

Chapter 38

Quantifying Land Cover Change Due to Petroleum Exploration and Production in the Haynesville Shale Region Using Remote Sensing

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ABSTRACT

The Haynesville Shale lies under areas of Louisiana and Texas and is one of the largest gas plays in the U.S. Encompassing approximately 2.9 million ha, this area has been subject to intensive exploration for oil and gas, while over 90% of it has traditionally been used for forestry and agriculture. In order to detect the landscape change in the past few decades, Landsat Thematic Mapper (TM) imagery for six years (1984, 1989, 1994, 2000, 2006, and 2011) was acquired. Unsupervised classifications were performed to classify each image into four cover types: agriculture, forest, well pad, and other. Change detection was then conducted between two classified maps of different years for a time series analysis. Finally, landscape metrics were calculated to assess landscape fragmentation. The overall classification accuracy ranged from 84.7% to 88.3%. The total amount of land cover change from 1984 to 2011 was 24%, with 0.9% of agricultural land and 0.4% of forest land changed to well pads. The results of Patch-Per-Unit area (PPU) index indicated that the well pad class was highly fragmented, while agriculture (4.4-8.6 per sq km) consistently showed a higher magnitude of fragmentation than forest (0.8-1.4 per sq km).

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1. INTRODUCTION

Oil and natural gas exploration has increased substantially in recent years due to increased demand and improvements in technologies that allow for access to geologic strata once considered impractical to pursue for petroleum. With the increases in oil and gas activities comes a conversion of land cover, such as forest or agricultural land, to oil and gas well pads. 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.

During oil and gas development, a complex system of well pads, roads, pipelines, and other infrastructure is created across the landscape. Louisiana and Texas have experienced an increase in natural gas exploration due to recent advances involving hydrofracturing and horizontal drilling. Currently, one of the largest and most active gas plays in the United States is in the Haynesville Shale formation, which is located in northwest Louisiana and northeast Texas.

The Haynesville Shale region encompasses approximately 2.9 million hectares, and has been subject to intensive exploration. The full spatial extent of the Haynesville Shale is not yet known and the mapped region is continually changing due to new discoveries. The Haynesville Shale lies in an area that has had significant oil and gas development due to the Louisiana-Mississippi Salt Basins and the East Texas Basin (Grant et al., 2009). Oil and gas exploration also continues that is not related to the Haynesville Shale, so identification of wells specific to the Haynesville Shale is based on drilling depth and composition of the gas produced (Grant et al., 2009).

Land cover changes are continually occurring due to natural and anthropogenic activities, and monitoring of natural resources has been significantly enhanced with improvements in satellite imagery. With the availability of sequential satellite imagery, temporal changes on the Earth's surface may be evaluated. Land cover change detection has been applied in various situations, and is especially useful in monitoring changes due to human impact (Bi et al., 2011; Phalke & Couloigner, 2005; Tang et al., 2008; Vescovi et al., 2002).

Change detection is a valuable tool for analyzing biophysical and anthropogenic alterations to the Earth's surface. Change detection is the process of identifying differences by viewing an image of a specific location at different times. Examples of uses for change detection are land-use and land-cover changes, forest or vegetation changes, environmental change, and urban change (Lu et al., 2004).

One method for change detection is post-classification comparison. Using post-classification of images to detect change has been successful, since it better handles effects of bias and variance between images (Phalke & Couloigner, 2005). Post-classification comparison of Landsat Thematic Mapper (TM) imagery has shown to be a successful method for change detection and quantification of the changes (Döner, 2011; Vescovi et al., 2002; Zhao et al., 2004). With the use of Landsat TM imagery, changes over time to forests and agricultural lands due to oil and gas well pads may be quantified within the Haynesville Shale region.

Changes due to abrupt and gradual disturbances to land surfaces are in need of investigation. Surface disturbance is caused by distinct events that alter the physical environment (Farina, 1998). This can lead to fragmentation, which is a continuous process that subdivides the land cover into smaller, isolated patches (Farina, 1998; Li et al., 2009). Abrupt change is caused by a disturbance, such as well pads, while gradual change is a linear trend due to something like long-term annual rainfall or land degradation (Verbesselt et al., 2010). Disturbance of land from petroleum exploration and production may result in a fragmented landscape.

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