Land surface predictors of diarrheal diseases:

A spatial comparison of urban slum and rural villages in southern India

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Introduction

The rate of diarrheal diseases is high in Indian rural villages and urban slums, contributing to malnutrition and death in young children. These diseases are faecal-orally transmitted, i.e. are contracted through contact with faecal matter or from contaminated drinking water. Lack of closed sewage drainage and the open-field defecation increase the likelihood of the transport of enteric pathogens through the subsurface into the groundwater, the sole source of the public drinking water, and the probability of direct contact with pathogen contaminated soil. In this preliminary study we applied GIS and spatial analysis to explore whether soil properties are related to water quality and enteric infections.

Our main objectives were to:

- Gather soil samples from two rural and two urban slum areas in the Vellore district of southern India
- Characterize the differences in physiochemical soil properties between the rural and urban areas
- Interpolate the soil properties values across the land surface within each area
- Determine whether soil properties affect nearby water quality and/or household diarrhea rates

Data Collection

All data was collected by the Christian Medical College Department of Community Health in India. Ten soil samples were collected from each area, five from an area where children play and five from an area next to an open sewer, over a four week period in June 2011. Diarrhea cases were recorded daily from 300 households with children under five-years-old. Monthly water samples were collected from public distribution taps starting in January 2011.

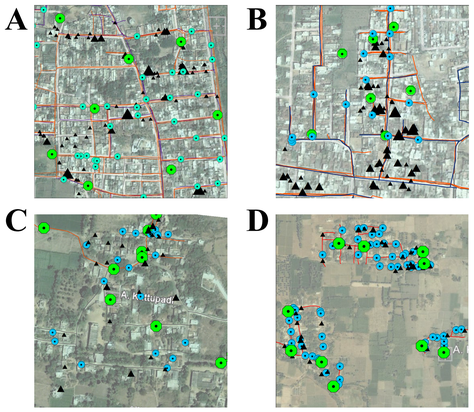
Water samples tested for:

- Coliform
- Fecal Coliform
- Total Dissolved Solids
- pH
- Nitrite
- Chlorine

Soil samples tested for:

- pH
- Cation Exchange Capacity
- Moisture Content
- Porosity
- Sand, Silt, and Clay
- Ammonia
- Total Soluble Organics

The Sites



The basic layout of each study site (Urban: Kaspa (**A**) and RNP (**B**) ; Rural: A. Kattupadi (**C**) and A. Kattuputhur (**D**)) including the soil sampling locations, the public water taps, and the total number of diarrhea episodes at each study house to date.

Legend

- Soil Sampling Sites
- Public Distribution Water Taps

Study Houses

- 0 episodes
- 1-2 episodes
- >3 episodes

Preliminary Results

Several soil properties showed significant accuracy in predicting diarrhea cases at nearby study houses as well as coliform counts in nearby public water taps. The following models were developed:

$$\text{Exp}[\log(Y_1)] = 0.70692 - 0.07919\ CEC$$

$$\text{Exp}[\log(Y_2)] = 3.90571 + 0.16443 * pH - 0.45176 \log(Moisture)$$

Where Y_1 is the predicted number of diarrhea episodes at a study house within the study year, *CEC* is that cation exchange capacity, Y_2 is the predicted fecal coliform counts within 1 mL of water from the nearby public water taps, *pH* is the soil pH, and *Moisture* is the soil water content.

Legend

Water Taps

Fecal Coliform

- NA
- 0 - 80
- 81—150
- > 150

Soil Sampling Sites

Study Houses

- 0 episodes
- 1-2 episodes
- >3 episodes

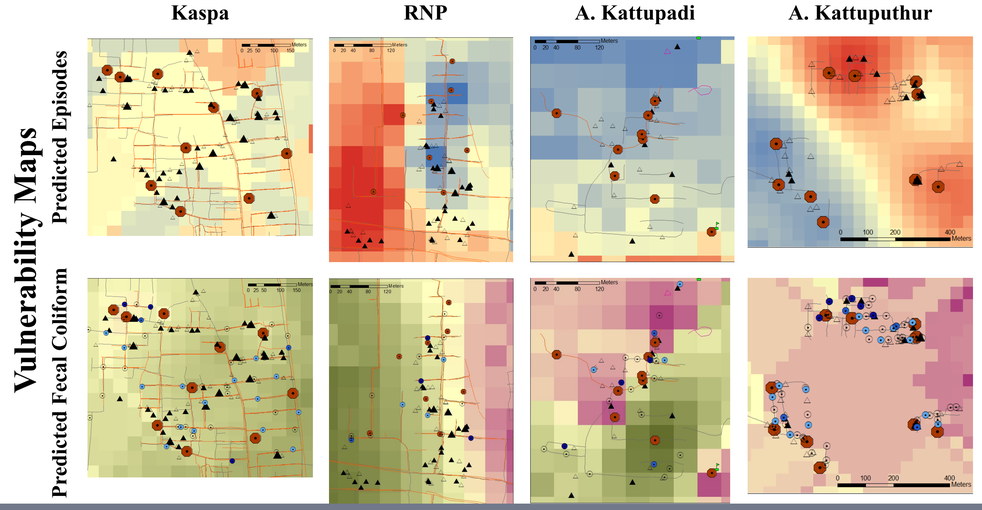
Pr[Episodes]

High: 1.0

Pr[Fecal Coliform]

High: 130

Low: 45



Methods and Analysis

Soil characteristics were linked to geocoded locations of 300 households in rural and urban study sites, their main source of drinking water, coliform counts in nearby public drinking water taps, and recorded diarrheal disease occurrences. Standard statistical methods were used to compare the soil physiochemical properties between rural and urban study sites. ArcGIS was used to interpolate the soil properties across each area (**Figure 2**).

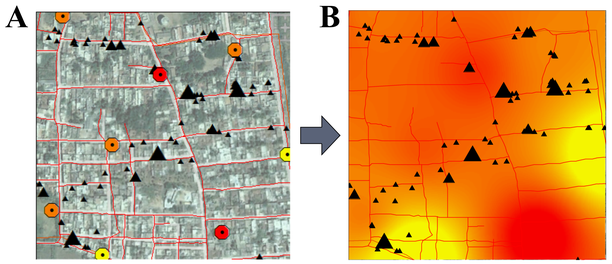


Figure 2: The process of interpolation in ArcGIS from several soil sampling points (**A**) to a value for every point across the study site (**B**)

Interpolated values were reanalyzed for statistical significance in predicting diarrheal disease rates and/or water quality. Two models were developed, one predicting household diarrhea episodes and a second predicting the vulnerability of public taps to fecal coliform contamination. The previously created interpolation rasters were used to calculate and display overall vulnerability maps created for each site.

Conclusions

- Soil properties do vary by study area, with noticeable variation between rural and urban areas
- Lower soil moisture and higher soil pH may predict fecal matter entering the water taps
- Lower CEC may indicate the likeliness of children picking up diarrhea pathogens from the land surface
- Conclusions can be made about the impact of diarrheal disease transmission as a growing rural population moves to urban slum areas

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