Defining Suitability for Purchasing Oil and Gas Lease Acreage-Southeastern New Mexico, United States

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Open source or vendor aggregated Geographic Information System (GIS) data is very typically available for the oil and gas industry, from simple subsurface geologic maps to well and pipeline locations. However, this data will generally require some type of processing or modelling work be done to meet the specifications of the end user; this work can either be contracted out to consultants or performed by in-house GIS experts. This project seeks to outline a parsimonious, repeatable, and adaptable workflow for determining suitability of lease acreage for purchase, dependent upon a completely flexible set of parameters provided by the client and using publicly available data for the state of New Mexico, USA.

Introduction

The typical large oil and gas producer (e.g. BP, Marathon, Pioneer, etc.) will have the internal resources and bandwidth to host their own Geographic Information System (GIS) department or team to integrate subsurface and surface matters. However, the US onshore market is also awash with numerous smaller operators, sometimes running with very minimal, key function only staff such as a geologist and an engineer. In this case, understanding the surface realm via GIS may be outside the scope of their knowledge base or daily duties. The purpose of this project is to provide a simple yet effective modelling workflow for delineating desired active lease acreage, which will be demonstrated using commercially available software (ArcGIS Pro) and publicly available datasets. This model example should be useable by a technically inclined person with a modest understanding of geography and associated concepts (e.g. a geologist). This model may be modified to add or remove data and parameters which may be required to add or remove complexity, as individual stakeholders require.

Data

The data utilized will consist of vector- points, lines, and polygons. This data type is utilized here because it is generally the most commonly available data type for simple oilfield use. Data originators will typically provide vector data in shapefile format (.shp), however a geodatabase (.gdb) may be available as well. Vector data is very useful for representing non-continuous (single value type) data, e.g. oil well locations, city streets, or any polygonal area which is of a discrete single value type (grassland, commercially zoned land, etc.)

The second data type often seen in GIS is raster data, or a matrix of cells (i.e. pixels) which are most commonly used to represent continuous data, such as imagery or digital elevation models (DEM). Raster data is available in different resolutions, ranging from large, continent-wide extents to sub-centimeter pixel sizes In this instance, a raster dataset collected by NASA and METI will be used. This DEM raster represents surface elevation at 1 arc second (about 30 meters), however, it will be converted into a slope product, and then to a vector data type for integration into this model (discussed in Methodology).

The data layers used are listed below (names simplified for readability, vector data unless noted). Data sources are listed fully in the Appendix.

- New Mexico counties
- USGS National Hydrography Dataset- Waterbodies of New Mexico
- Historical wildfire locations- 1911-2014
- Active lease acreage - 2018
- Oil and gas well locations, New Mexico

- New Mexico DEM (raster)

Methodology

Quality Control

All data was loaded into ArcGIS Pro and quality controlled via a cursory inspection on a map instance to ensure that data files provided were labelled properly as well as represented what was expected. Any good geographic modelling endeavour begins with a justification and unification of the geographic coordinate system (GCS); in this case it was decided, based upon the GCS utilized by data provided directly from the state of New Mexico, as well as the relatively limited spatial area involved in the study (SE New Mexico) to use the North American Datum 1983 (NAD83) and the projection Universal Transverse Mercator 13N (UTM 13N). Any data that was provided in another system (e.g. WGS84) was transformed to the required system via the "Project" geoprocessing tool in ArcGIS.

Conceptual Model

The conceptual model for this project (Figure 1) involves a hypothetical situation in which a project owner has tasked the GIS modeler to provide the general location and amount of lease acreage available for purchase within Chaves, Eddy, Lea, and Roosevelt counties in New Mexico. This area is fairly developed in terms of exploration and delineation of hydrocarbon production, therefore limiting to any specific geologic basin is not required. The project owner is primarily concerned with four primary obstacles:

1) Fire hazard: As the state of New Mexico is typically arid, wildfires can, and do, occur regularly. A term commonly used in preparing for the inevitable wildfires is defensible space. Defensible space is a zone created around an area where weeds, brush, and other natural vegetation are removed. Oil and

Gas infrastructure such as electrical equipment, power pole and pipe lines are especially susceptible to this wildfire risk, making it important to base your defensible area on fire history and topography. Thus, it is required that potential acreage remains a set distance (buffer) away from historical fire locations, dependent upon acreage burned.

   i. < 25,000 acres: 0.5 miles
   ii. 25,000-75,000 acres: 1 mile
   iii. 75,000-225,000 acres: 2 miles
   iv. > 225,000 acres: 4 miles

2) Water availability: the owner wishes that there be sufficient water sources within a two (2) mile reach of the potential acreage for hydraulic fracturing and general rig site use. For this case, “sufficient water” is defined as any waterbody greater than or equal to two (2) acres.
3) Slope: to minimize rig pad construction costs, the owner requests that any acreage considered be on land with a slope of less than a 35 percent. Slopes greater than that are possible but come with more stringent criteria involving aspects such as vegetation types, depth to bedrock, soil types, and potential for below ground seeps or springs. Due to the flexible and simplistic goals of this model, the decision was made to avoid unnecessary complications and hold to a more straight forward methodology.
4) Existing wells: to avoid conflict with existing oil and gas wells, it has been requested that acreage under consideration be a minimum of 100 yards from oil wells, and 300 yards from gas wells.

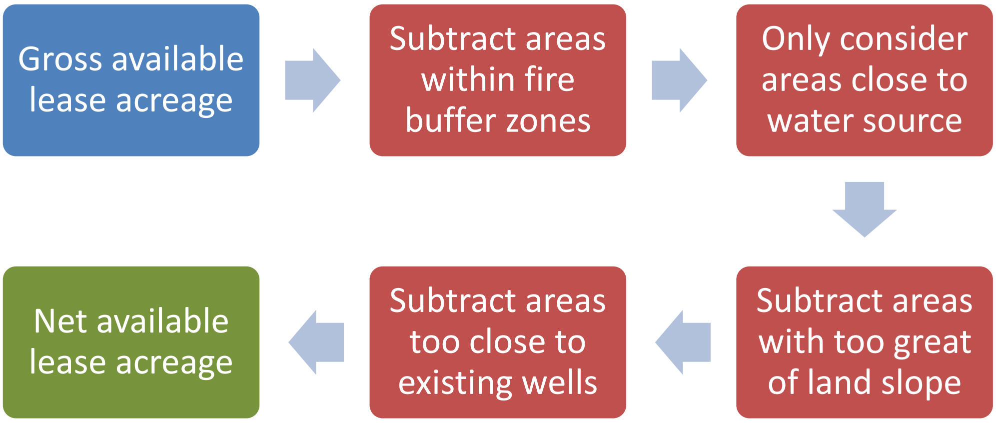

Figure 1: Conceptual model for determining desirable active lease acreage.

The extent of model, in this study of South East New Mexico, is a large one. To grasp the full extent of the data being processed and to gather a generalized understanding, one should keep a relatively large scale. Although, since our model is a vector model, the scale is flexible. If an area peaks the interest of the researcher, and the researcher wishes to analyse the area at a more defined, smaller scale, that option is readily available as well.

Data Manipulation: Extracting Necessary Data

The Polygonal data publicly available was not in correct form for the computations required in the model, therefore it is necessary extract only the required data. Shapefile data will often come embedded with attribute data that is viewable in the attribute table of each data piece. In the case of the historical fire and waterbodies data, it was first necessary to provide a rank with which to apply the proper distance buffer. A "Calculate Geometry" geoprocessing was run obtain areas in units of acres. Next, a simple python script was written for each to provide this rank, as seen in Figure 2.

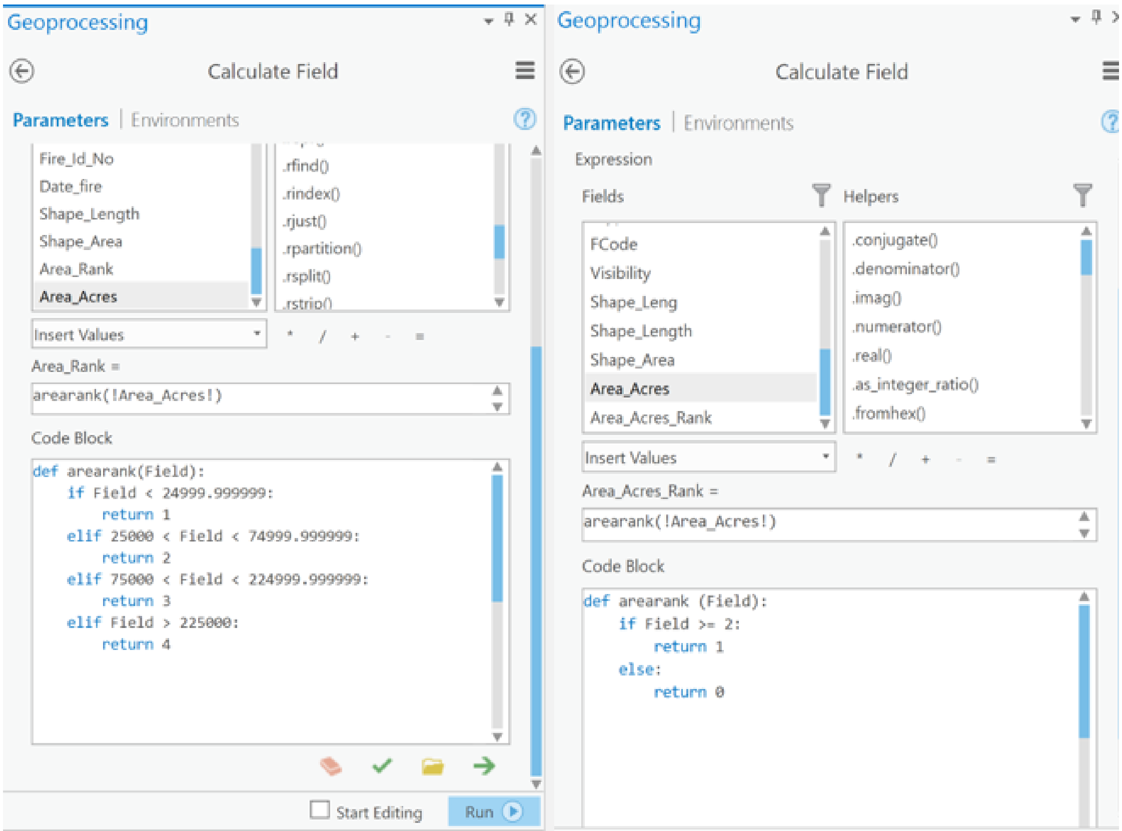

Figure 2: Creating rank for historic fire areas and waterbodies.

Once rank was assigned, the polygonal areas (both fire and waterbodies) were split on attribute “Rank” by using the “Split” geoprocessing function. Similarly, a split was applied to New Mexico counties along the attribute “Name”, and well locations were split along attribute “Well Type” (Figure 4).

Slope: Raster Data Conversion and Slope Creation

In order to create the final product showing a polygon feature of areas deemed unsuitable for well site and construction, several conversions needed to be executed. Initially, the raster GDEM data was converted from its original elevation state into a slope format with the Spatial Analysis Arc tool “Slope”. The input DEM raster goes in, and a raster showing slope percentage values is returned. This format contained the data needed, though being in raster format, it was in the wrong data type for our vector model. This necessitated the use of the Arc tool “Raster to Polygon”. There is a step in between, however; since the raster returned from our “Slope” geoprocessing was in a float format. Float format allows for the use of decimals in the raster value table. “Raster to Polygon” is only compatible with integer vales (whole numbers). This required the use of the tool “Int” to convert float values of the slope raster into the integer values compatible with the “Raster to Polygon” tool. Once these polygons were created, a query was ran to separate all slope values over 35 percent. These polygons were then buffered by 400ft to ensure a reasonable distance was kept from the unsuitable area (Figure 3).

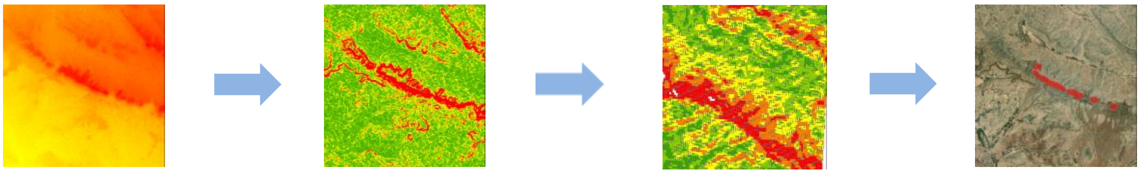

Figure 3: DEM to Buffer Result Steps Illustrated.

Buffer, Merge, and Clip Operations

For all modelling work, the ArcGIS ModelBuilder function was utilized for transparency, repeatability, and ease of manipulation of the workflow.

The required well counties (Chaves, Eddy, Lea, and Roosevelt) were merged together using the “Merge” geoprocessing tool so that only the area of the necessary counties was included. Next, the variable distance buffers for fire hazards were applied to each rank (1-4 as seen in Figure 2). Once complete, the four datasets were merged together so they would represent a single cohesive unit of area. The “Fire_Buffer_Merged” was then clipped to the extent of the four counties (Figure 4). Waterbodies of Rank 1 (> 2 acres) were buffered with the necessary 2 miles, and subsequently clipped to the extent of the required counties. (No merge was necessary as water Rank 0 was not considered in the model) (Figure 4). The oil and gas wells were buffered with the required distances, clipped to the required counties, and finally merged together to form a single area for consideration in the model. Lastly, the "Final_Bad_Slope" layer was clipped to the required counties (Figure 4).

As an intermediary product, the "Active_Leases_2018" data layer was clipped to the required counties, and next clipped to the "WaterRank_1_Buffered". This creates the area of active lease acreage that is only spatially within the two mile buffer of potential water sources, creating layer "ActiveLeases_GoodWater" (Figure 4).

Final Merge and Erase

To complete the workflow and arrive at the final answer product, a simple final "Merge" and "Erase" function were required. This entailed merging 3 data negative valued data layers- "Fire_Buffered_Merged_Clipped", "Oil_Gas_Wells_Buffered_Merged_Clipped", and "Final_Bad_Slope_Clipped" into a single data layer. This, along with the intermediate product "ActiveLeases_GoodWater", were then fed into the "Erase" geoprocessing module. The Erase function works as the inverse to a Clip- instead of providing only the area inside of the clip layer, it provides only the area outside of the erase layer (Figure 5). The final product produced from this model is "ActiveLeases_Suitable" (Figure 4).

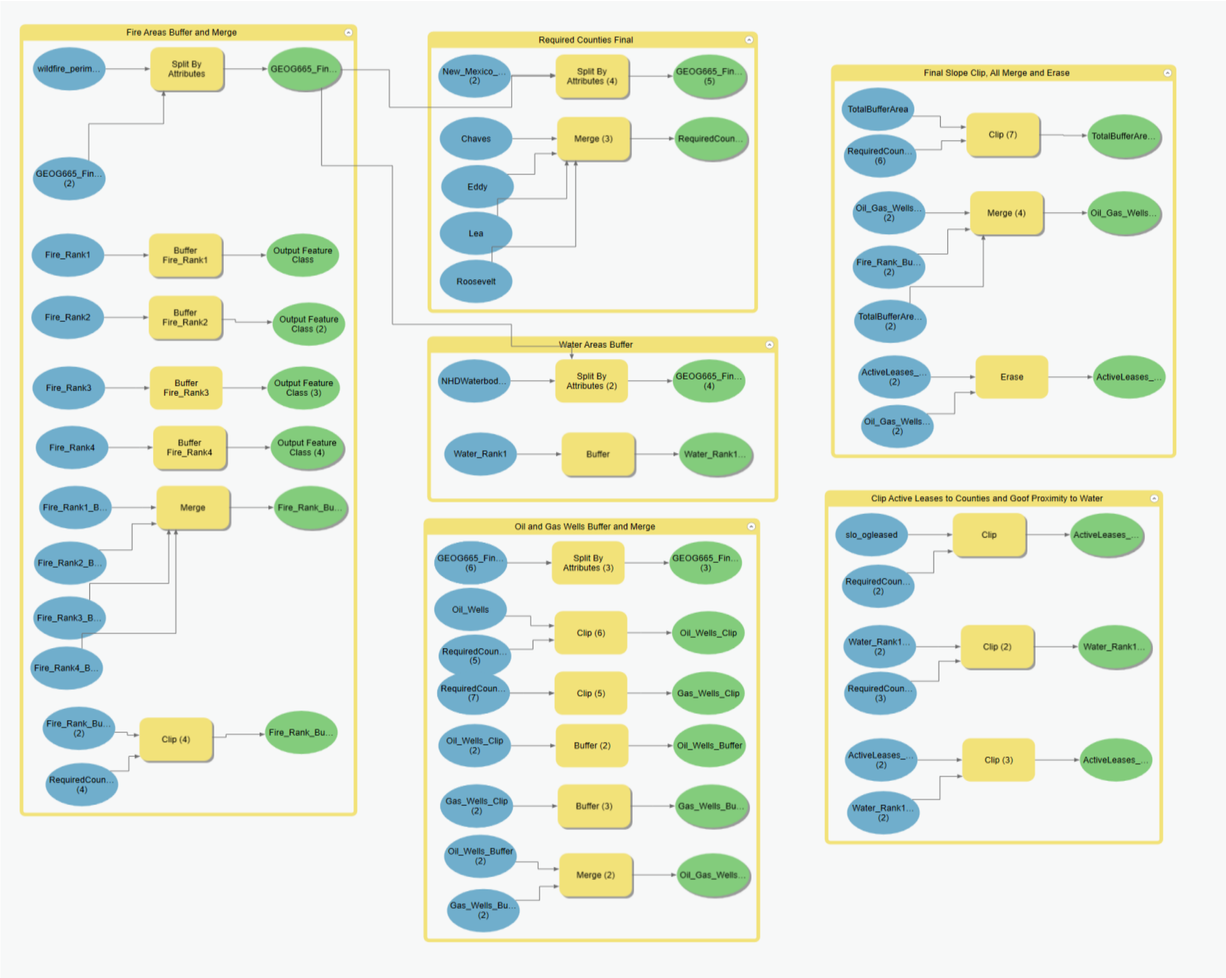

Figure 4: ModelBuilder for determining suitable active lease acreage.

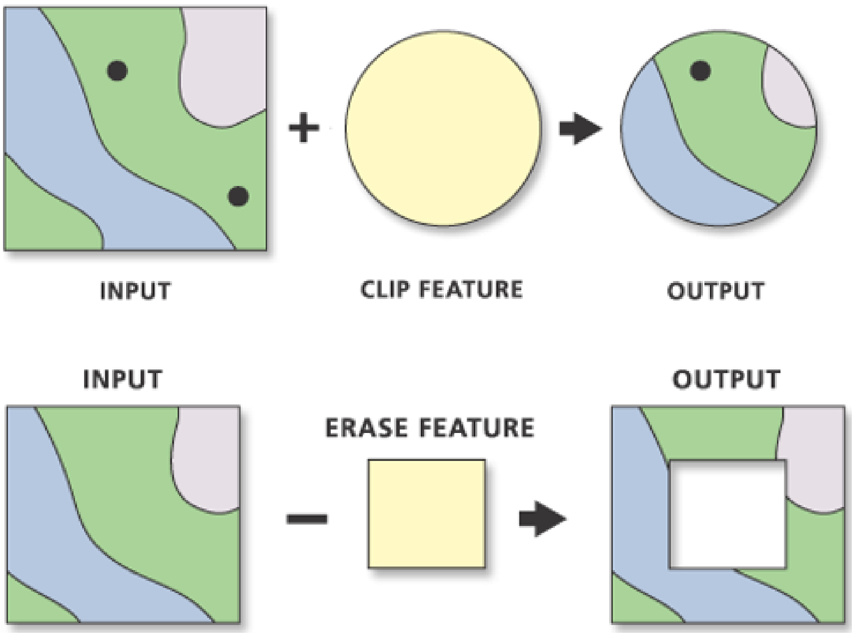

Figure 5: Clip (upper) vs Erase (lower). Source: http://pro.arcgis.com/en/pro-app/tool-reference/main/arcgis-pro-tool-reference.htm

Results and Discussion

The designed model was built to analyse and return a defined area based on limiting, real-world factors including proximity to water features, well sites, historic wildfire sites, and slope percentage. To the best of our knowledge, all spatial features were adequately represented, as the datasets were current and readily available from New Mexico's public database. The main difficulties arising from this model did not come from the model itself, but the immense size of the data being implemented. These large data sets caused long processing times as well as slow drawing. After running our model with the previously described data sets, the model returned 494,323 acres of available, suitable lease acreage. This was narrowed down from an original lease acreage of 1,604,183 (Figure 6).

Conclusions

Apart from the lengthy processing time, the model was satisfactory and provided a usable data layer that could be implemented in the initial stages of well site location research. These lengthy processing times are an issue that could be perused later in the form of smaller datasets or more powerful processing machines. This model cut the searchable area down by a third, saving a geologist countless hours of research. With this focused search area, choosing a well site has just become more efficient.

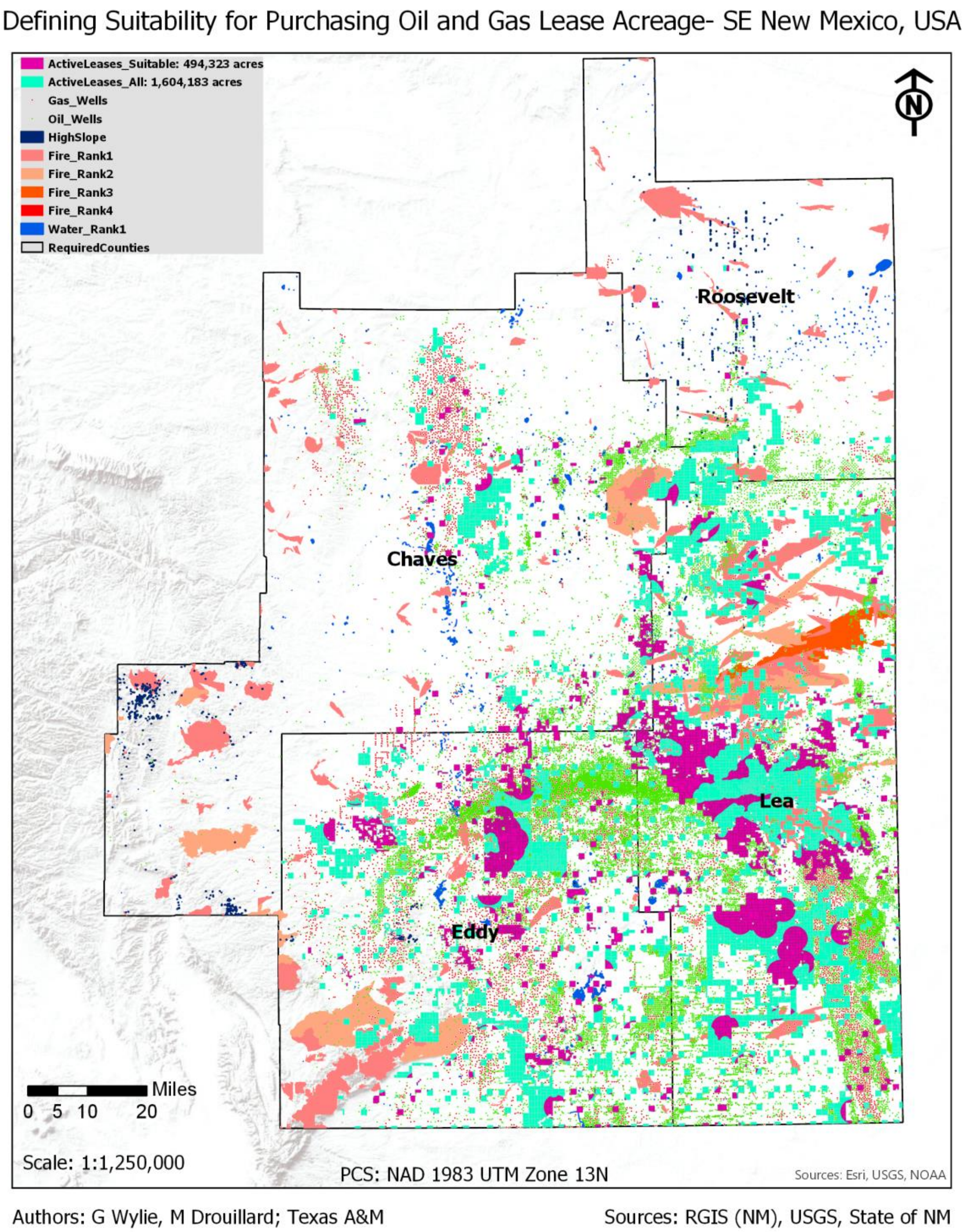

Figure 6: Final map of suitable lease acreage and model variables.

Appendix

New Mexico counties: https://rgis-data.unm.edu/rgisportal/

USGS National Hydrography Dataset- Waterbodies of New Mexico:

https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View#productSearch

Historical wildfire locations- 1911-2014: https://rgis-data.unm.edu/rgisportal/

Active lease acreage- 2018: http://mapservice.nmstatelands.org/GISDataDownloads/

Oil and gas well locations, New Mexico:

ftp://164.64.106.6/Public/OCD/OCD%20GIS%20Data/Shape%20Files/

New Mexico ground slope (raster): https://earthexplorer.usgs.gov/

Information on preferable slope choice:

U.S Department of the Interior (1999). Oil & Gas Leasing and Development: Final Supplemental Environmental Impact Statement Location: Glenwood Springs