Malaria transmission vulnerability in Ethiopia: a spatial analysis

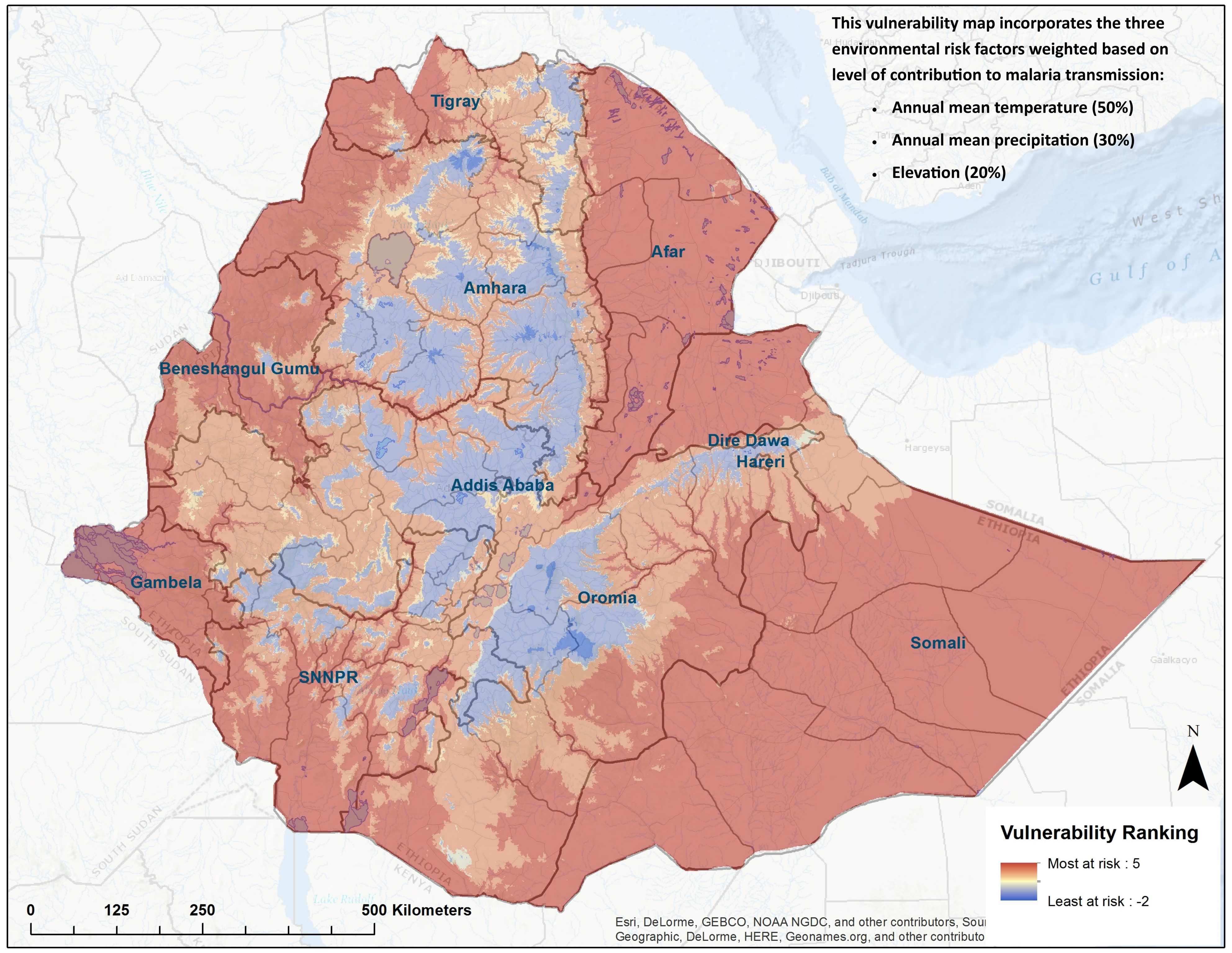
Introduction

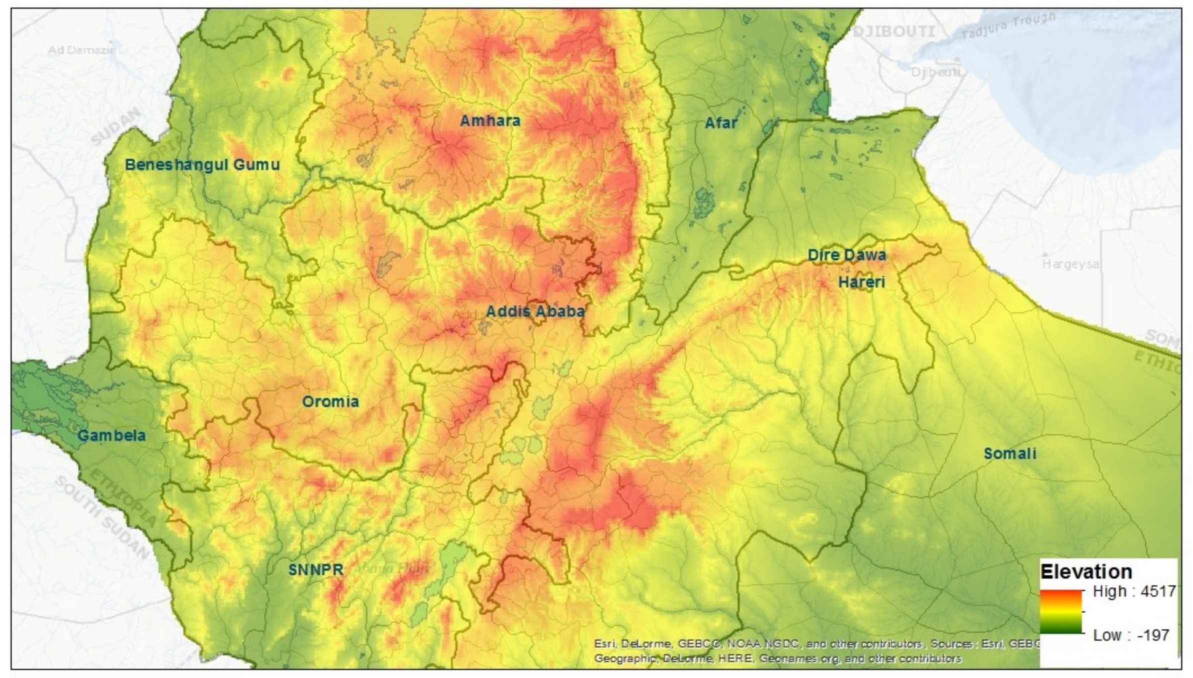
Malaria is a life-threatening disease caused by Plasmodium parasite infection. According to records from the Ethiopian Federal Ministry of Health, 75% of the country is malarious with about 68% of the total population living in areas at risk of malaria. That is, more than 50 million people are at risk of malaria, and 4-5 million people are affected by malaria annually. The disease causes 70,000 deaths each year and accountant for 17% of outpatient visits to health institutions. This has serious consequences for Ethiopia's subsistence economy. Transmission of malaria mainly depend on environmental factors such as precipitation, temperature and altitude. Identification of high risk areas will help inform intervention planning and will also ensure effective allocation of resources. The aim of this project is to identify areas most vulnerable to malaria transmission in Ethiopia by analyzing environmental risk factors.

Methodology

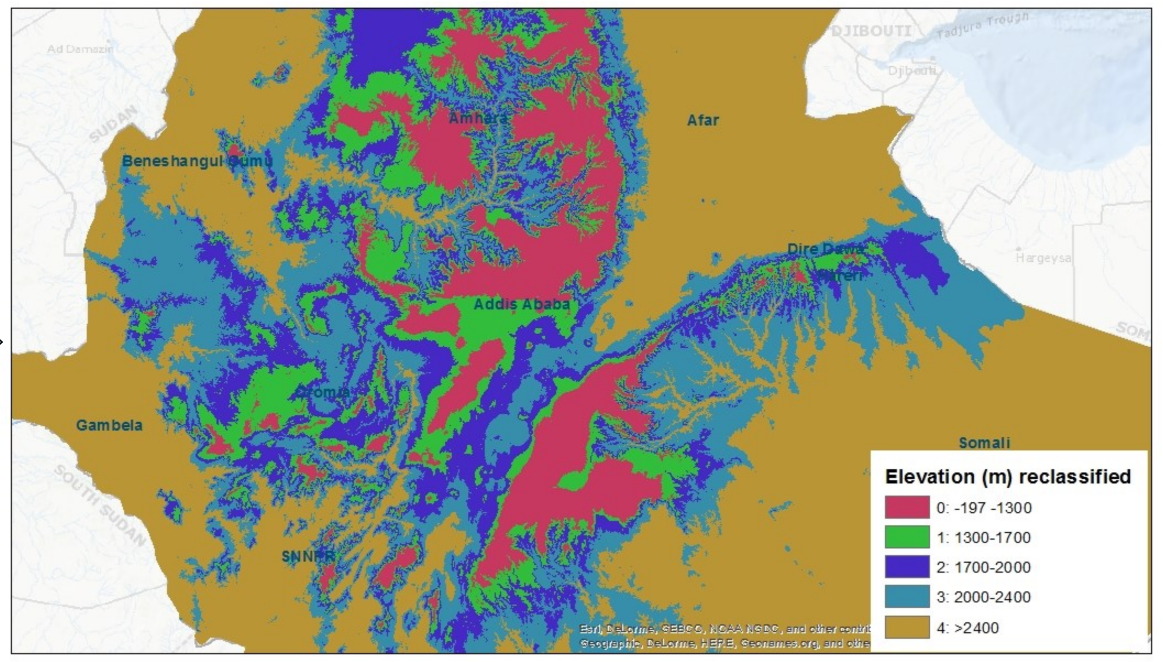
Vulnerability is often complex and difficult to define as it is a function of several factors. For the purpose of this analysis, however, we simply defined vulnerability as the predisposition of a society and its population to the burden of malaria by taking into account spatial differences in susceptibility. This approach examines the propensity of individuals to be negatively affected by malaria as a result of environmental risk factors. Three risk factors were taken into account i.e. temperature, precipitation and altitude. Annual mean temperature and precipitation datasets were represented as raster layers with each cell (pixel) assigned 2 byte integer values. These layers were generated through interpolation of bioclimatic data from 24,542 weather stations all over the world on a 30 arc-second resolution grid (often referred to as "1 km2" resolution) and represent a 50 year average (1950-2000). Lastly, the digital elevation model raster was used to represent altitude in meters. These rasters were first reclassified into 5 classes based on their respective suitability levels for the transmission of malaria using the ArcGIS "reclassify" analytical tool. This suitability levels were adopted from previously documented scientific literature. Previous research have indicated that average temperatures between 18°C and 32°C, precipitation accumulation over 80mm and elevation level ranging from 1,000-1,200 meters above sea level are known create suitable conditions for easy transmission of the parasite. These specific ranges were made to represent the most suitable classes while ranges that were below and above were made to assume relative scores. Following this, the 3 reclassified layers were combined using the "Weighted Overlay" ArcGIS analysis tool. The Weighted Overlay tool scales the input data on a defined scale, weights the input rasters, and adds them together. Weighted Overlay assumes that more favorable factors result in the higher values in the output raster, therefore identifying these locations as being most at risk. Before running the model, different weights were assigned to average temp (50%), precipitation (30%) and elevation (20%). Based on this model, a vulnerability map was developed with a combined score ranging from -2(low) to 5(high) malaria risk. Finally, the "Zonal Statistics as Table" was employed to summarize population density of each vulnerability zone based on the 2000 population estimates of Ethiopia. The population density raster were presented in a 2.5 arc-minute grid cells and are in the unit of persons per square kilometer.

Results

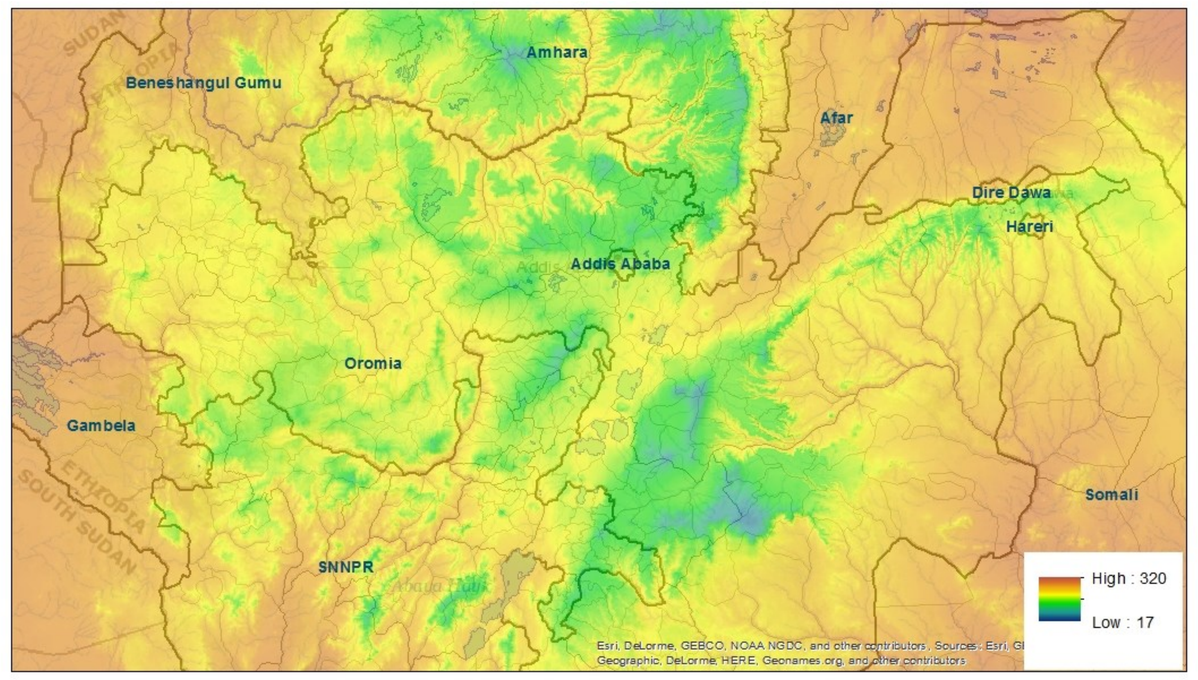




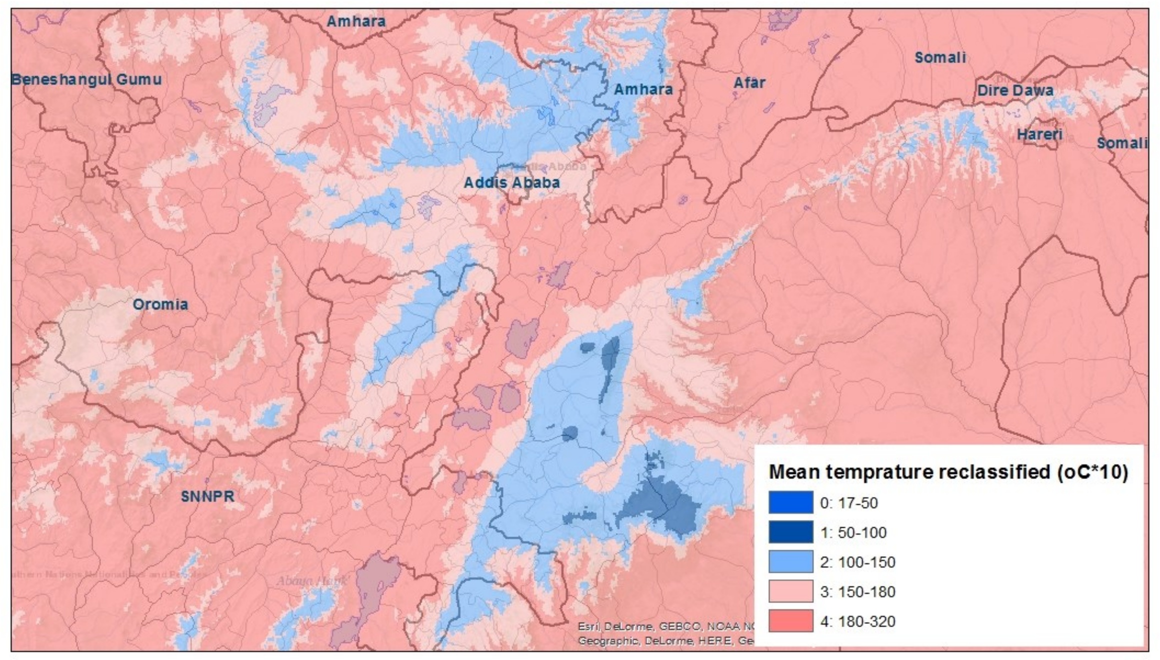
Elevation raster (DEM-90m UTM)



Elevation raster (DEM-90m UTM): reclassified based on suitability for malaria transmission



Annual mean temprature



Annual mean temprature- reclassified based on suitability for malaria transmission

Tufts University | Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy

Cartographer: Robel Alemu
Class: Nutr 231, Date: Dec 22, 2015
Projection: GCS Adindan/UTM zone 37N

Discussion and Conclusion

The model generated 5 vulnerability zones with varying levels of suitability to the malaria transmission . The map shows that most of the Northern and Eastern highlands of the country were the least vulnerable for malaria transmission. On the other hand, the North Eastern, North Western and South Eastern low lands with relatively higher annual mean temperatures were the most at risk of malaria transmission. Interestingly, similar patterns have already been established by numerous on ground studies. According to this studies, the *Dega zone* (altitude above 2,500 meters and mean annual temperature of 10-15 degree Celsius) is categorized as malaria free while much of the *Woina Dega zone* (altitude 1500-2500 meters) is also mostly malaria free, especially the zone in the 2000-2500 meters above sea level. On the other hand, malaria epidemics is often common below 2000 meters but could also extend up to 2400 meters during periods that are conducive for both vector survival and parasite development. As can be expected, the zonal statistic table indicated that the population density tends to be higher for geographies with low vulnerability scores. The most vulnerable zone had the least (24) average number of persons per square kilometers. The population density tends to increase as the vulnerability level decrease .

Risk zone	Mean # of people/ Km^2
-2 [Low]	97.23
1	151.19
2	128.76
3	122.18
4	84.61
5 [High]	16.61

Accurate information on the geographic distribution of malaria risk and of the human populations it affects is a critical element of malaria control program design. Outputs of such models could be used to better inform malaria control interventions- for instance, more resource could be allocated to high risk locations with high population density.

Limitations

Seasonality of transmission: the bioclimatic datasets were derived from monthly temperature and rainfall values. As such, these data only represent the annual trends of these variables. In reality, malaria transmission is highly seasonal. Malaria transmission peaks bi-annually from Sept-Dec and Apr-May. Given this, it is highly likely that the annual bioclimatic data may have under or over-estimated suitability for malaria transmission. Future work could focus on examining seasonal variability by using more granular bioclimatic data.

Limited datasets: 3 datasets may not adequately represent vulnerability as there are many other factors known to contribute to vulnerability. These include, socio-economic (education, knowledge, behavior, income, etc.), biological (age, acquired immunity, drug resistance and nutritional/health status), geographic (landuse, distance from waterbodies, etc.) and institutional (access to health services, quality of care, etc.). Model could be made to represent reality by incorporating socio-economic, biological and institutional factors

Data sources and references:

Annual mean temp and precipitation: WorldClim-Global Climate: GeoTIFF Zone 27. Museum of Vertebrate Zoology, University of California. Free climate data for ecological modeling and GI.

Elevation: Consultative Group for International Agricultural Research– Consortium for Spatial Information (CGIAR-CSI). United Nations-OCHA Ethiopia. Jan 01, 2004.

Population Density: Center for International Earth Science Information Network—CIESIN– Columbia University

Picture credit: QIMR Berghofer Medical Research Institute

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