

Mapping Energy Expansion: Remote Sensing Insights into Oil and Gas Infrastructure and Land Use Changes in Midland, TX

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Abstract

Rapid expansion in global energy demand driven primarily by oil and gas consumption has spurred significant environmental concerns. This study delves into the intricate relationship between energy development and environmental impacts focusing on Midland County, Texas, a pivotal region within the Permian Basin. Leveraging satellite imagery and Geographic Information Systems (GIS) techniques, the research meticulously examines land use dynamics from 2001 to 2019. The findings illuminate a marked decline in vegetation health and density attributable to the burgeoning oil and gas infrastructure in the area. Moreover, the analysis underscores the emergence of barren lands and the displacement of agricultural areas, indicative of the profound alterations in land cover patterns over the study period. These insights underscore the urgent need for concerted efforts to mitigate the adverse environmental effects of energy expansion, emphasizing the importance of collaborative approaches to foster sustainable land use practices. Additionally, the study explores the socio-economic implications of land use changes, addressing how energy expansion affects local communities and economies. Previous studies have emphasized the need for comprehensive assessments of cumulative environmental impacts, advocating for the implementation of effective mitigation strategies.

Keywords

Remote Sensing, Land Cover Change, Energy Infrastructure, Energy Sprawl, Texas

1. Introduction

Worldwide population growth and escalated energy consumption have led to increased energy production to meet the needs of individuals and enhance the expected quality of life in societies. Oil and Gas extraction are one of the top energy sources that have amplified over the past years, due to developments in drilling technologies. It is estimated that the world's energy usage increase by 50% in 2050 worldwide (Soltani et al., 2024; Monfaredi, Emami, & Moghadam, 2022; Osaki, 2019; Nazarpour, Monfaredi, & Moghadam, 2019), with oil and gas remaining the top energy source being on top. United States leads global oil production and will account for 20% of the total share of world oil production in 2022 (Monfaredi, Nazarpour, & Moghadam, 2021; U.S. Energy Information Administration (EIA), 2024). Along with such developments, concerns about the impact of human activities on the environment are widespread. Therefore, it is important to better understand how the environment is affected by these activities. Recent research has investigated the association of energy activities, particularly oil and gas production, and environmental alterations including landcover and land change and degradation (Wang et al., 2024; Mansourmoghaddam et al., 2024; Mansourihanis et al., 2023; Rouhi, Shafiepour Motlagh, & Dalir, 2023; Kordi & Yousefi, 2022; Ebrahimi Sirizi et al., 2023; Fallahtafti et al., 2024; Rostam-Alilou et al., 2022), loss of biodiversity (Kazemi Garajeh et al., 2023; Mohammadpouri et al., 2023; Bevilacqua et al., 2023; Sohrabi et al., 2023; McClung et al., 2019; Johnston et al., 2020), health deterioration (Elser et al., 2020; Cushing et al., 2020; Eskandari et al., 2024), environmental fragmentation (Ahmadi et al., 2022; Khosravian et al., 2024; Rouhi et al., 2024; Naghedi et al., 2024; Hajrasouliha & Ghahfarokhi, 2021; Drohan et al., 2012; Howden et al., 2019; Bargahi, Barati, & Yazici, 2023; Soltani et al., 2024), decreased air quality (Kazemi Garajeh et al., 2023; Bevilacqua, Sohrabi, & Hamdy, 2022; Cushing et al., 2020), soil and water contamination (Kazemi Garajeh et al., 2024; Ghafari, Shourangiz, & Wang, 2024; Nelson & Heo, 2020; Fink & Drohan, 2015; Hassani et al., 2023), climate change (Rouhi et al., 2024; Chen et al., 2024; Hosseini, Yahouni, & Feizabadi, 2023; Wang et al., 2024; Abdoli, 2021; Fetisov et al., 2023; Hemmati et al., 2024; Keivanimehr et al., 2021; Jahromi et al., 2020; Platt & Mahmoudi, 2024; Bargahi & Yazici, 2022; Bargahi et al., 2024), demographics of people living near the fields (Johnston et al., 2020).

It is notable that the majority of the studies have been conducted at small scale, considering few counties and a limited number of wells. Although the small sample size and small number of study locations give an image of how energy activities affect regions, they do not consider the overall influence, the major differences, and the overall ensuing comprehensive changes. Existing research on land change in the southern part of the United States has primarily focused on a limited number of areas or specific subbasins (Wang, 2021; Wolaver et al., 2018). Some studies focused on larger scales (Pierre et al., 2020; Preston & Kim, 2016; Haggerty et al., 2018; Grushecky, Harris, et al., 2022a; Xu, Elba-

kidze, & Etienne, 2023).

The environmental impacts of energy activities, particularly in oil and gas production, have been extensively discussed and researched due to their multi-faceted effects. Research has delved into various environmental impact dimensions, including the impact on land degradation, loss of biodiversity, public health, habitat fragmentation, air pollution, and soil and water contamination (Trainor, McDonald, & Fargione, 2016; Brehm & Culman, 2022; Grushecky, Zinkhan, et al., 2022b; Hosseini, Yahouni, & Feizabadi, 2023; Oshaghi, 2024; Mozafarjazi & Rabiee, 2024).

Potential environmental impacts resulting from significant growth of energy activities such as oil and gas explorations, have become a great concern recently. This literature review aims to synthesize the findings from several studies that investigate land use changes and associated environmental consequences of energy development in different regions by reviewing multiple studies conducted by Pierre et al. (2017, 2018, 2020), Wolaver et al. (2018), Wang (2021), Nelson & Heo, (2020), Trainor et al. (2016), Grushecky et al. (2022a), Aung et al. (2020), Donnelly et al. (2017), and Adu-Gyamfi et al. (2021). These studies cover various aspects of land use changes related to energy development, including oil and gas infrastructure, wind energy, and shale gas development, in different regions of the United States and internationally.

The studies collectively highlight the significant land use changes attributed to energy development activities. Pierre et al. (2017) observed an increase in landscape fragmentation as energy infrastructure developed, with well-pad construction having a greater impact over time. Pierre et al. (2018), found that oil and gas infrastructure was the most influential factor causing land-use changes in Texas during 2008-2012. In another study, Pierre et al. (2020), projected extensive landscape changes in the Permian Basin due to well pad construction, posing threats to habitats, soil erosion, and air pollution.

Wolaver et al. (2018), developed a forecasting approach for ecological impacts in the Bakken shale play, emphasizing the need for conservation planning. H. Wang (2021) studied the impact of shale energy production on shrubland and grassland/pasture, highlighting the importance of considering production volume and transportation. Nelson and Heo (2020) monitored environmental parameters in the Permian Basin, assessing land-cover changes and groundwater quality.

Trainor, McDonald, and Fargione (2016) discussed energy sprawl and its implications for land use change, emphasizing the need for sustainable energy planning. Grushecky, Zinkhan, et al. (2022b) characterized the land cover change associated with unconventional wells in the Marcellus shale and Utica plays.

Aung, Fischer, and Buchanan (2020) examined land use changes along the China-Myanmar O&G pipelines. Donnelly, Cobbinah Wilson, and Oduro Appiah (2017), compared land change impacts between the Utica and Marcellus regions, finding higher rates and extents of land change in Marcellus.

Adu-Gyamfi et al. (2021) analyzed the geologic and hydrocarbon production

differences between Texas and New Mexico regions of the Permian Basin. Overall, the literature review reveals the significant land use changes caused by energy development activities, including oil and gas infrastructure, wind energy, and shale gas development. These changes have implications for habitat fragmentation, soil erosion, air and water quality, and the conversion of natural land covers to developed areas. The findings emphasize the need for sustainable energy planning, conservation efforts, and the consideration of production volume, transportation, and geological variations when assessing the environmental impacts of energy development. The literature review provides insights into the diverse research conducted in different regions, contributing to a better understanding of the land use changes associated with energy development and its environmental consequences.

Despite extensive research on the environmental impacts of oil and gas development, there remains a significant gap in understanding the specific socio-economic impacts of energy expansion, particularly in regions like Midland County, Texas. Previous studies have predominantly focused on the environmental and ecological dimensions, often overlooking the broader implications for local communities and economies. This study aims to bridge this gap by providing a comprehensive analysis that not only assesses the environmental impacts but also delves into the socio-economic consequences of land use changes driven by energy development.

This study aims to identify and analyze current land use patterns in Midland County, Permian Basin using satellite imagery, and examine how these patterns have changed from 2001 to 2019 due to oil and gas infrastructure development. It investigates the drivers of land use changes and their variations across different land use types, while also assessing the socio-economic impacts of these changes on local communities and economies. Ultimately, the study seeks to recommend strategies for mitigating adverse environmental and socio-economic impacts of energy expansion and promoting sustainable land use practices in the region.

Midland County, situated within the Permian Basin, is the highest oil-producing county in the region, contributing significantly to the United States' oil output. The Permian Basin itself spans Texas and New Mexico, constituting nearly 40% of all oil production and nearly 15% of natural gas production in the United States (*The Railroad Commission of Texas*, 2023). The region has experienced a dramatic increase in oil and gas activities, which has had profound impacts on the local environment and land use patterns.

Studies have shown that energy development in the Permian Basin has led to significant landscape alterations, including habitat fragmentation, soil erosion, and changes in vegetation cover (Pierre et al., 2018; Wang, 2021; Wolaver et al., 2018). However, there is a lack of detailed understanding of how these changes affect the socio-economic fabric of local communities. This research aims to fill this gap by providing a comprehensive analysis of both environmental and socio-economic impacts, thereby offering a more holistic understanding of the

consequences of energy expansion.

2. Methods and Materials

2.1. Study Area

Midland County, located in the heart of West Texas, is a significant region within the larger Permian Basin. Spanning approximately 902 square miles, Midland County is renowned for its high oil production, making it the leading oil-producing county in the Permian Basin. The county's landscape has been profoundly shaped by the rapid expansion of oil and gas activities, particularly since the early 2000s ([The Railroad Commission of Texas, 2023](#); [U.S. Energy Information Administration \(EIA\), 2024](#)).

Midland County's environment is characterized by a semi-arid climate with hot summers and mild winters. The vegetation primarily consists of grasses, shrubs, and scattered trees, which are increasingly under threat from land disturbances caused by oil and gas extraction. The soil in the region is prone to erosion, and the introduction of infrastructure, such as roads and pipelines, exacerbates this issue ([Grushecky et al., 2022a](#)).

Socio-economically, Midland County has a population that heavily relies on the oil and gas industry for employment and economic stability. The rapid development of this sector has brought significant economic benefits, including job creation, increased local revenue, and overall economic growth. However, this economic boom has also raised concerns about environmental sustainability and the quality of life for local communities. The increase in industrial activities associated with the oil and gas sector has led to noticeable changes in land use patterns.

Agricultural lands, once the backbone of the local economy, have been increasingly repurposed for industrial use, resulting in a reduction of arable land available for farming. This shift has not only impacted the agricultural output of the region but has also contributed to the emergence of barren lands and altered vegetation cover. The expansion of industrial zones has led to habitat fragmentation and a decrease in biodiversity, posing challenges to local wildlife. Furthermore, the environmental impact of increased drilling and extraction activities, including potential contamination of soil and water resources, has become a pressing issue. Local communities are grappling with the balance between economic gains and the preservation of their environmental resources, as well as the long-term health implications of living in close proximity to heavy industrial operations ([Pierre et al., 2018](#); [Wang, 2021](#)).

Figure 1 shows Midland County, located within the Midland Basin in West Texas, is renowned for its oil production, making it the leading oil-producing county in the Permian Basin.

According to the Energy Information Administration (EIA), Midland County contributed to 15% of US crude oil production in 2020. Encompassing an area of 13,000 square miles, Midland County has emerged as a key player in the energy sector, topping the list of Texas counties in terms of barrels of oil equivalent

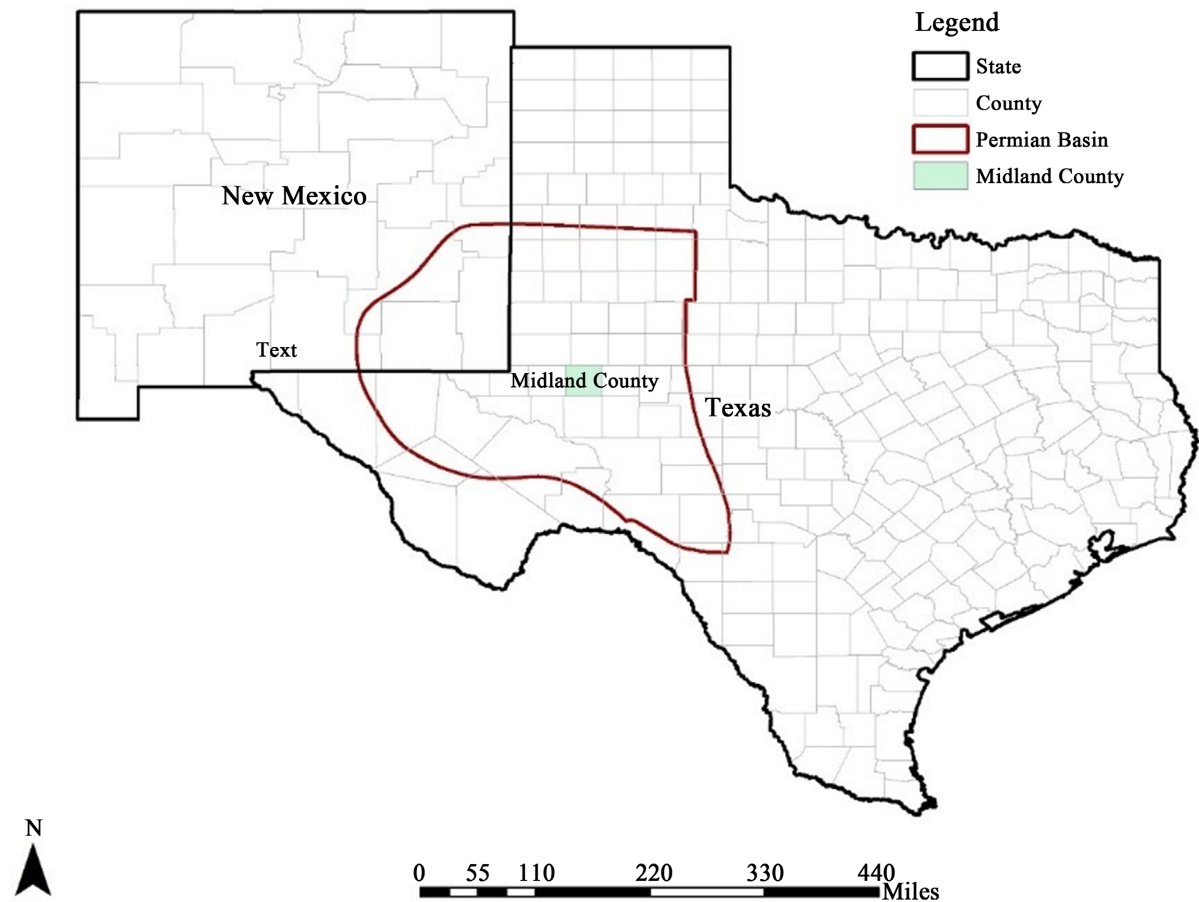


Figure 1. Study area.

(BOE) produced as of June 2022 (Oil & Gas Leads). According to the U.S. Census Bureau, Midland County spans 902 square miles and had a population of 169,983 as of 2022 (U.S. Census Bureau, 2020). Various sources were utilized for obtaining the data used in this research.

2.2. Data

The shapefiles for state and county were obtained from Tiger shapefiles by Census data (Census), and the shapefiles for Midland County were obtained from the Texas Railroad Commission. Land cover assessment for the year 2001 was conducted using Landsat 5 Thematic Mapper (TM), while Landsat 8 Operational Land Imager (OLI) was used for the year 2019. These images provided a 30 m resolution and were obtained from open-source USGS with a maximum of 20% cloud coverage for the months of June, July, and August. The image with the least cloud coverage, which was obtained in June, was used for both years.

2.3. Methods

This study used Landsat satellite images from 2001 and 2019. **Figure 2** illustrated the data flow and methodology that was utilized in this study. Landsat TM images, each with a 30m resolution, were collected from the United States

Geological Survey website Earth Explorer. ArcGIS Pro was utilized to conduct the data analysis for this study. The necessary shapefiles, including the county, state, and Permian Basin shapefiles, were obtained from the Census website, while Landsat images for the years 2001 and 2019 were downloaded from the USGS website. Landsat 5 was used for the year 2001 as it was the only option available for that year, while Landsat 8 was used for 2019. Both Landsat images had cloud coverage limited to 20% for the months of June, July, and August to ensure that the available data covered areas with minimal cloud cover during the months when vegetation health and land cover are typically at their peak.

The methodology involved the calculation of the Normalized Difference Vegetation Index (NDVI) with values ranging from -1 to 1 , which allowed for a comparison of land cover changes between the two years to identify alterations. The NDVI measures the density of vegetation and the activity of growing plants, with a higher NDVI indicating denser vegetation and more active plant growth. The Landsat images were added to the map in ArcGIS Pro, and the Extract Raster function was used to clip the Landsat images to the shapefile of the study area, Midland County. The NDVI function in ArcGIS Pro was used to calculate the NDVI.

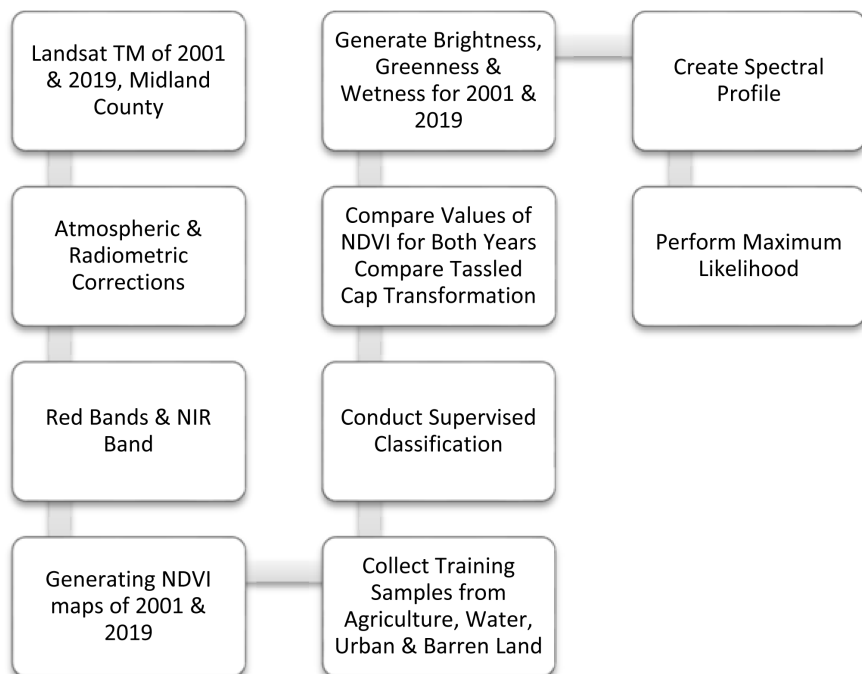


Figure 2. Data flow and methodology.

The NDVI measures the density of vegetation and the activity of growing plants, with a higher NDVI indicating denser vegetation and more active plant growth. The Landsat images were added to the map in ArcGIS Pro, and the Extract Raster function was used to clip the Landsat images to the shapefile of the study area, Midland County. The NDVI function in ArcGIS Pro was used to calculate the NDVI.

The following formula was used to calculate the NDVI for both years:

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED}) \quad (1)$$

where NIR represents the Near Infrared Band and RED represents the Red Band. This formula allowed for the calculation of the NDVI values for each pixel within the Landsat images, providing a comprehensive overview of the vegetation health and land cover changes within the study area.

$$\text{NDVI (L05-2001)} = (\text{band 5} - \text{band 4}) / (\text{band 5} + \text{band 4}) \quad (2)$$

$$\text{NDVI (L08-2019)} = (\text{band 4} - \text{band 3}) / (\text{band 4} + \text{band 3}) \quad (3)$$

For the year 2001, the Near Infra-Red (NIR) band was represented by band 5, and the Red band was represented by band 4. For the year 2019, the NIR band was represented by band 4, and the Red band was represented by band 3. The Tasseled Cap Transformation was utilized to assess changes in land cover and vegetation density over time. This transformation calculates brightness, greenness, and wetness, with higher values representing bright surfaces and lower values representing dark surfaces. In 2019, higher brightness values were observed compared to 2001. Additionally, greenness was calculated, with high greenness values representing dense vegetation. Lower greenness values were observed in 2019 compared to 2001. Wetness was also calculated, with high values representing wetter areas and lower values representing dry areas. Lower values of dryness were observed in 2019.

The following formula was used to calculate brightness, greenness, and wetness:

$$\begin{aligned} \text{Brightness} = & 0.2043 * \text{Band 1} + 0.4158 * \text{Band 2} + 0.5524 * \text{Band 3} \\ & + 0.5741 * \text{Band 4} + 0.3124 * \text{Band 5} + 0.2303 * \text{Band 7} \end{aligned} \quad (4)$$

$$\begin{aligned} \text{Greenness} = & -0.1603 * \text{Band 1} - 0.2819 * \text{Band 2} - 0.4934 * \text{Band 3} \\ & + 0.7940 * \text{Band 4} - 0.0002 * \text{Band 5} - 0.1446 * \text{Band 7} \end{aligned} \quad (5)$$

$$\begin{aligned} \text{Wetness} = & 0.0315 * \text{Band 1} - 0.2021 * \text{Band 2} + 0.3102 * \text{Band 3} \\ & + 0.1594 * \text{Band 4} - 0.6806 * \text{Band 5} - 0.6109 * \text{Band 7} \end{aligned} \quad (6)$$

By comparing the values of NDVI and Tasseled Cap for both years, the results showed significant changes in land cover and vegetation density within Midland County, Texas over the studied period. Consequently, the 2019 Landsat image was selected for supervised classification targeting land cover classes such as agriculture, urban, water, and barren. This choice was made in anticipation of detecting an increase in barren lands and the displacement of agricultural areas. The supervised classification method was employed using Landsat 8 imagery to classify land use/land cover in Midland County for the year 2019. The methodology involved several steps including collecting training samples and applying the maximum likelihood algorithm for classification. The Landsat 8 OLI image was downloaded from the USGS website and imported into ArcGIS Pro. The image was preprocessed by performing radiometric calibration and atmospheric correction to enhance the quality of the image. Training samples were collected for four land cover classes, namely agriculture, water, urban, and barren. The training samples were collected using the digitizing tool in ArcGIS Pro by vi-

sually interpreting the high-resolution imagery from the National Agriculture Imagery Program (NAIP) and Google Earth. A minimum of 80 training samples were collected for each class. The Maximum Likelihood Classification (MLC) algorithm was used to classify the Landsat 8 OLI image.

3. Results

The NDVI calculations revealed a notable decline in vegetation cover and health between 2001 and 2019 in Midland County, Texas. **Figure 3** shows the NDVI values indicating a decrease in vegetation density and vitality in 2019 compared to 2001. This decline was characterized by sparse vegetation cover and fewer actively growing plants, likely attributed to the escalating energy activities in the region. Over the 18 years, the expansion of oil and gas operations has contributed to environmental degradation and fragmentation, impacting the local vegetation ecosystem. The decrease in NDVI values suggests significant ecological stress, potentially leading to long-term biodiversity loss and habitat fragmentation. This finding underscores the need for continuous monitoring and implementing mitigation strategies to effectively manage vegetation health.

The results of the Tasseled Cap transformation echoed the decline in vegetation density observed in 2019. **Figure 4** shows that greenness values exhibited a reduction, indicating diminished vegetation density. The discernible reduction in greenness values reflects a noteworthy decline in vegetation density within the region. This decrease serves as a vital indicator of environmental shifts potentially stemming from factors such as deforestation, agricultural expansion, or natural habitat degradation. Such alterations in greenness values underscore the

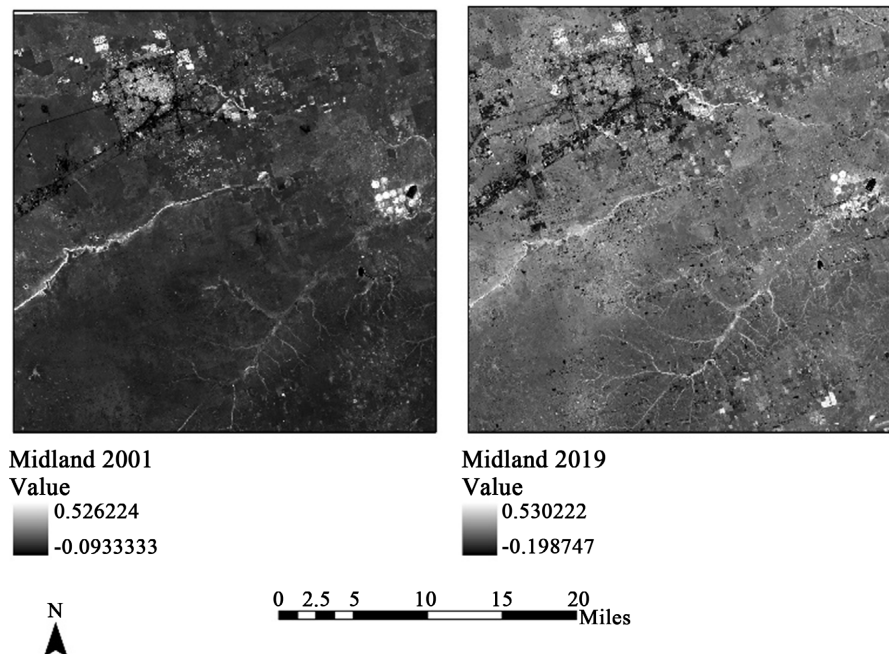


Figure 3. Map of the calculated NDVI for the years 2001 and 2019 in Midland County, TX.

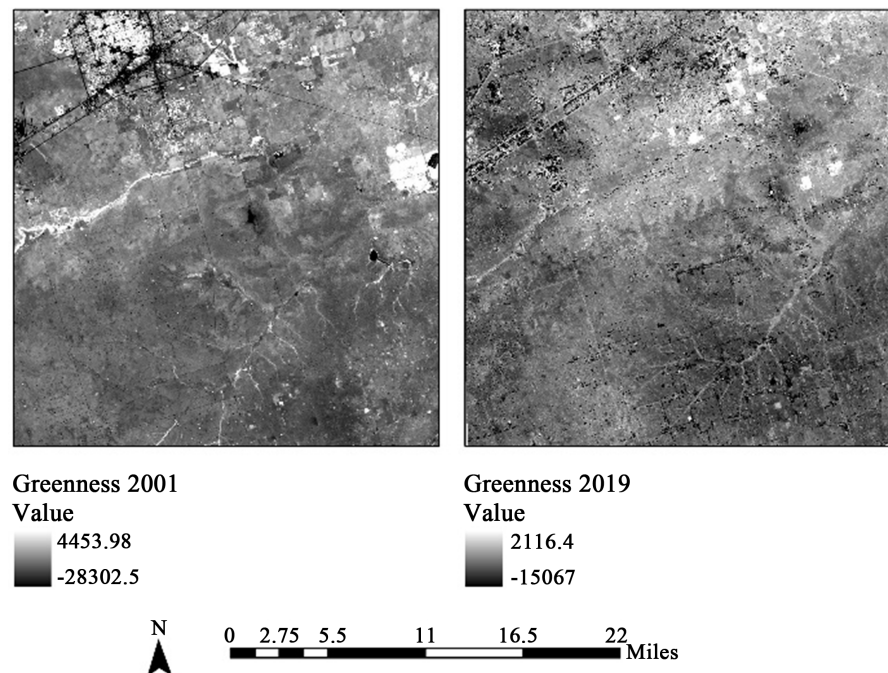


Figure 4. Map of the calculated Greenness for the years 2001 and 2019 in Mid-land County, TX.

importance of monitoring and addressing ecological changes to preserve biodiversity and ecosystem health. Additionally, the reduction in greenness values could be linked to increased soil erosion and decreased soil fertility, further exacerbating land degradation in the region. Effective land management practices and reforestation efforts are critical to reversing these trends.

Figure 5 shows the results of brightness calculations in the study area, revealing a significant rise in brightness values. This increase is indicative of accelerated urbanization and extensive development activities taking place within the locality. Urban areas typically exhibit higher brightness due to increased reflectance from built-up surfaces, which are prominent in the visible spectrum.

The observed trend towards heightened brightness highlights the urgent need for sustainable urban planning strategies. Such strategies are crucial for mitigating the adverse impacts of urban sprawl on natural landscapes and ecological systems. The escalation in brightness values also suggests an expansion of impervious surfaces, contributing to elevated runoff and reduced groundwater recharge.

To effectively manage these urbanization impacts, the implementation of green infrastructure and low-impact development practices is imperative. Green infrastructure, such as green roofs, permeable pavements, and urban green spaces, facilitates stormwater infiltration and promotes biodiversity in urban settings. These approaches not only mitigate runoff but also enhance the resilience of cities to environmental changes. In conclusion, integrating sustainable urban planning practices is essential for balancing development with environmental conservation. By adopting proactive measures like green infrastructure and

low-impact development, cities can foster sustainable growth while preserving natural ecosystems and improving overall urban livability.

Figure 6 illustrates this decrease, contrasting with trends in greenness and brightness, suggesting significant environmental changes over the period. The observed decline in wetness values in 2019 compared to 2001 indicates increasingly drier conditions. This reduction in wetness values could be attributed to

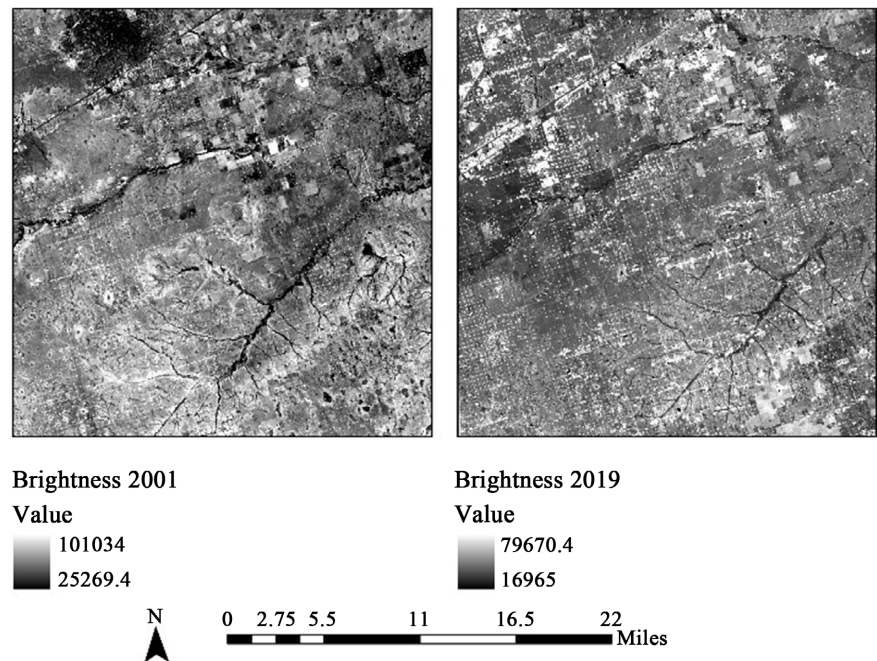


Figure 5. Map of the calculated Brightness for the year 2001 and 2019 in Mid-land County, TX.

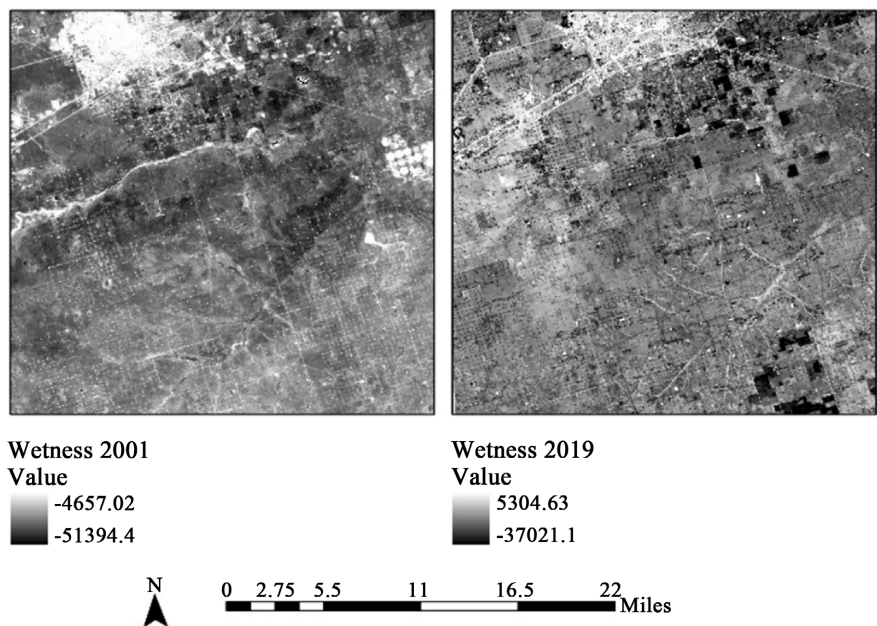


Figure 6. Map of the calculated Wetness for the years 2001 and 2019 in Midland County, TX.

several factors, including changes in precipitation patterns, such as reduced overall rainfall, extended drought periods, or more erratic precipitation events. Additionally, alterations in land cover, such as deforestation, urbanization, and shifts in agricultural practices, may significantly impact the land's ability to retain water. These modifications can reduce soil moisture and groundwater recharge, contributing to the observed drier conditions.

Furthermore, shifts in regional hydrological processes driven by both natural variability and human activities might also play a role. Human activities, such as increased water extraction for agriculture and industry, can exacerbate the drying trend. Climate change, with its influence on weather patterns and temperature, also plays a critical role in altering hydrological cycles and precipitation distribution. The impact of these changes is multifaceted, affecting not only water availability but also the health of ecosystems and agricultural productivity.

Addressing these drier conditions is crucial for effective water resource management, agricultural sustainability, and ecosystem resilience. Measures such as adopting drought-resistant crops, improving irrigation efficiency, and implementing water conservation practices are essential to mitigate these impacts. Additionally, restoring wetlands and promoting sustainable land management practices can enhance the land's capacity to retain water. Policymakers and stakeholders must collaborate to develop comprehensive strategies that balance economic development with environmental preservation, ensuring the long-term viability of water resources and the well-being of local communities and ecosystems.

Collectively, these findings underscore significant alterations in land cover and vegetation density within Midland County, Texas, over the studied period. Consequently, the 2019 Landsat image was selected for supervised classification targeting land cover classes such as agriculture, urban, water, and barren. This choice was made in anticipation of detecting an increase in barren lands and the displacement of agricultural areas.

The supervised classification method employed Landsat 8 imagery to classify land use/land cover in Midland County for the year 2019. **Figure 7** shows the methodology involved several steps, including collecting training samples and applying the maximum likelihood algorithm for classification. The Landsat 8 OLI image was downloaded from the USGS website and imported into ArcGIS Pro. The image was preprocessed by performing radiometric calibration and atmospheric correction to enhance the quality of the image. Training samples were collected for four land cover classes, namely agriculture, water, urban, and barren. The training samples were collected using the digitizing tool in ArcGIS Pro by visually interpreting the high-resolution imagery from the National Agriculture Imagery Program (NAIP) and Google Earth. A minimum of 80 training samples were collected for each class. The Maximum Likelihood Classification (MLC) algorithm was used to classify the Landsat 8 OLI image.

The classification results indicated a significant shift in land use patterns, with a noticeable increase in barren land and a corresponding decrease in agricultural areas. Urban expansion was also evident, correlating with the increased brightness

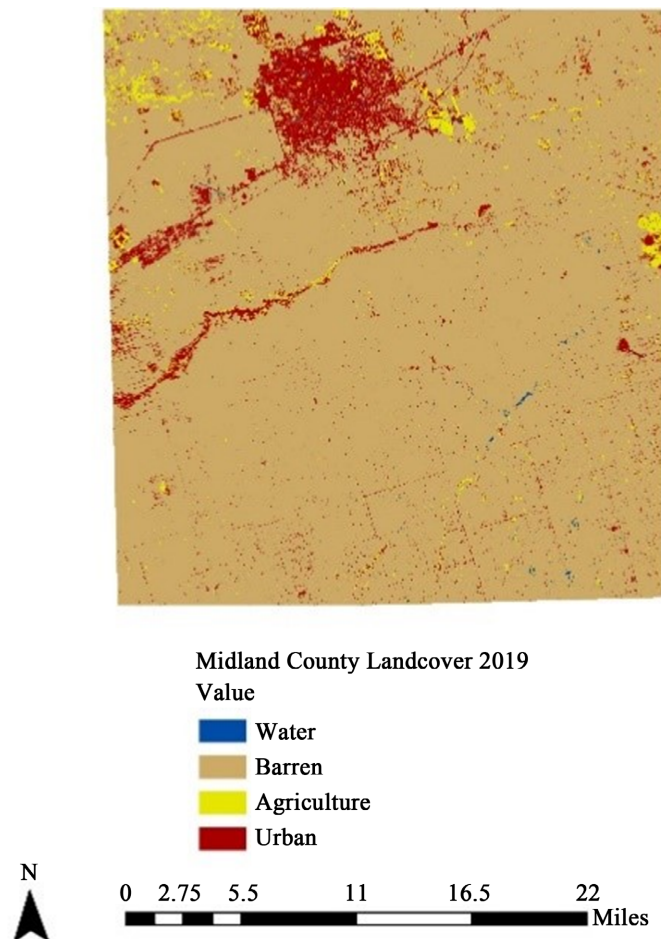


Figure 7. Map of the supervised Classification in Midland County, TX, 2019.

values observed in the Tasseled Cap transformation. Water bodies showed minimal changes, suggesting that the primary impacts of oil and gas activities were on terrestrial ecosystems and agricultural land. These results highlight the need for integrated land use planning and stringent regulations to control oil and gas infrastructure expansion and minimize its environmental footprint.

The observed decline in wetness values in 2019, compared to 2001, indicates drier conditions. This decrease, contrasting with trends in greenness and brightness, suggests significant environmental changes over the period. The reduction in wetness values could be attributed to changes in precipitation patterns, such as reduced overall rainfall, extended drought periods, or more erratic precipitation events. Additionally, alterations in land cover, including deforestation, urbanization, and shifts in agricultural practices, may impact the land's ability to retain water. These modifications can reduce soil moisture and groundwater recharge, contributing to the observed drier conditions. Furthermore, shifts in regional hydrological processes, driven by both natural variability and human activities, might also play a role.

Understanding and addressing these drier conditions are crucial for effective water resource management, agricultural sustainability, and ecosystem resi-

lience. Effective water resource management requires adapting to changing water availability through efficient practices and policies. In agriculture, sustaining productivity under drier conditions involves adopting drought-resistant crops and improving irrigation efficiency. For ecosystems, changes in wetness can impact biodiversity and habitat health, making conservation efforts that account for hydrological shifts essential for maintaining ecosystem resilience amidst climate variability and change.

Collectively, these findings underscore significant alterations in land cover and vegetation density within Midland County, Texas, over the studied period. Consequently, the 2019 Landsat was selected for supervised classification, targeting land cover classes such as agriculture, urban, water, and barren. This choice was made in anticipation of detecting an increase in barren lands and the displacement of agricultural areas.

Figure 7 shows the land cover classification of Midland County in 2019, presenting a detailed spatial representation of different land use categories. The color-coded legend identifies four primary land cover types: water (blue), barren land (yellow), agricultural areas (green), and urban regions (red). The map clearly indicates a significant concentration of urban development in the northern part of the county, characterized by extensive red areas, suggesting a densely populated or highly developed region. The vast majority of the county, shown in green, is dominated by agricultural land, underscoring the rural and agrarian nature of Midland County. Scattered patches of barren land are visible, primarily in the northeastern and central parts of the county, which may indicate regions with sparse vegetation or non-arable land. Water bodies, although present, appear minimally, marked by small blue areas primarily in the eastern part of the county. This land cover map is crucial for understanding the spatial distribution of different land use types, aiding in urban planning, resource management, and environmental conservation efforts within Midland County.

4. Conclusion

The impact of oil and gas development on both the environment and the landscape has long been a subject of concern. This study sheds light on the significant repercussions of such development, focusing specifically on Midland County within the Permian Basin, the foremost oil-producing county, to track environmental shifts from 2001 to 2019. Leveraging satellite imagery, the research identifies prevailing land use patterns and scrutinizes their transformations to elucidate the drivers of change across diverse land use categories.

The findings underscore a substantial alteration in Midland County's landscape over the study period, driven by the expansion of oil and gas activities and infrastructure, coupled with escalated production levels. This transformation manifests in sparse and less robust vegetation cover, the displacement of agricultural lands, and an uptick in barren areas. The NDVI analysis revealed a significant decline in vegetation health and density, indicating ecological stress that

could lead to long-term biodiversity loss and habitat fragmentation. The Tasseled Cap transformation further highlighted the reduction in greenness values, emphasizing the need for monitoring and addressing ecological changes to preserve biodiversity and ecosystem health.

Moreover, the increase in brightness values points to heightened urbanization and developmental activities, underscoring the imperative for sustainable urban planning strategies to mitigate the adverse impacts of urban sprawl on natural landscapes. The observed decline in wetness values suggests drier conditions, likely resulting from changes in precipitation patterns and land cover modifications, highlighting the importance of effective water resource management and agricultural sustainability.

The supervised classification results showed a significant shift in land use patterns, with a notable increase in barren land and a corresponding decrease in agricultural areas. Urban expansion was evident, aligning with the increased brightness values. These findings call for integrated land use planning and stringent regulations to control the expansion of oil and gas infrastructure and minimize its environmental footprint.

Evidently, oil and gas development activities have instigated profound shifts in land use dynamics, leading to habitat fragmentation and biodiversity loss. These insights carry crucial implications for land use planning and resource management, emphasizing the imperative to mitigate adverse environmental impacts stemming from energy activities. Furthermore, the study underscores the necessity of adopting a holistic approach to evaluate the cumulative effects of energy sprawl on landscapes and land cover, necessitating collaboration among stakeholders across various sectors.

The collective results of these methods demonstrate the effectiveness of utilizing satellite imagery and GIS techniques in monitoring and analyzing land cover changes over time. The integration of NDVI analysis, Tasseled Cap transformation, and supervised classification provided a comprehensive assessment of the environmental impacts of oil and gas development in Midland County. This multi-faceted approach allowed for the identification of specific areas experiencing significant ecological stress, urban expansion, and land degradation, thereby providing a robust foundation for developing targeted mitigation strategies.

In conclusion, this research furnishes invaluable insights into the environmental ramifications of oil and gas operations in Midland County, advocating for informed decision-making and proactive measures to safeguard the environment amidst burgeoning energy development. Effective mitigation strategies, sustainable land use practices, and comprehensive monitoring are essential to address the environmental and socio-economic challenges posed by energy expansion in the region.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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