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Identifying Well Pads in the Haynesville Shale Region, Louisiana and Texas, with Digital Imagery

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Abstract

The Haynesville Shale is an underlying rock formation in northwest Louisiana and northeast Texas that contains vast quantities of natural gas. With new technology has come the ability to extract more natural gas from one of the largest gas deposits in the United States. With increased production, increased change in the local ecosystem will occur. It is necessary to examine oil and gas exploration effects on the local ecosystem due to changes in land cover, such as habitat loss and increased soil erosion. Remotely sensed imagery were utilized to ascertain the use of various digital image processing techniques to determine which digital transformation would more accurately identify current well pads within the Haynesville Shale region. Techniques evaluated included digital ratios, digital vegetation indices and digital principal component analysis. Results indicate that all vegetation indices and principal component analysis were extremely useful in visually identifying well pad locations while the effectiveness of digital ratios depended on the ratio utilized.

Introduction

Energy demand has risen in recent years and is expected to continue to increase. Oil and gas are the primary sources for energy and this demand intensifies efforts in the petroleum industry to increase exploration and production. Concerns of the potential environmental impacts due to the exploration and production of petroleum have also increased in recent years.

Oil and gas drilling typically involves disturbing approximately 0.5 - 2.3 hectares (1.2 - 5.7 acres) of land by clearing, leveling, and surfacing for placement of the pad, pit, road, and drilling equipment. This disturbance of land can fragment the land cover and result in loss of productive forests and agricultural lands, and may affect other resources, such as water resources and wildlife habitats.

While oil and gas production has occurred in the region for decades, current production has dramatically increased due to new technologies, such as hydraulic fracturing and directional drilling. Drilling in the Haynesville Shale started in 2007, with approximately 891 completed wells by October 2010. The majority (715) of these wells were located in Louisiana.

Monitoring of natural resources has been significantly enhanced with the improvements in satellite imagery. The combination of remote sensing and Geographic Information Systems (GIS) allows for improved methods to monitor and assess ecosystems. Satellite sensors are able to record electromagnetic energy reflected from the Earth's surface and report the collected values in band segments. The different segments of the electromagnetic energy represent the different bands recorded by the sensor (Table 1). Landsat satellite images are often used due to ease of access and economical value. Landsat Thematic Mapper (TM) imagery is available from the United States Geological Survey (USGS) Glovis website (http://glovis.usgs.gov).

Various digital analysis techniques can be applied to satellite imagery to extract meaningful information. Two techniques useful in the identification of well pads in satellite imagery are principal component analysis (PCA) and vegetation indices.

PCA is a method of data compression that allows redundant data to be compacted into fewer bands. PCA data bands are uncorrelated and independent, which makes them more easily interpreted than the original data.

Indices are used in vegetation and mineral analyses to differentiate between small differences in vegetation classes or rock types. With the appropriate indices chosen, differences not observed in the original color bands can be enhanced and highlighted.

Table 1. Landsat 5 TM Bands

Band Number	Spectral Range (μm)
1	0.45-0.52 (blue)
2	0.52-0.60 (green)
3	0.63-0.69 (red)
4	0.76-0.90 (near-infrared)
5	1.55-1.75 (mid-infrared)
6	10.4-12.5 (far-infrared)
7	2.08-2.35 (mid-infrared)

Methods

The image used for analysis was a mosaic of four Landsat 5 TM images taken in August 2011. Path 24, Rows 37 and 38 were taken August 5, 2011, and Path 25, Rows 37 and 38 were taken August 28, 2011. Images were downloaded from the USGS Glovis website (http://glovis.usgs.gov) and mosaicked using ERDAS IMAGINE 2010 software. The Haynesville Shale boundary was set using a shapefile obtained from the Department of Energy, Energy Information Administration website (http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm). The boundary was last updated in May 2011.

Digital analysis techniques were performed using ERDAS IMAGINE 2010 software.

PCA was performed using the principal components tool found under spectral resolution for raster images. Each band of the image was visually inspected to see the amount of variability in the image. All layers were stacked using the model maker to produce the final image.

All digital ratios and vegetation indices were performed using the indices tool found under unsupervised classification for raster images. The indices used to identify well pads were difference vegetation index, normalized difference vegetation index (NDVI), ratio vegetation index, square root transformation of the ratio vegetation index (SQRT), clay minerals index, and iron oxide index. Each indices uses a different algorithm, and is listed below using the TM bands listed in Table 1.

$$\text{Difference Vegetation Index} = TM4 - TM3$$

$$\text{Ratio Vegetation Index} = \frac{TM4}{TM3}$$

$$\text{Clay Minerals Index} = \frac{TM4}{TM5}$$

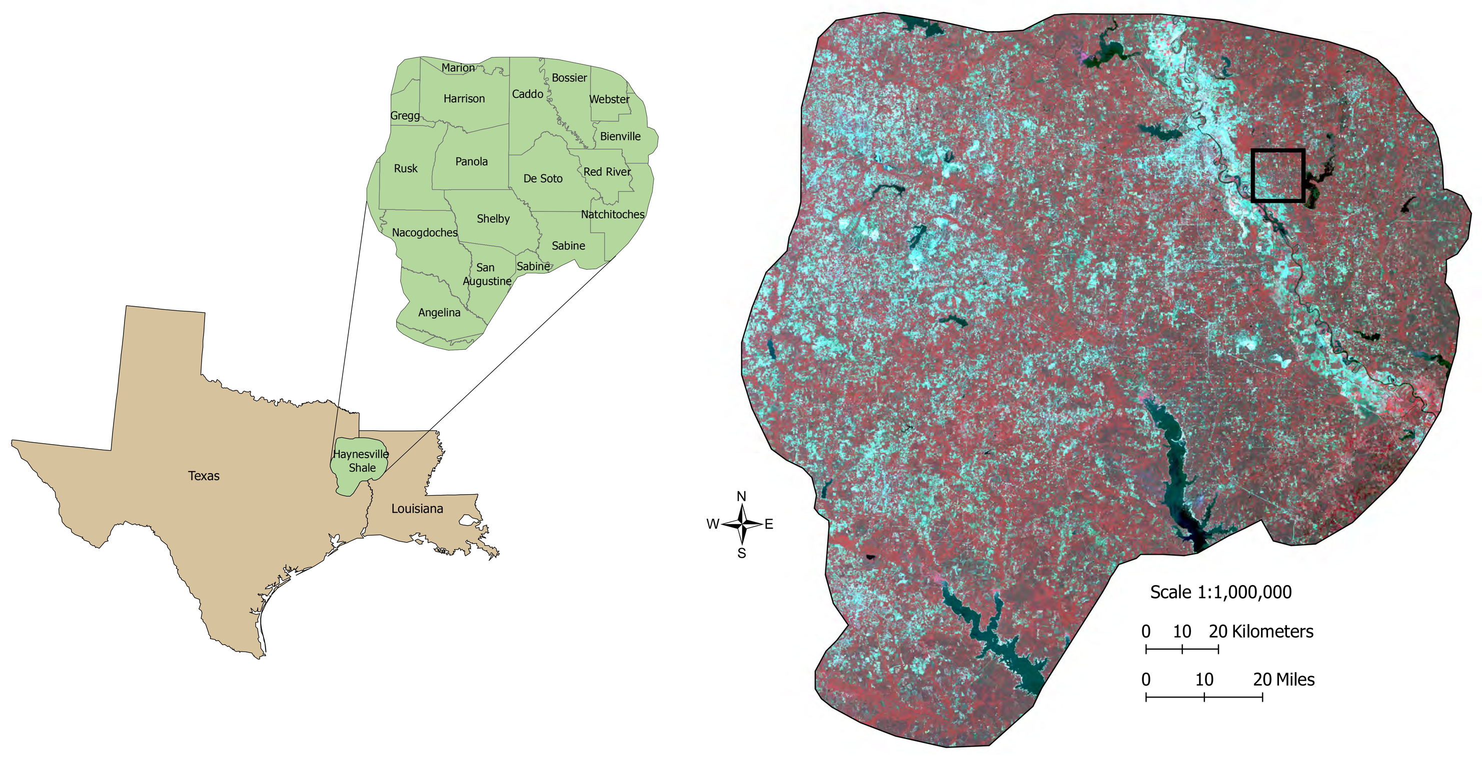
$$NDVI = \frac{TM4 - TM3}{TM4 + TM3}$$

$$SQRT = \sqrt{\frac{TM4}{TM3}}$$

$$\text{Iron Oxide Index} = \frac{TM3}{TM1}$$

Study Area

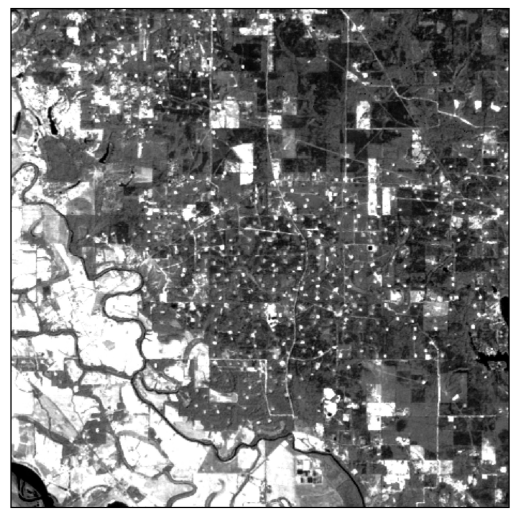
The Haynesville Shale is an underlying rock formation in northwest Louisiana and northeast Texas that contains vast quantities of natural gas. The Haynesville Shale is deeper than most other shale plays at 3.1 - 4.3 kilometers (1.9 - 2.7 miles), and is approximately 91 meters (299 feet) thick. The Haynesville Shale region encompasses approximately 2,890,770 hectares (7,143,248 acres). The full spatial extent of the Haynesville Shale is not yet known, and is continually changing due to new discoveries.



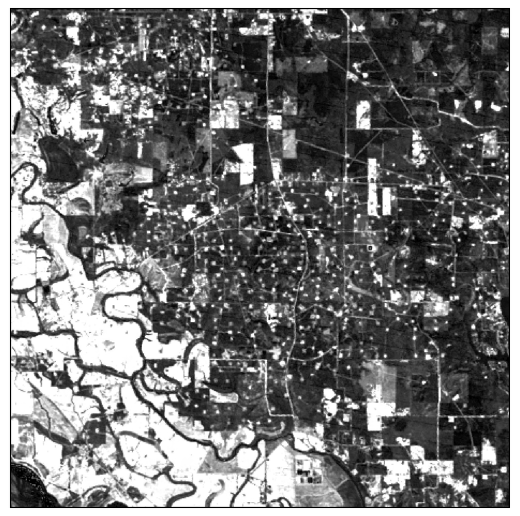
Results

Principal Component Analysis

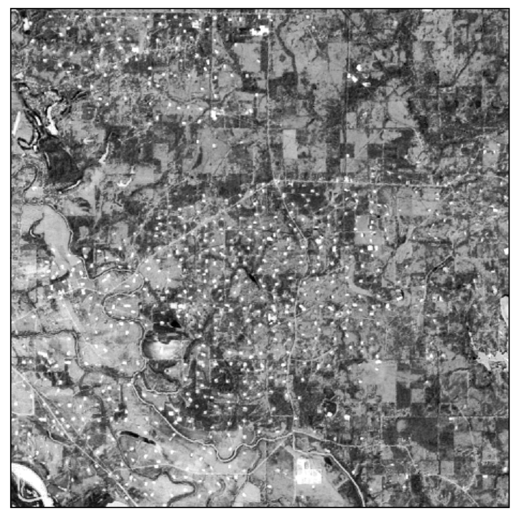
PCA was performed on all seven bands of the mosaicked Landsat TM image. To better understand the results, an area of Bossier Parish, LA is used below to aid in visually comparing five of the seven bands. Bands 6 and 7 had the most amount of variance and were not as useful for the identification of well pads. Also shown below is what was determined to be one of the best band combinations to identify well pads (bands 5-4-3).



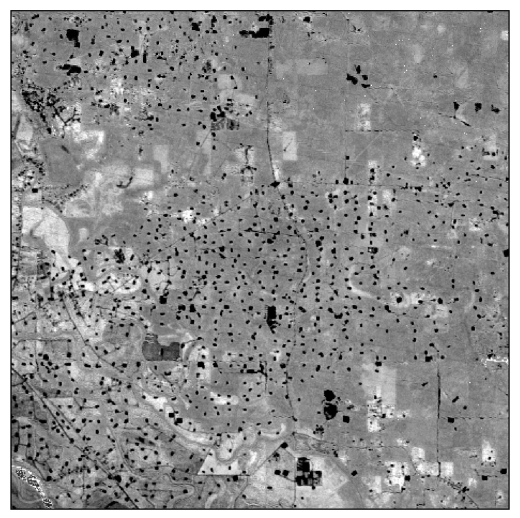
Band 1



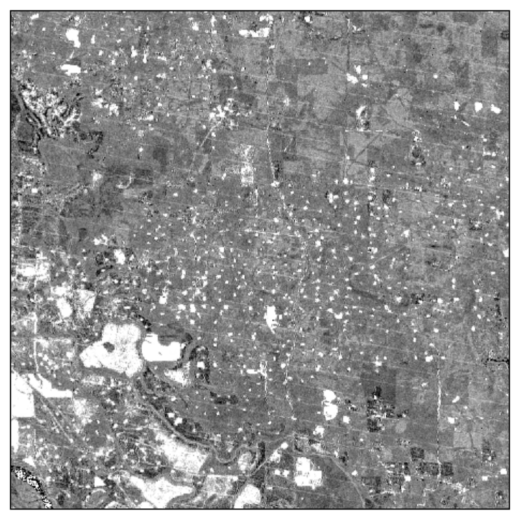
Band 2



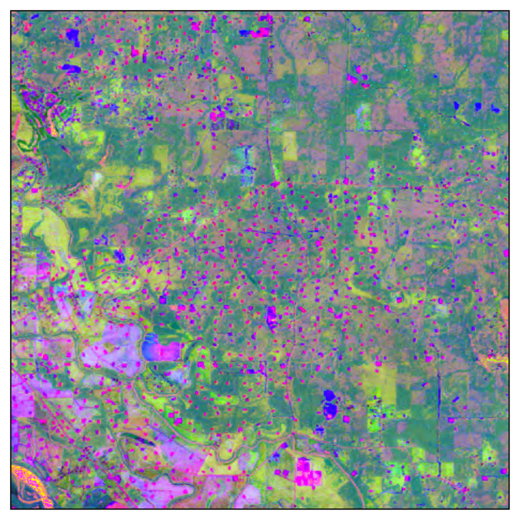
Band 3



Band 4



Band 5



Bands 5-4-3

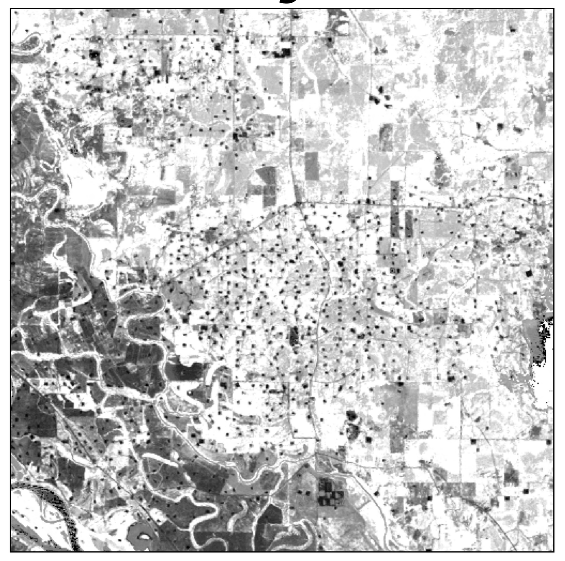
Scale 1:100,000
0 1 2 Kilometers
0 1 2 Miles

Results

Vegetation Indices

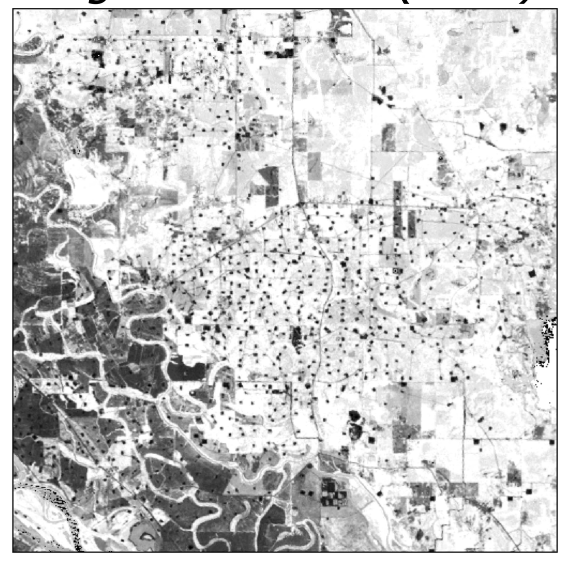
Indices were performed on the mosaicked Landsat TM image, and an area of Bossier Parish, LA is used below to aid in visually comparing the different indices. The identification of well pads showed promise using four different indices: difference vegetation index, normalized difference vegetation index (NDVI), ratio vegetation index, and square root transformation of the ratio vegetation index (SQRT). Clay minerals index and iron oxide index were not as useful when applied to the identification of well pads.

Difference Vegetation Index



Difference vegetation index is the difference of green leaf scattering in the near-infrared and chlorophyll absorption in the red. The difference vegetation index is calculated by subtracting red from near-infrared.

Normalized Difference Vegetation Index (NDVI)



NDVI is the normalized difference of green leaf scattering in the near-infrared and chlorophyll absorption in the red band. NDVI is calculated using (near-infrared minus red) divided by (near infrared plus red).

Ratio Vegetation Index

Ratio vegetation index represents the ratio of green leaf scattering in near-infrared and chlorophyll absorption in red. This is calculated by dividing near-infrared with red.

Square Root Transformation of the Ratio Vegetation Index (SQRT)

SQRT is the square root of the ratio of green leaf scattering in near-infrared and chlorophyll absorption in red. SQRT is calculated using the square root of (near-infrared divided by red).

Scale 1:100,000
0 1 2 Kilometers
0 1 2 Miles

Conclusion

Numerous remote sensing and GIS tools are available that aid in the study of anthropogenic activities on the Earth's surface. Using digital analysis techniques, images were adjusted in a manner that visually improved the identification of well pads within the Haynesville Shale region. The techniques studied were able to assist in better identification of well pads using satellite imagery. When visually assessing each band of the PCA, band 4 showed the most promise for use in well pad identification. Different band combinations were also used, resulting in another way to visually identify well pads. Though clay minerals index and iron oxide index were not as applicable in the identification of well pads, the four vegetation indices, difference vegetation index, NDVI, ratio vegetation index, and SQRT, were useful in visually identifying well pads in the Haynesville Shale region.

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