Judy Hellmich
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Site Suitability Analysis for Animal Manure Methane Digesters in California

Introduction:

Anaerobic manure digesters (also called methane digesters) collect manure and convert the energy stored in its organic matter into methane, which is used to produce energy (gas or electricity) for on-farm or off-farm use. The conversion to methane is the result of anaerobic digestion—a biochemical process in which organic matter is decomposed by bacteria in the absence of oxygen. Methane is often called biogas even though biogas is methane plus other anaerobic digestion by-products, it will be referred to as both names in this paper but they are synonymous for the purpose of this assessment. The gas can then be flared or combusted to generate energy—a process with multiple other benefits including (among others) significantly reduced feedlot odors and greenhouse gas emissions.There is growing interest in installing anaerobic digesters on farms to use animal wastes as a biomass resource for both economic value and environmental benefit (Ma, 2005). This potential expansion prompts the need for land suitability assessment.

Site Assessment:

This study examines the site suitability of methane digesters in California. After looking at the national biogas production due to animal manure, California was chosen as the desired state of study due to its high level of biogas production relative to the rest of the country (Fig.1).

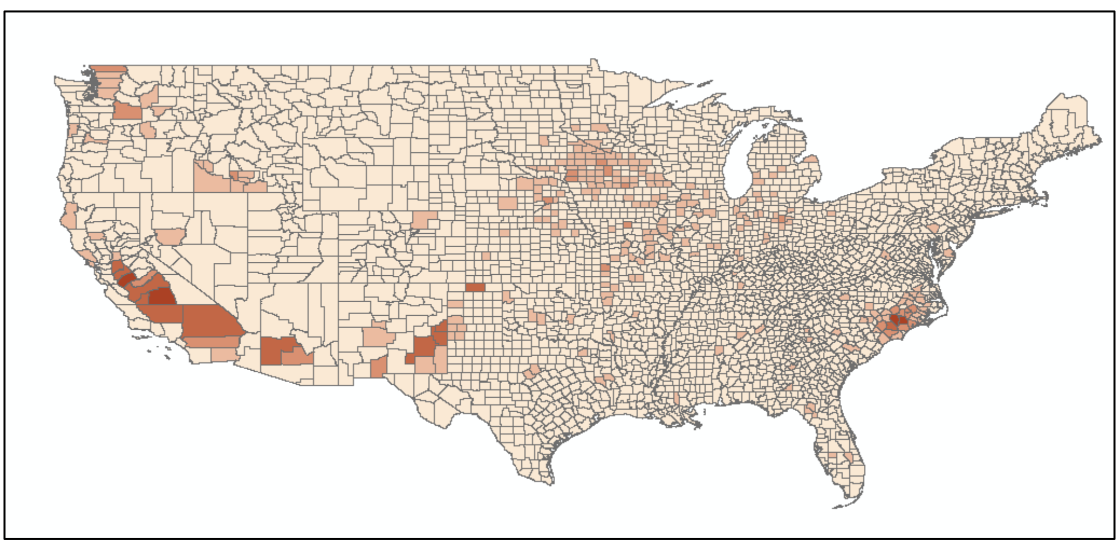

Figure 1. A view of the biogas methane potential of the continental U.S. showing high potential in California.

In order to pick the most suitable site for a methane digester five parameters gathered from a research paper that did a similar site suitability analysis for methane digesters in Tompkins County, New York were assessed (Ma, 2005).

1. Methane potential from animal manure (>500 tonnes/year): The potential bio-energy systems are preferably sited as close to or on existing dairy farms as possible to minimize transportation costs and environmental problems such as odor and nuisance. Ideally, most of the bio-energy systems should be located on existing farms if suitable. However, in some cases it may be required to develop new sites or centralized plants.

2. Proximity to roads (<30m avoided): Beyond the restricted buffer zone for minimizing odor and view, the closer to roads, the better to save transportation cost in the case of collecting dairy manure to a central plant.

3. Proximity to streams (<100m avoided): Animal waste in streams can lead to eutrophication and the transport of fecal related contaminants.

4. Proximity to natural gas pipelines (<100m avoided): Beyond the buffer zone for safety reasons, the closer to natural gas pipelines, the better to save costs if farmers choose the option of introducing cleaned biogas into the pipeline instead of generating electricity and heat.

5. Exclusion from city boundaries: Waste associated with the biogas process creates foul odors, pollution and noise making it undesirable in cities near large populations.

Animal wastes have long been criticized as a primary source of air and water pollution, raising both environmental and social issues. Because of this, bioenergy systems that utilize manure must be properly placed to avoid sensitive areas, such as streams, residential areas, roads, airports, etc. (Ma, 2005). In addition, safety concerns prevent any construction near power systems such as transmission lines, power plants, etc. Areas of steep slope are also restricted for development. To narrow down the number of factors in the assessment the assessment focused on the five parameters listed above.

Data Utilized:

File Name	Source	File type
biogas_methan_pot_animal_manure	NREL- Biofuels atlas	Shapefile
USA_Rivers_and_Streams	Esri data and maps	Shapefile
Natural_Gas_Liquid_Pipelines	Esri data and maps	Shapefile
CA_counties	US Census Bureau	Shapefile
USA_Major_Roads	Esri data and maps	Shapefile
California_cities_points	US Census Bureau	Shapefile

* To determine the biogas methane potential the following animal types were included in this analysis: dairy cows, hogs, and chickens (broilers). The methane generation potential was calculated by animal type and manure management system at county level using data from the USDA, National Agricultural Statistics Service, 2007 Census (NREL).

Preprocessing:

Since all of the files were for the entire U.S. and the assessment only required the data for California, I ended up clipping all of my files to a California county shapefile before projecting them (Fig. 2). I then projected all data sets to NAD 1983 UTM Zone 10N projection. California is split evenly among UTM zone 10N and 11N. Since I wanted to do a zoomed in image of the northern half I chose UTM zone 10N to minimize the distortion in my analysis (Fig. 3).

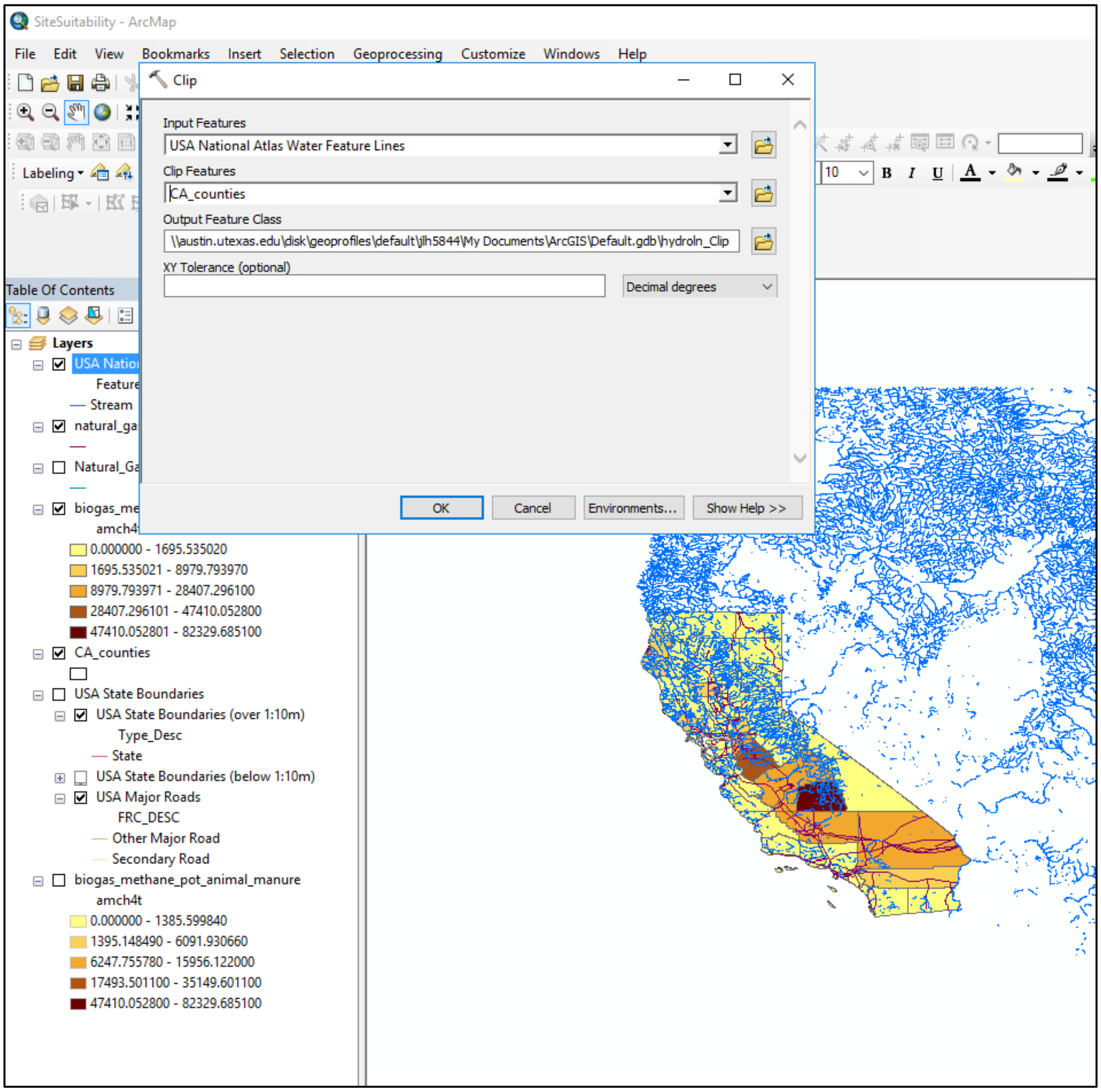

Figure 2. Image of the USA River file being clipped to the California county file.

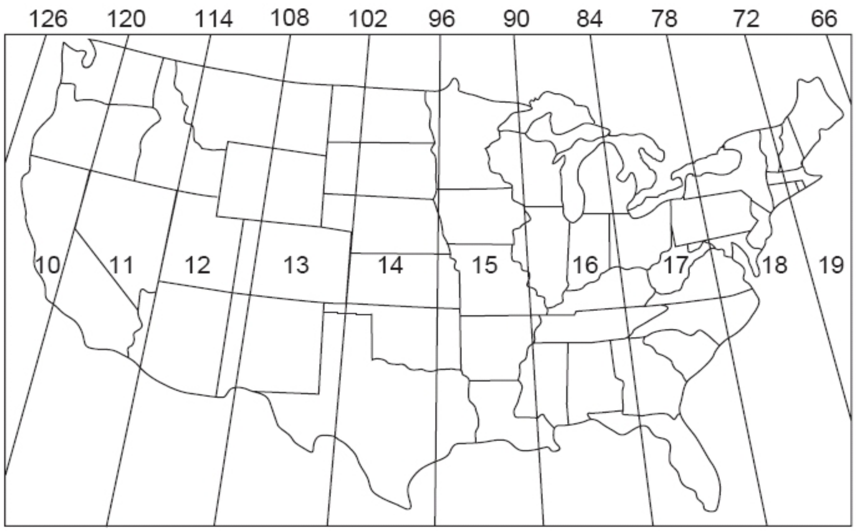

Figure 3: UTM zones for the U.S. show California split into zone 10N and 11N.

The assessment was started by first converting the biogas shapefile of methane potential into a raster. This was done by using the “Feature to Raster” tool. I chose the same resolution for each raster in order to properly analyze the data later on. I then went into symbology and changed the break intervals for the different measurements of methane potential from natural breaks to ones that I could manually enter (Fig.4). I choose the breaks of 500; 1,000; 2,500; 5,000 and >5000 tones/year because this is how the data was classified by the data source (NREL). A biogas potential of >500 tones/year is more than sufficient to justify the installation of a digester.

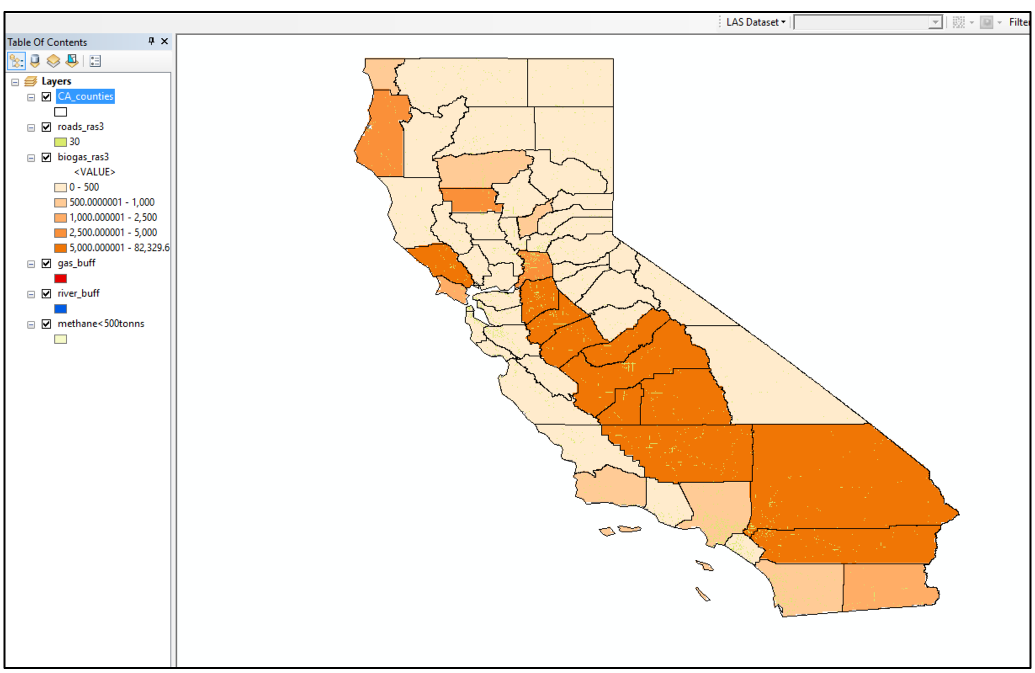

Figure 4. California after using the “Feature to Raster” tool and reclassification.

I then went about putting buffers on the rivers, roads and natural gas pipeline files according to their minimum distance. When I buffered the features the buffers were so small that they were hard to distinguish from the full view of California (Fig.5). By zooming in, the areas that were unsuitable were easier to differentiate (Fig.6).

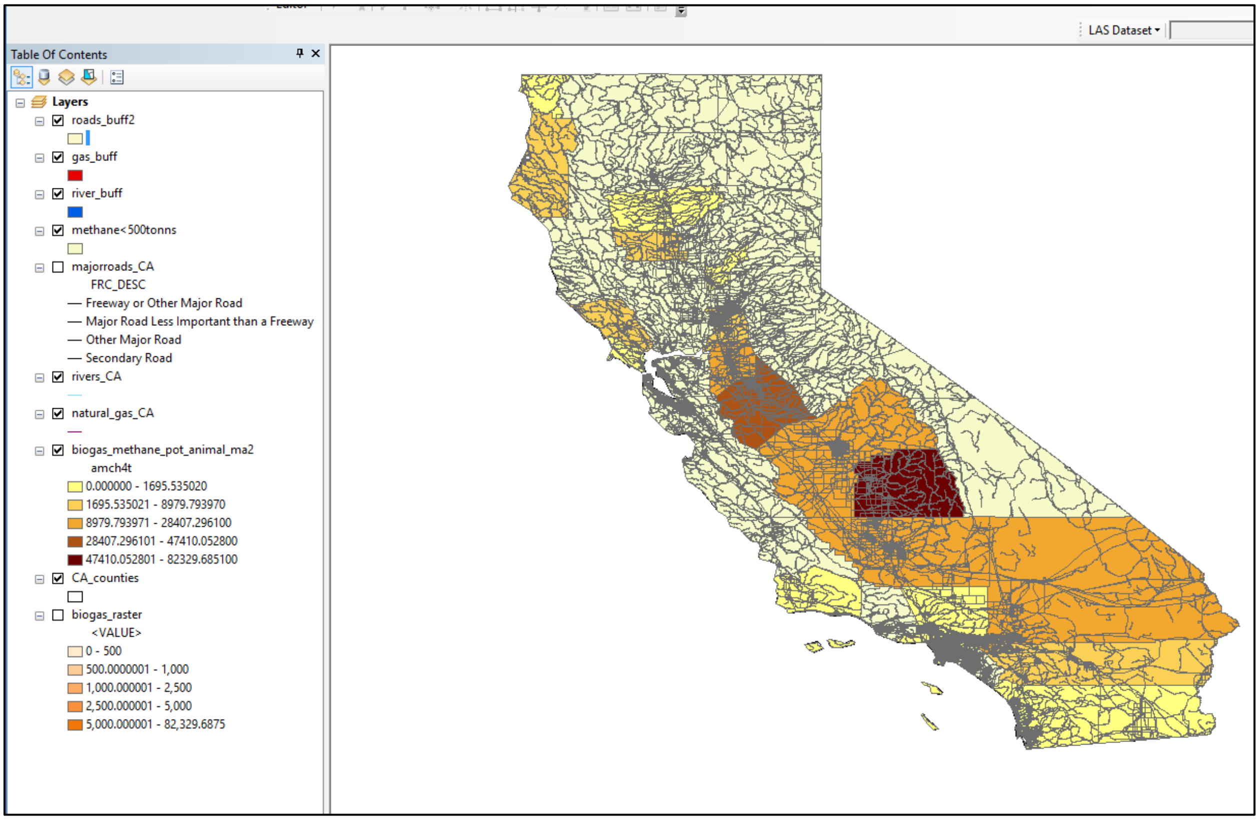

Figure 5. California after all features have been buffered.

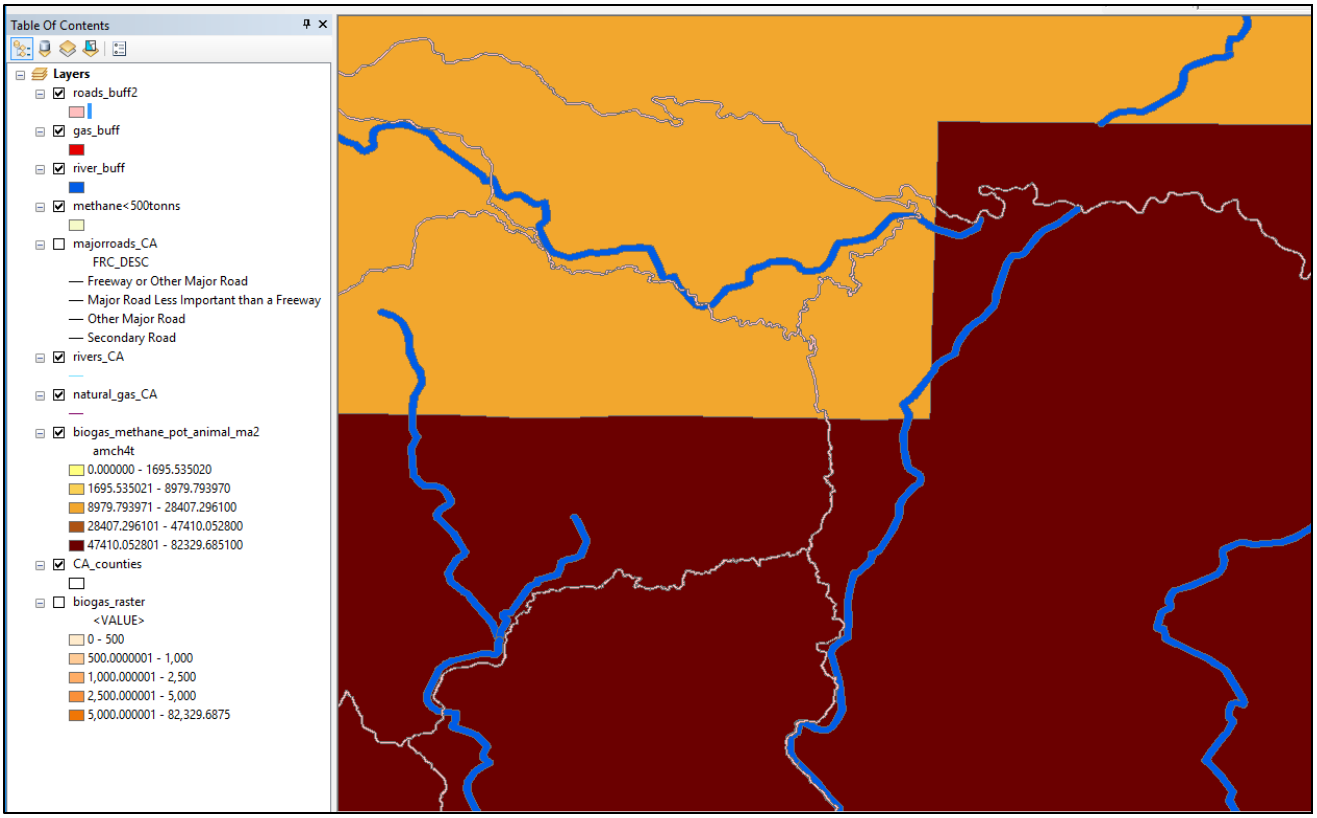

Figure 6. Zoomed in image of California with rivers buffered to 100m and roads buffered to 30m.

All of the buffered zones, city areas and areas with biogas production potential <500 tones/year are sites that are unsuitable for the installation of methane digesters. In order to distinguish these areas from suitable sites I performed a ranked raster analysis. First I converted all other features to rasters using the “Feature to Raster” tool (Fig.7).

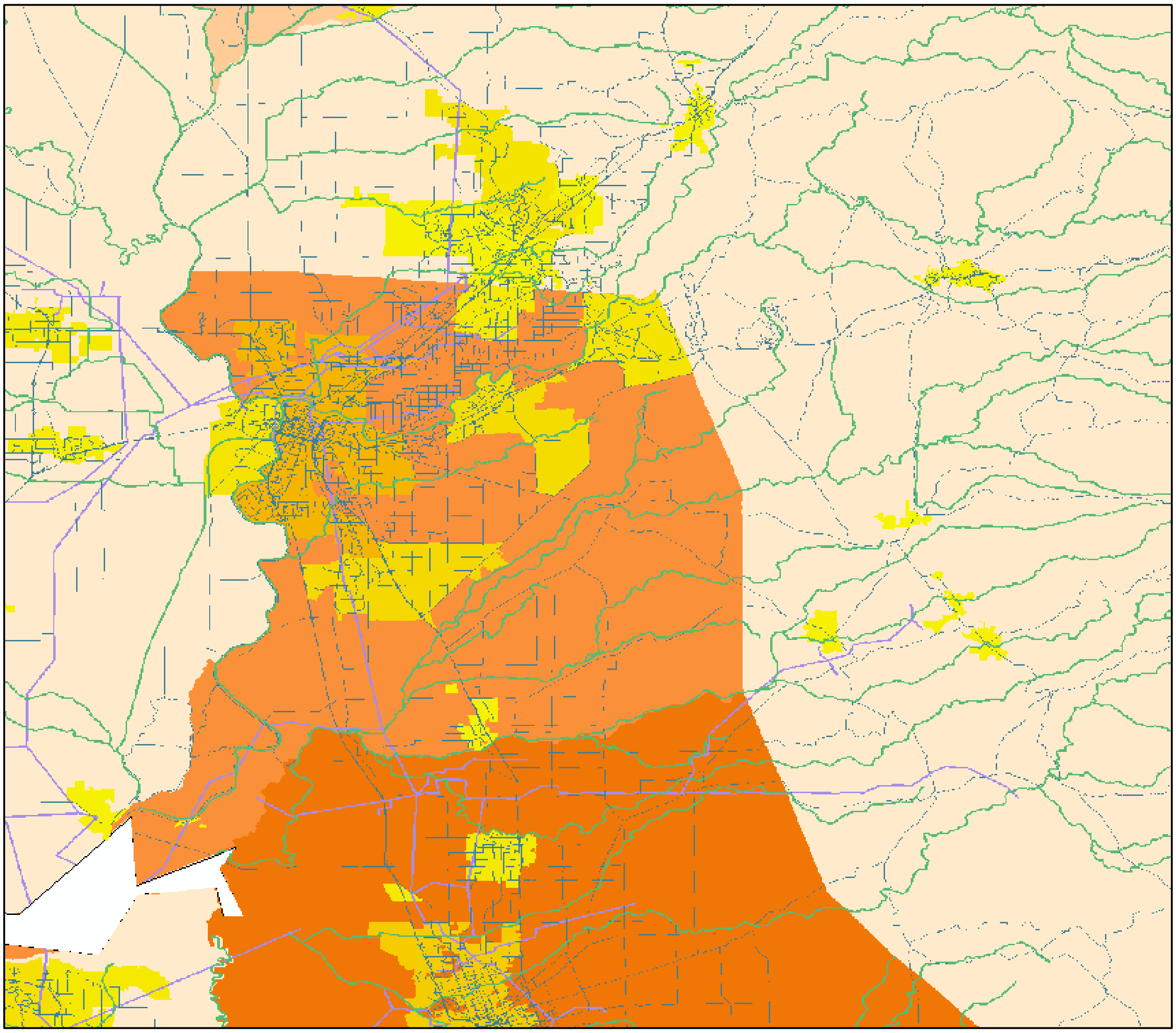

Figure 7. Zoomed in image of California after all features are converted to a raster.

To perform a rank analysis each feature needs to be given a rank and then all the ranks can be added together to get the most suitable sites. I decided to rank the methane potential 1-5, 1 being the best methane potential and suitable site for the installation of a methane digester. All unsuitable sites were given a value of 10 to distinguish without a doubt which sites were unsuitable when I calculated rank totals. I used the “Reclassify” tool to rank each unsuitable site with a value of 10 or 0 (Fig.8 and 9).

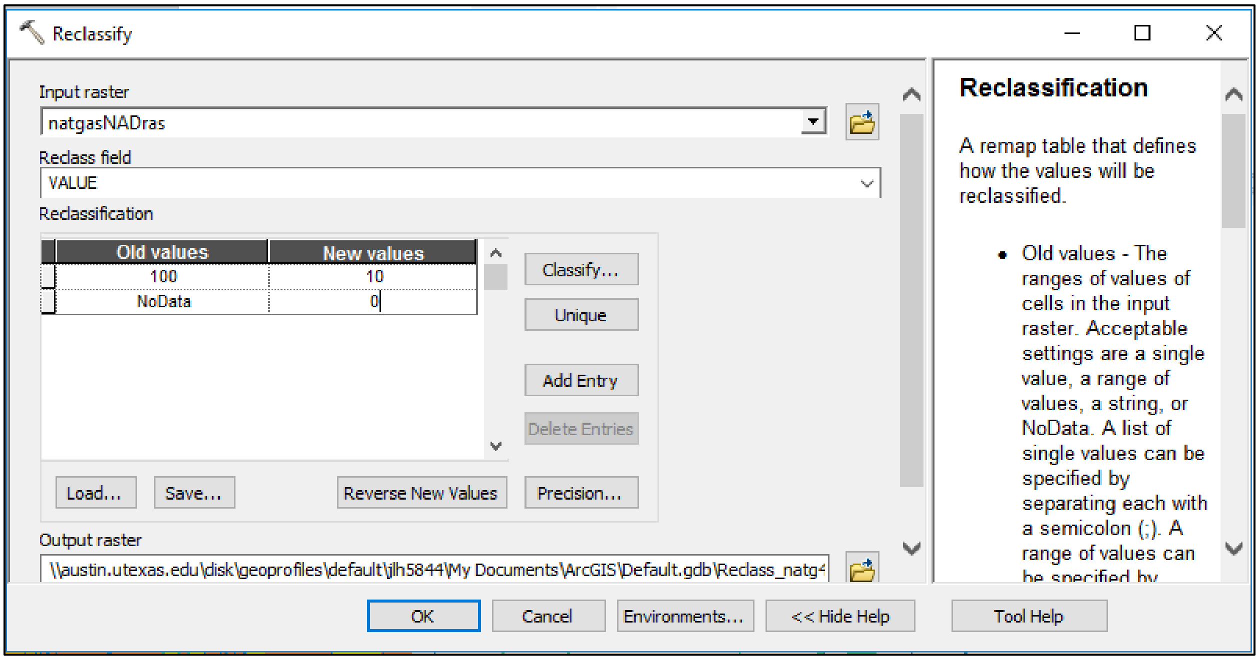

Figure 8: Reclassification window for reclassifying the values for natural gas pipelines.

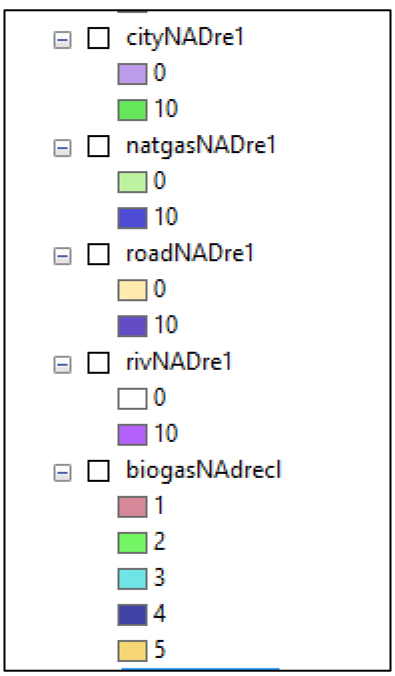

Figure 9. Table of contents after all rasters are reclassified.

I then used the "Raster Calculator" tool to total all of the ranks together to get a final ranking of the most suitable sites (Fig.10). The final ranks were numbered 1-45 (Fig.11).

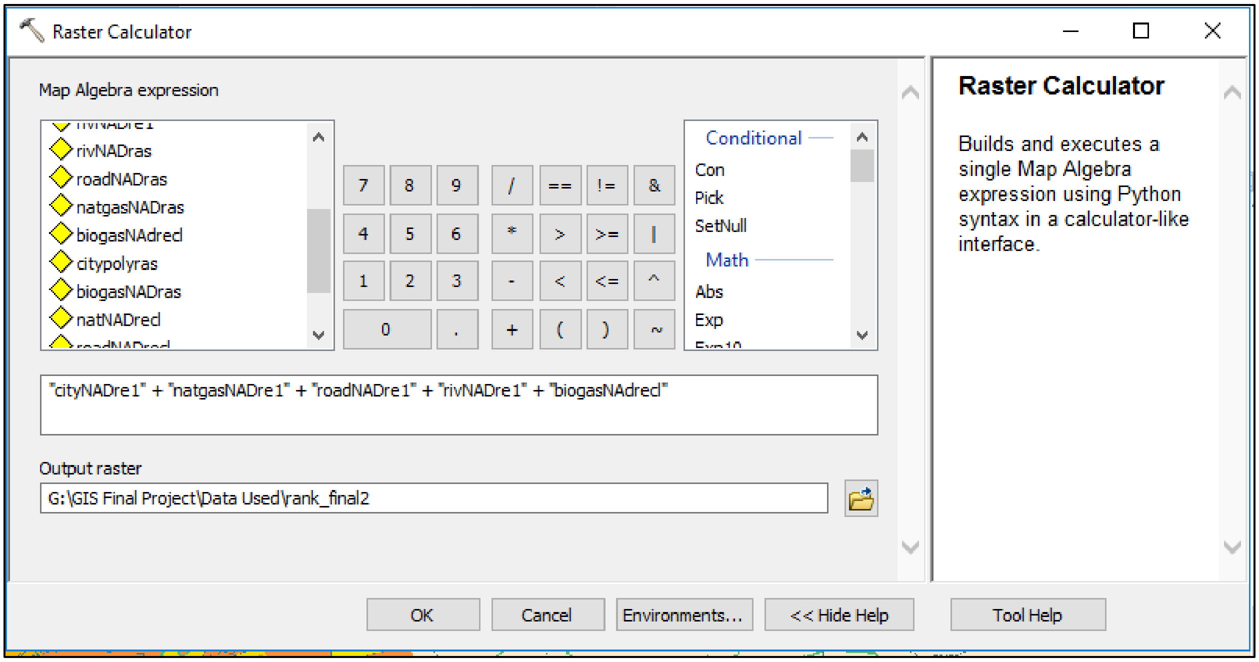

Figure 10. All reclassified rasters are added together in the raster calculator.

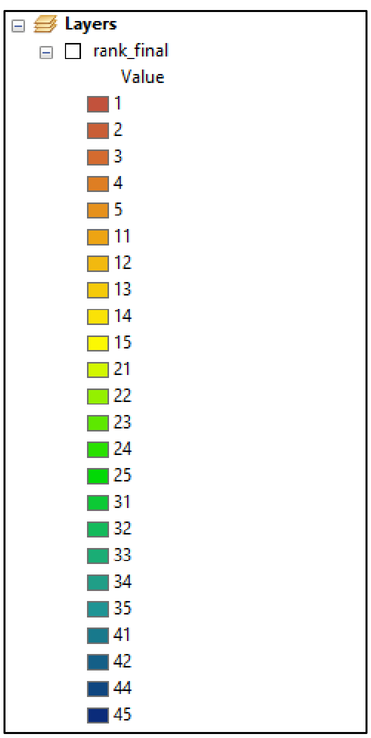

Figure 11. Final ranking by color of most to least suitable sites.

Results:

The only suitable sites are the ones ranked 1-4. 1 being the best methane potential. All other ranks are a combination of either too little methane potential or location within one or more of the unsuitable parameters. A rank of 45 means that the location is within all of the unsuitable parameters: within 30m of a road, within 100m of a river, within 100m of a natural gas pipeline, within a city boundary and in an area with a methane potential of <500 tonnes/year. The other ranks are a combination of unsuitable factors.

Conclusions:

The growing interest in installing anaerobic digesters on farms to use animal wastes as a biomass resource for both economic value and environmental benefit has prompted the need for a land suitability analysis. After taking into consideration proximity to cities, rivers, natural gas pipelines and methane potential, I have established suitable sites for the placement of methane digesters (Fig.12). From a view of the entire state there is a lot of biogas methane potential. To further assess the suitability of a site, the map must be viewed on a smaller scale to capture the small buffers of 30m and 100m around roads, rivers and natural gas pipelines.

Although this assessment considered multiple parameters, It is not practical to run the manure from all livestock through digesters. The potential for methane production from livestock waste depends on size of the farm operation, freshness of the waste, and concentration of digestible materials in the manure. Free-stall dairy operations with daily-scraped alleys work well with digesters because the manure does not get mixed with dirt or stones and is moved into the digester while fresh. Further addition of these parameters will contribute to a stronger site suitability analysis.

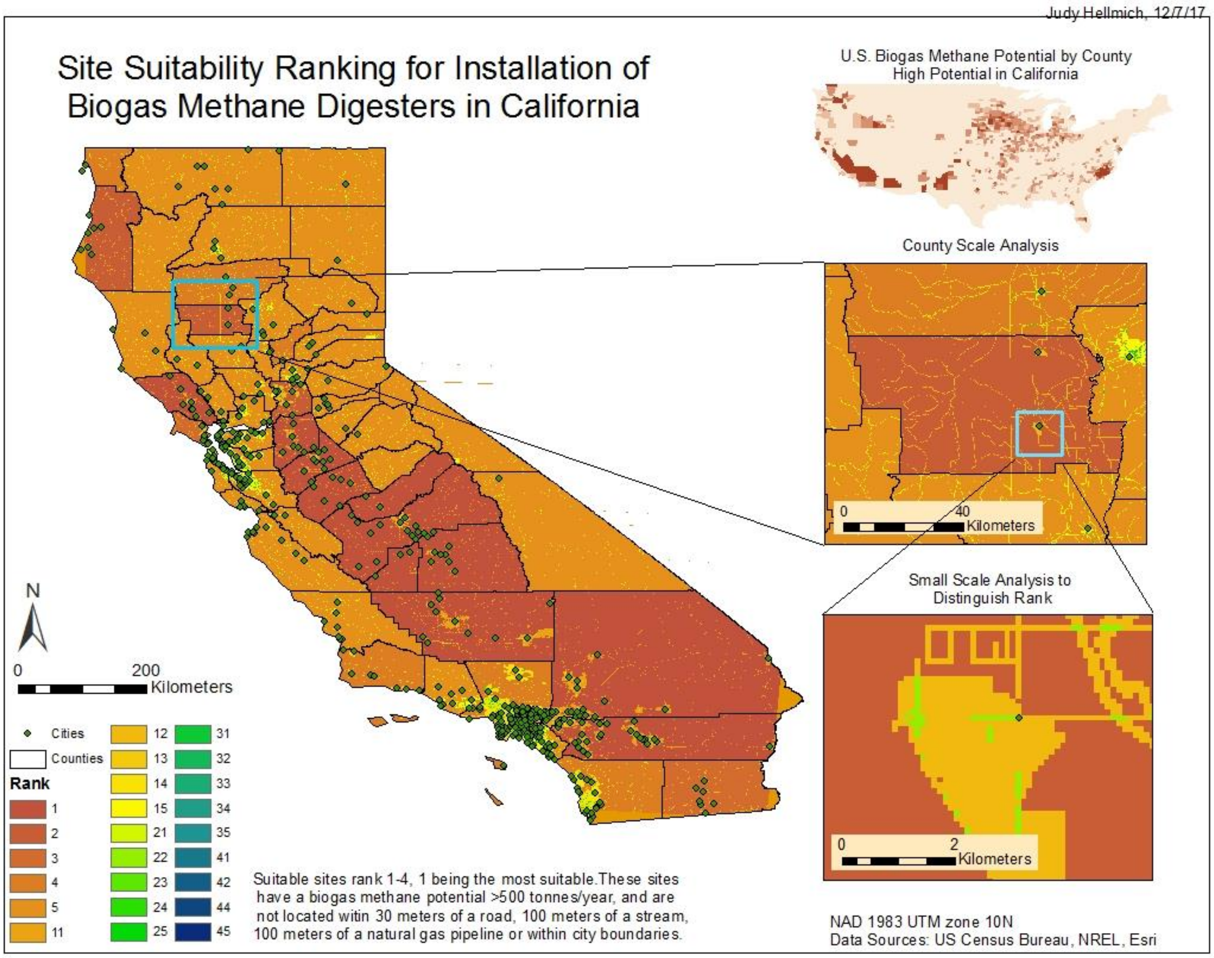

Figure 12. Final site suitability map ranking most suitable sites 1-4, 1 being the best sites.

References:

Ma, Jianguo, et al. “Siting analysis of farm-Based centralized anaerobic digester systems for distributed generation using GIS.” Biomass and Bioenergy, vol. 28, no. 6, June 2005, pp. 591–600., doi:10.1016/j.biombioe.2004.12.003.