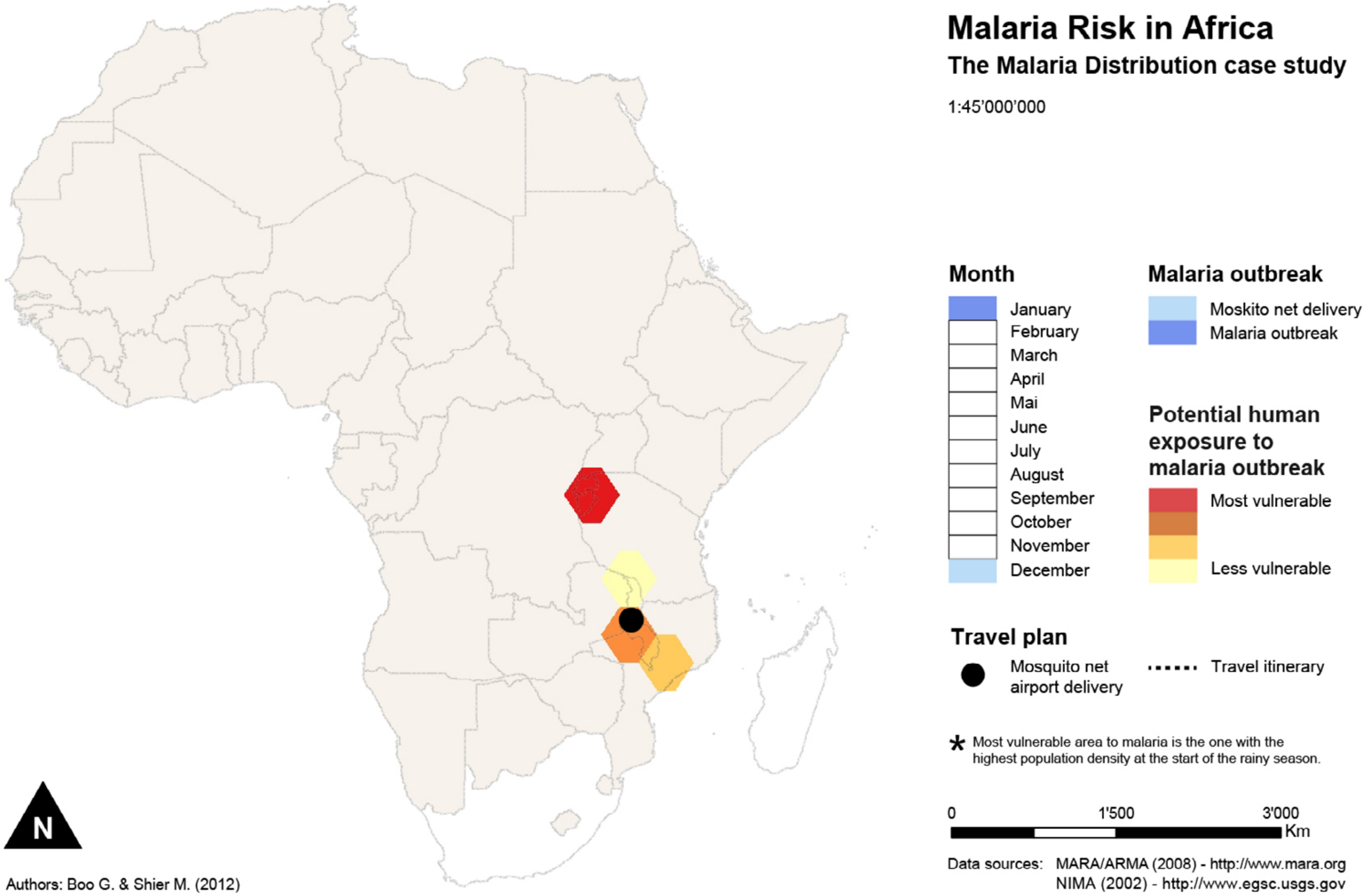
Malaria Risk in Africa
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1:45’000’000
Month
January
February
March
April
Mai
June
July
August
September
October
November
December
Malaria outbreak
Moskito net delivery
Malaria outbreak
Potential human exposure to malaria outbreak
Most vulnerable
Less vulnerable
Travel plan
Mosquito net airport delivery
Travel itinerary
* Most vulnerable area to malaria is the one with the highest population density at the start of the rainy season.
0
1'500
3'000
Km
N
Authors: Boo G. & Shier M. (2012)
Data sources: MARA/ARMA (2008) - http://www.mara.org
NIMA (2002) - http://www.egsc.usgs.gov

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