Modeling and Mapping of *Coccidioides* Soil Habitat

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Summary: The soil survey database of the United States is used to produce spatially explicit maps of locations where *Coccidioides* spp may be expected to live.

INTRODUCTION:

- The saprophytic stage of *Coccidioides* spp exists in the soil where and when certain soil properties and climatic conditions that control the habitat are suited to the growth of the fungus.
- Current understanding of the geographic distribution of *Coccidioides* is primarily defined by skin test studies performed in the late 1940s and 1950s and also by outbreaks outside of these historically-defined areas.
- *Coccidioides* testing in soil has indicated patchy distribution.
- The United States Department of Agriculture, Natural Resources Conservation Service maintains a database called the Soil Survey Geographic Database (SSURGO) which contains tabular and spatial information about soils.
- We developed a model to identify suitable habitats for *Coccidioides* in soils of the western United States based on attributes similar to locations where the fungus has been identified.

Table – Key soil and site attributes for model

Soil or site attribute	Too low	Optimum	Too high
Electrical Conductivity of upper 30cm (dS/m)	<0.5	10	200
Mean annual precipitation (mm)	0	300-400	800
Mean annual air temperature (C)	10	15-16	30
pH of upper 30cm	8.0	9.0	--
Saturation within 30cm (months)	--	<=1	>10
Slope shape (up and down)	Convex	Concave	--

METHODS:

- SSURGO parameters in the model include: electrical conductivity, temperature, precipitation, pH, organic matter content, depth to water saturation, water holding capacity, and land surface morphometry.
- A rule based fuzzy system model was developed to determine a habitat suitability index for *Coccidioides* spp. In a fuzzy system, each item is indexed from 0 to 1, with 0 meaning that the attribute is outside the range needed by the organism and 1 meaning the attribute is optimal.
- Optimal values or ranges for each soil and site attribute were gleaned from the literature as much as possible.
- The rules for each attribute are processed and weighted and a habitat suitability index derived, which also ranges from 0 to 1. An index of one indicates the soil and site characteristics are very similar to known highly endemic areas while an index of zero suggests the soil and site will not allow the growth of the fungus.
- We mapped the index outputs from the soil survey spatial data visually using a geographic information system. The scale of the resulting map is in the range of the soil survey, 1:24,000 to 1:12,000; thus, the resolution of the display is 540 times that of a 1:13,000,000 scale map (which depicts the western United States on a page). This allows possible habitat areas as small as a few hectares to be identified.

RESULTS:

- The model accurately identifies known historically endemic areas, such as Phoenix, Arizona and the San Joaquin Valley of California, as being highly suitable for *Coccidioides.*
- The figure depicts the habitat index in a series of maps progressing from a national scale and zooms in to a local scale on an area just west of Phoenix, Arizona. The land area that is highly suitable for the organism is a relatively small proportion of the country.
- Some suitable habitat borders the unpublished areas on the map. These unpublished areas are typically on publically owned land often used for recreation.
- Additionally, the model predicts outliers where the spatial and temporal conditions relative to temperature and rainfall may provide a suitable habitat in some years but not in others. Some of these outliers have been sites of coccidioidomycosis outbreaks including; Swelter Shelter, Dinosaur National Monument, Utah, and areas of northern California.
- In the Pacific Northwest, the model also predicted areas in Southcentral Washington State where locally-acquired cases were identified.

CONCLUSIONS:

- Increased understanding of habitat suitability for *Coccidioides* is important as a marker of geographic risk for public health and healthcare providers.
- Awareness of likely *Coccidioides* soil habitats and spatially explicit mapping of these areas could help the public and industry mitigate risk when conducting soil-disturbing activities and could help providers improve diagnosis and treatment of ill persons.

Figure -- Modeled prediction of the distribution of the likelihood of *Coccidioides* soil habitat, from national, state, county, to local scales.