The research site: looking up at Table Mountain from the south. Cover is oak woodland.

# Cartographic Modeling with SSURGO and DEM Data Using a Combination of GIS and POVRAY

Dylan Beaudette, Minghua Zhang, Anthony O'Geen. AGIS Lab, UC Davis. 2004.

Another view of Table Mountain. Note the exposed trachyandesite (an intermediate between andesite and basalt) lava flow.

## ABSTRACT

Cartographic modeling is a powerful tool that can be used to better understand the dynamics that exist between many kinds of spatially related phenomena. Estimating habitat suitability, potential erodibility, and landslide probability are some examples of how cartographic modeling can be used. One roadblock to developing useful cartographic models is the availability of relevant, and more importantly, accurate data. The purpose of this project is to demonstrate one way that freely available digital soil survey data (SSURGO) and elevation data (USGS DEM) can be used to produce useful thematic maps, cartographic models, and 3D visualizations pertaining to soil management. An example model was developed to estimate soil erodibility based on 4 factors derived from SSURGO and DEM data: soil organic matter, soil permeability, slope, and wind erodibility group. The software tools used to accomplish this were ArcGIS (ESRI) and POVRAY (3D visualization). Results pertaining to the extraction of data, problems that were encountered, and overall quality of the example applications will be discussed. Ideally this project will serve to promote the use of digital soil survey data, as well as provide a starting point for those who are interested in modeling soil phenomena. Planned future research deals with how to accomplish the same goals, using only open source (free) software tools.

## OBJECTIVES

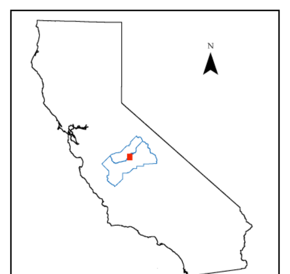
1. Demonstrate how the SSURGO digital soil survey database can be used to create various thematic maps relevant to soil properties.

2. Create a model that can be used to estimate an index of erodibility based on data that can be extracted from digital soil survey (SSURGO) and elevation data (USGS 10 meter DEM).

3. Display the output from the erosion model and thematic maps using a photo realistic rendering engine (POVRAY).

## MATERIALS AND METHODS

Cartographic modeling, otherwise known as composite variable mapping (Robinson, 1995), can be described as the process of combining several related variables into a single index that represents the sum of the contributions from each input. The resultant index can be used to visualize complex environmental interactions that may not be immediately visible when looking at maps of the individual inputs. Since it is extremely important that all of the input data have been registered to a common grid system, a GIS is usually the best environment when working with purely digital data. In this project the ArcInfo (produced by ESRI) GIS package was used.

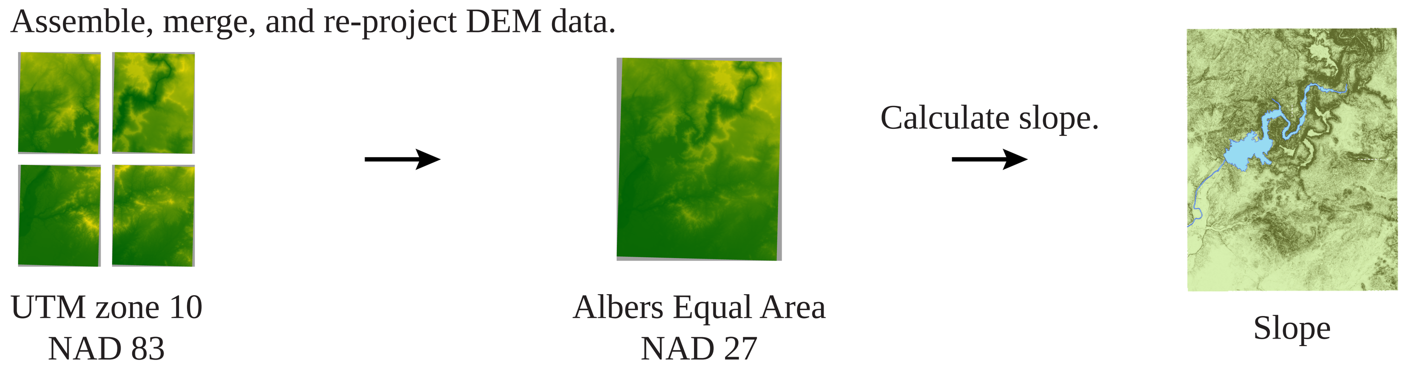


Study Site

A simple soil erosion model was created in order to demonstrate how the data from the SSURGO digital soil survey database, along with topography data extracted from USGS digital elevation maps, can be incorporated into a cartographic model. The study site for this model consists of the area enclosed by four 7.5 minute USGS quads (Millerton East, Millerton West, Friant, and Academy), located on the border of Fresno and Madera counties. Site is labeled in red on the adjacent map of California.

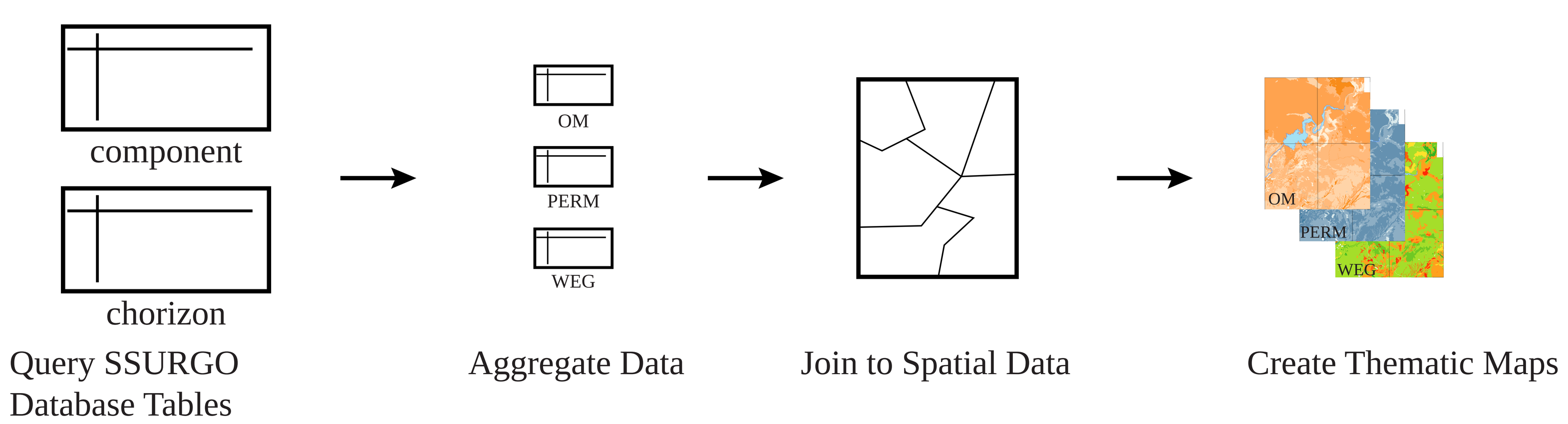
1. Create slope map for site area:

Assemble, merge, and re-project DEM data.

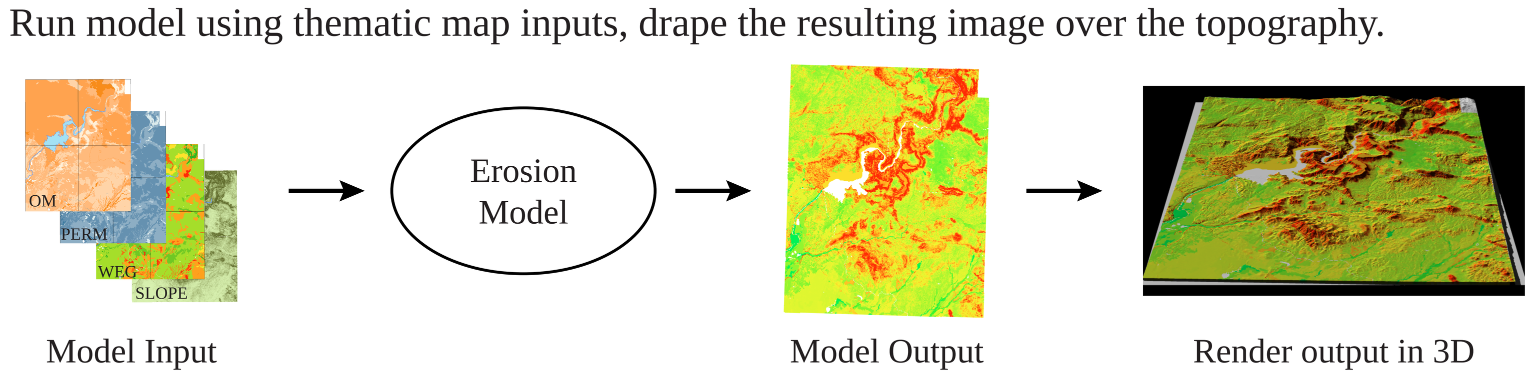



2. Process, average, aggregate, and join data tables to SSURGO polygon features: soil organic matter, soil permeability, and wind erodibility group.

3. Create a thematic map for each: soil organic matter, soil permeability, wind erodibility group, and soil erodibility index (K value used in the universal soil loss equation).




4. Run model using thematic map inputs, drape the resulting image over the topography.




## EXTRACTING DATA FROM THE SSURGO DATABASE (NOTES ON VERSION DIFFERENCES)

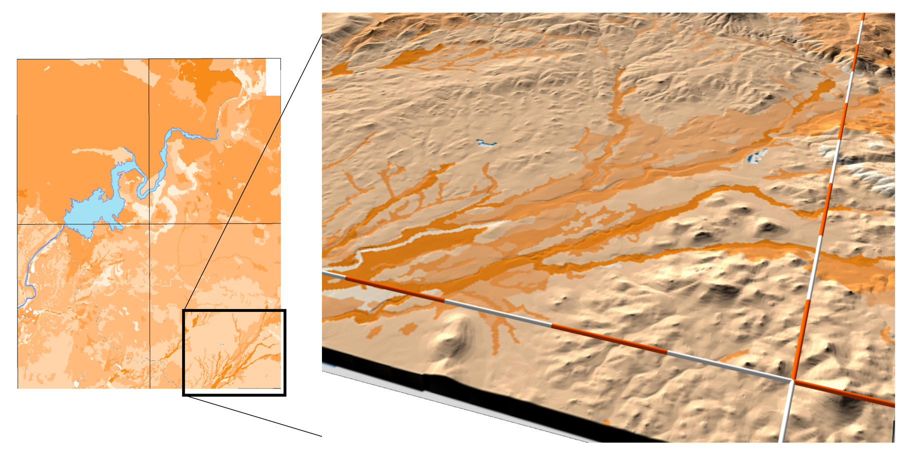
### SSURGO I

SSURGO version 1 attribute data provided in INFORMIX or text format. In order to create thematic maps from attributes located in the 'component' or 'layer' table, you must first aggregate the data starting from the 'layer' table. Since there are up to 3 components for every mapunit (polygon), any information from the layer table must be aggregated again. For example the amount of organic matter contained in each mapunit was calculated by summing the amount of organic matter in its components, whereas the permeability and WEG components were averaged. After aggregation at the 'component' table level, the data may then be joined to the spatial layer and visualized.

### SSURGO II

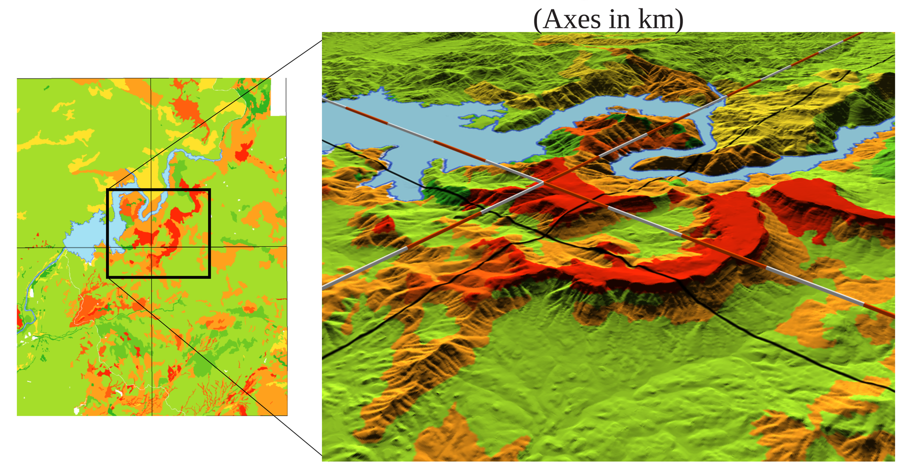
SSURGO version 2 data is distributed in download able text files. The table names, column names, units, relationship classes, and overall structure of SSURGO version 2 data are quite different that of version 1. Furthermore, the tabular data cannot be directly imported into ArcGIS because the files are missing the column headings. One way to access the tabular data is to import the files into an access database template that the NRCS provides. Then, individual tables can be exported in the appropriate format. Once the tabular data has been exported, and loaded into ArcGIS, the techniques for aggregating data are the same as those used with version 1 tabular data.

## THEMATIC MAPS CREATED FROM SSURGO DATA AND VISUALIZED IN 3D BY POVRAY



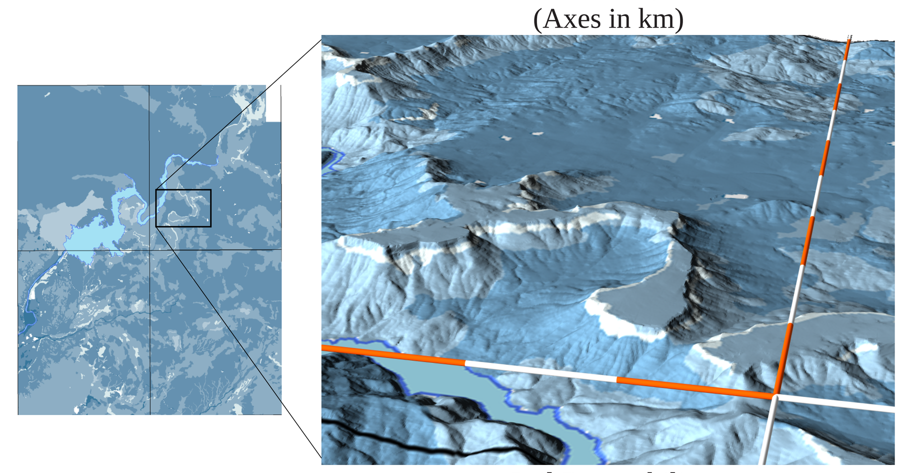
Soil Organic Matter
(Axes in km)

Weighted average of soil organic matter calculated by multiplying the percent SOM in the topmost horizon by that horizon's thickness. The resultant thematic map was then draped over the digital elevation map, and rendered by POVRAY. Darker colors indicate more soil organic matter. Note higher levels of soil organic matter visible in riparian areas.



Wind Erodibility Group
(Axes in km)

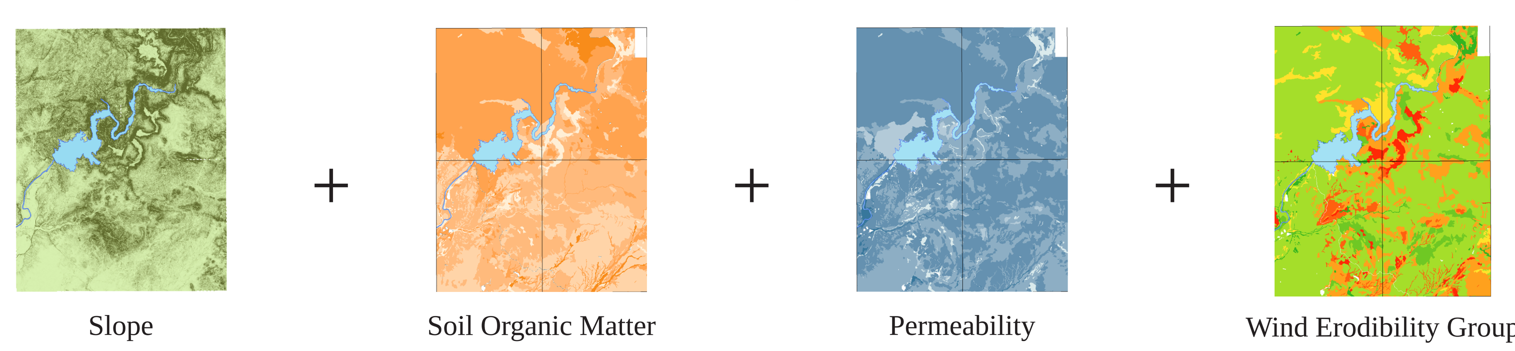
The wind erodibility group (8 groups) is based on the properties of the surface horizon that are considered to be related to the susceptibility to wind erosion (Soil Survey Manual, 1993). The gradient from group 1 to group 8 is designated by the transition in color from green - yellow - orange - red. Note the high susceptibility to wind erosion of the exposed ridges and lava caps.



Soil Permeability
(Axes in km)

Soil permeability, a term used in place of saturated hydraulic conductivity in SSURGO I databases, of the topmost soil horizon. Darker colors indicate a higher permeability. Note the relatively high permeability of the soil covering the top of the lava flows, as compared to the much lower permeability of the steep slopes. The white band, indicating very low permeability, corresponds to the layer of exposed lava.

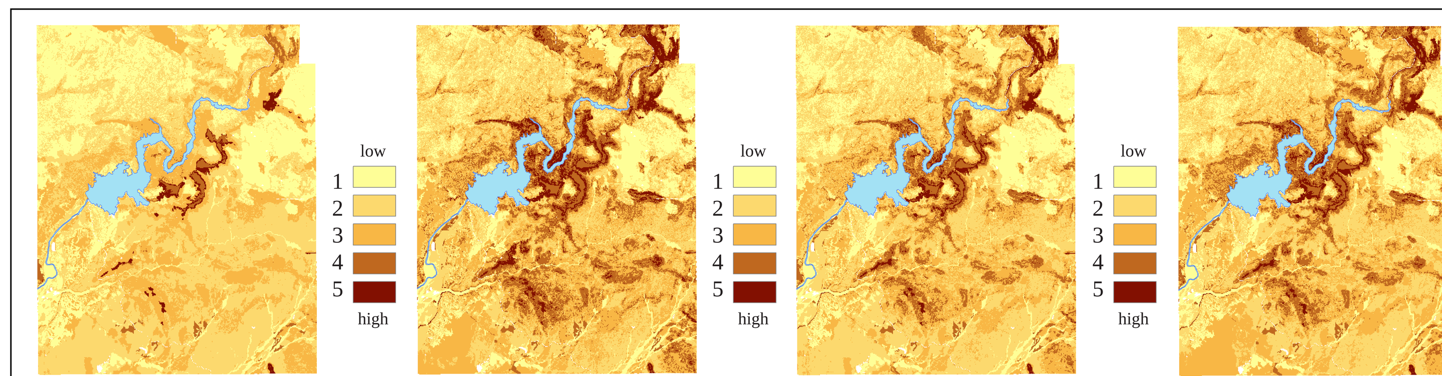
## THE MODEL




$$E = k_1(slope/slope_{max}) + k_2(-om/om_{max}) + k_3(-perm/perm_{max}) + k_4(weg/weg_{max})$$

**Equation 1**

RUSLE (revised universal soil loss equation) can be very effective at predicting soil loss on agricultural land or areas where intensive surface studies have taken place, however it may not be as effective at predicting erosion on non-agricultural land or in areas with little surface data (Regard, 1997). A simple model was created to estimate potential erosion (E), due to wind and water, in areas where the use of RUSLE was not otherwise feasible (see Equation 1). Larger E values denote a higher amount of predicted erosion. Note that the soil organic matter and permeability variables contain a negative sign due to the fact that erosion *usually* does not increase with increased soil organic matter or increased permeability (Singer, 2002). The calculation, or map algebra, was done with the raster calculator function in ArcGIS.




**1.** $k_1 = 1, k_2 = 1, k_3 = 1, k_4 = 1$

**2.** $k_1 = 1, k_2 = 0.75, k_3 = 0.5, k_4 = 0.1$

**3.** $k_1 = 1, k_2 = 0.75, k_3 = 0.5, k_4 = 0.25$

**4.** $k_1 = 1, k_2 = 0.5, k_3 = 0.75, k_4 = 0.25$

**Fig. 1**: Potential erosion (in 5 classes) as calculated by the model.

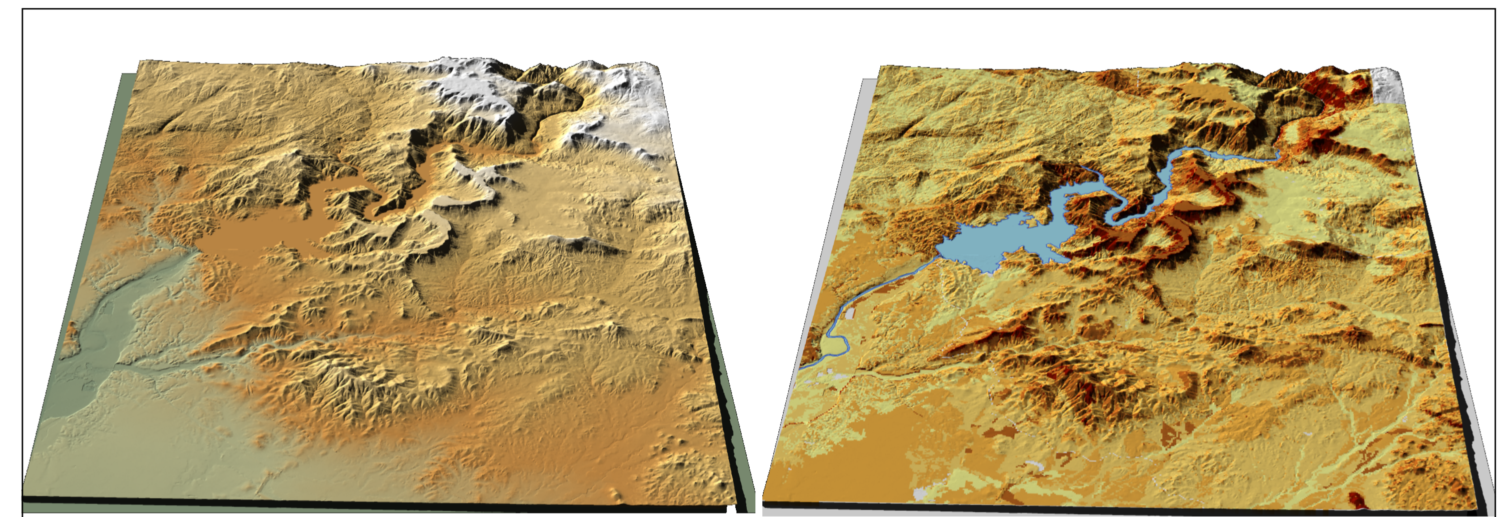


**Fig 2:** 3D visualization of topography (left) and potential erosion calculation 4 (right).

## RESULTS AND CONCLUSIONS

**Working with SSURGO**

Creating the thematic map inputs for the model was complicated by the fact that the research site spanned two counties, and two versions of SSURGO data. In order to integrate both versions, the attribute data from each must be converted to the same units. It was found that certain numerical columns in both versions of SSURGO were defined as character columns, thus preventing an average to be taken when summarizing the table. Manually creating a new table was the only way to overcome this minor inconvenience. An exciting new way to work with SSURGO is the Soil Data Viewer extension for ArcView 3, provided at no cost by the NRCS.

**Creation of Thematic Maps**

The thematic maps created from the SSURGO database provided a glimpse of how soil information can be quickly displayed in a convenient manner. Given the amount different variables recorded in the database, there is great potential for creating maps of interest to soil scientists, hydrologists, geologists, as well as the general public. With the aid of 3D visualization it is possible to view these maps from an infinite number of perspectives (Fig.2).

**The Erosion Model**

Four permutations of the model were run, with different weighting of each term in each run (Fig. 1). The weighings were based on the assumption that slope was the most important factor, followed by soil organic matter or permeability, and finally the wind erodibility group. In order to qualitatively compare the 4 outputs, the data were classified into 5 groups using the natural breaks method. While far from conclusive, the four examples above give some insight on how manipulating the weighting of each term affected the output. The accuracy of this model could have been drastically improved by including other factors such as surface cover, slope length, and average precipitation. After including these factors, a few days of ground truthing would be required in order to validate the results.

## FUTURE RESEARCH

A GIS is obviously the best environment for working with SSURGO-based cartographic models. A future project could explore and document that process of implementing a SSURGO-based cartographic model using an open source (free) GIS product. In conjunction with an open source GIS approach, it would be of interest to explore the use of a more robust database management system such as MySQL or POSTGRESQL- both of which are mature, open source products that can provide a more flexible way of managing tabular data such as that associated with SSURGO.

## REFERENCES

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CONTACT INFORMATION
Dylan Beaudette, debeaudette@ucdavis.edu, http://fungus.ucdavis.edu/~dylan/gis/
Minghua Zhang, mhzhang@ucdavis.edu
Agriculture Geographic Information Systems Lab, UCD
(530) 754-9292