

A Preliminary Study on Heavy Oil Location in Central Sumatra using Remote Sensing and Geographic Information Sytem

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ABSTRACT

Heavy oil which is classified as non conventional oil is the target of exploration in the world. In Indonesia, the potential for heavy oil exploration is quite large, especially in the Central Sumatra basin. This study aims to map the location of potential heavy oil based on remote sensing data and regional gravity data supported by a geographic information system. Landsat 8 OLI satellite data is processed to produce 567 (RGB) color composite images, then further processing is carried out with DEM data to produce fusion images; mapping the vegetation index, clay mineral index, iron oxide index, surface temperature. The gravity data is used for mapping subsurface geological structures. Overlay analysis is carried out on the results of remote sensing data processing and interpretation of surface and subsurface geology. Based on the analysis, it shows that heavy oil fields are generally found on the surface and subsurface structures which are relatively identical and located on the edge of the basement high. Based on this analysis, the locations that have the potential for heavy oil and gas traps are on the northeast edge, Dalu-dalu High, the edge of Kampar High, the west edge of Kuantan High, the southwest edge of the Beruk High, the southwest edge of the Sembilan High.

Keywords: Heavy Oil, Central Sumatra, Landsat, Gravity, GIS, Overlay Analysis.

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INTRODUCTION

Heavy oil is oil that has an API gravity of less than 20°API or greater than 0.93g / cm³ or with a viscosity greater than 100-cP (Briggs, *et al.*, 1988; Meyer, *et al.*, 2007). National Petroleum Agency of Brazil define API gravity of heavy oil $10 \leq \text{API} < 22$. In this study, the heavy oil is oil that has an API gravity equal or less than 25° API. In Indonesia, there are occurrences of heavy oil presence in Central Sumatra Basin, South Sumatra, Tarakan, and East Java Basin. Mayer, *et al.* (2007) reported 40.6 Billion bbl

of heavy oil accumulation in Central Sumatra Basin, eventhough the most realistic figure remain unknow. According to Hein (2017), bitumen and heavy oil resources are around 5.6 trillion barels spread across more than 70 countries. Heavy oil is mostly found in Venezuela, while bitumen is mostly in Canada. In general, heavy oil and bitumen are found at depths of less than 200 m and a maximum of up to 2000 m. The total resource of heavy oil and bitumen in Canada, Venezuela and the United States is estimated to be more than 80% of the world's resources (Bata, *et al.*, 2019).

Globally, the largest accumulation of heavy oil is in South America and North America (Roadifer, 1987). In Indonesia, heavy oil is predominantly located in Central Sumatra and is estimated to have an OOIP discovery of around 40.6 and is ranked 14th in the basin in the world. In addition, it was also reported that there were also occurs in South Sumatra, Sunda, Tarakan and East Java basins (Meyer, *et al.*, 2007).

The existence of non-conventional oil, especially heavy oil and the like, is a significant part of oil reserves in the world (Santos, *et al.*, 2014). However, heavy oil exploration has not been carried out intensively in Indonesia. There are only a few fields that specifically produce heavy oil, such as the Duri, Kulin, North Kulin, and Sebang fields. Even though the Central Sumatra basin is thought to have large resources, it is necessary to carry out exploration to find potential undiscovered heavy oil. In this study, a preliminary heavy oil exploration study was carried out based on remote sensing data and geographic information systems so that areas that could potentially contain heavy oil identified.

Remote sensing technology is a technology for identifying and analyzing the characteristics of an object that is recorded based on certain wavelengths. In oil and gas exploration, the use of remote sensing can be used for initial mapping of exploration targets, including through the presence of oil and gas seepage (Susantoro & Wikantika, 2017). Yang (1999) further explains that the presence of oil and gas seepage causes a geomorphic high anomaly, the presence of soil gas, geobotany changes, radiometric changes, changes in delta carbon, changes in clay minerals and iron ions. Specifically, heavy oil seepage will form a macro-seepage which processes through unconformities, tectonic structures that penetrate reservoirs and seals, reservoir rock as a carrier bed and sometimes there is surface expression from intrusions such as mud volcanoes or salt domes (van der Werff, *et al.*, 2007).

In general, heavy oil seepage or asphalt deposit has a spatial relationship with the presence of anticline structures. The results showed that within 4 km of the anticline axis there could be 78% heavy oil seepage or asphalt deposit. Heavy oil seepage also positively associated with thrust faults (Salati, 2014). Based on the above, an initial study of oil and gas exploration was carried out for mapping heavy oil in the Central Sumatra Basin. This study aims to map locations that are thought to contain heavy oil in the Central Sumatra basin based on remote sensing data

and regional gravity data supported by a geographic information system analysis.

METHODOLOGY

Study area

The Central Sumatra basin is a light oil and heavy oil producing basin. Heavy oil was first discovered in 1939 in the drilling of the Sebang-1 well (Indonesia Petroleum Association (IPA), 2006). In this basin there are several fields that are already producing heavy oil, and the best known is the Duri Field. The Central Sumatra Basin experienced complex tectonic events and experienced at least 3 different tectonic phases, namely the tensional phase in the Eocene - Oligocene, then changing to a transitional phase in the early Miocene - middle Miocene and finally the compressional phase in the middle Miocene - recent. This condition causes many oil and gas fields to be trapped structurally (Hendrawan, 2014).

Stratigraphically, the Central Sumatra Basin consists of several formation units and rock groups ranging from Pre-Tertiary to Quaternary. The rock group consists of the basement, the Pematang Group, the Sihapas Group, the Petani Formation and the Minas Formation. The Menggala Formation, which is part of the Sihapas Group, is the main reservoir in the Central Sumatra Basin. The source rock in this basin is the Brown Shale Formation which is in the Pematang group, and the rock seal is the Bangko Formation which has a dominant shale lithological composition deposited above the Menggala Formation. The location of the Central Sumatra Basin is shown in Figure 1.

Data Used

Landsat 8 OLI data consists of 4 scenes with path /row 126/059, 126/060, 127/059 and 127/60 which were recorded on 16 February 2015, 26 June 2016, 20 August 2016 and 25 May 2019 which were downloaded from <https://earthexplorer.usgs.gov>. used for preliminary studies of oil and gas exploration for mapping potential locations for heavy oil in the Central Sumatra Basin. Other data used are digital elevation model (DEM) Shuttle Radar Topographic Mission (SRTM) data sourced from <http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp>; gravity data is sourced from topex.ucsd.edu/cgi-bin/get_data.cgi; and Geological Maps sourced from the Geological Survey Center, Geological Agency. These data have

geographic references so that they can be used for overlapping studies in order to identify potential areas of heavy oil.

Processing and Analysis

Landsat 8 OLI data, which consists of 4 scenes, is processed data in the form of 567 (RGB) color composite settings, band ratios, mosaicking 4 scenes of 567 (RGB) color composite images into 1 image and combining 567 (RGB) color composite images with SRTM. A color composite image with a certain band combination can better display the desired object (Danoedoro, 1996). The color composite is made by combining 3 bands, namely Near Infrared, short wave infrared 1 and short wave infrared 2, which aims to sharpen the geological structure.

Landsat 8 OLI processing using a band ratio was carried out to map vegetation, clay minerals, iron oxides and temperature indices. The mapping of the vegetation index was carried out using the Normalized Difference Vegetation Index (NDVI) algorithm developed by Rouse, *et al.* (1974). The vegetation index formula used is:

$$\frac{(NIR-Red)}{(NIR+Red)} \quad (1)$$

Mapping of clay minerals was carried out using a band ratio at a wavelength of 1.55 -1.75 μm and 2.09 -2.35 μm (Sabins, 1987). The results are expected to detect the presence of clay minerals with a higher index value than other areas. The clay mineral formula used is:

$$\frac{SWIR1}{SWIR2} \quad (2)$$

Mapping of iron oxide is carried out to describe its spatial distribution so that it is expected to be able to identify existing surface anomalies. The band ratio is used by comparing the wavelength of 0.63 - 0.69 μm with a length of 0.45 - 0.52 μm (Drury, 1987; Ouattara, *et al.*, 2004). The iron oxide index formula used is:

$$\frac{Red}{Blue} \quad (3)$$

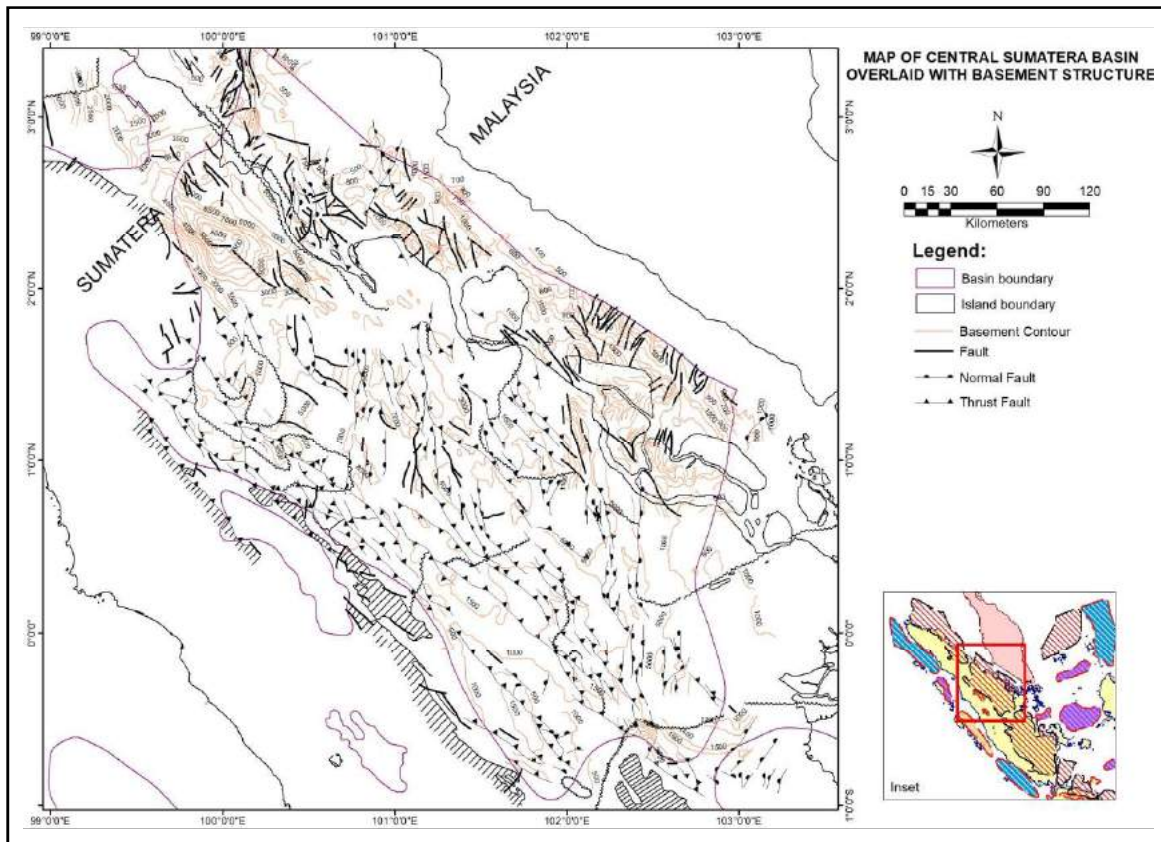


Figure1
Central Sumatra basin coverage and basement structure map (Lemigas, 2020).

Mapping of surface temperature was carried out using wavelengths on bands 10 and 11 Landsat 8 OLI. The stages carried out in this mapping include (1) changing the digital value (DN) to Top of atmosphere (ToA) in the form of radiance values; (2) Converting the radiance value to surface temperature (Kelvin); and (3) converting the Kelvin surface temperature into Celsius surface temperature. The formula used is:

$$L_{\lambda} = M_L * Q_{cal} + A_L \quad (4)$$

$$T1 = K_2 / \{\log (K_1 / L_{\lambda} + 1)\} \quad (5)$$

$$T2 = T1 - 273 \quad (6)$$

where: L_{λ} = TOA radiance; M_L = Band-specific multiplicative rescaling factor; A_L = Band-specific additive rescaling factor; Q_{cal} = DN for each pixel in the Landsat imagery band; $T1$ = brightness temperature (Kelvin); K_1 = band thermal constant 10 or 11; K_2 = band thermal constant 10 or 11; and $T2$ = temperature (Celsius).

The 567 (RGB) color composite image mosaic was carried out to produce a visualization of the study location so that it was comprehensive, making it easier to interpret the existing geological structures. The next process is carried out by combining 567 (RGB) color composite images with SRTM. This is done with the aim of sharpening the elements of geological interpretation, especially topography, relief and drainage patterns (Susantoro, 2009).

Band ratio analysis through mapping the vegetation, clay minerals, iron oxide and temperature indices is carried out to assess the potential anomalies that occur in the Central Sumatra basin. This anomaly is expected to be an indication of the undiscovered potential for heavy oil. The analysis is also carried out through the interpretation of surface and subsurface structures. The interpretation of the surface structure is carried out on the resulting 567 color composite (RGB) image and the resulting image merged with SRTM. and subsurface. The subsurface interpretation is carried out on regional gravity data which has been processed through the rasterization process of the gravity value points data.

Structural geology interpretation is performed by digitizing on screen with the interpreted object is geological structure. This interpretation is done using basic elements of image recognition and basic elements of geological interpretation. In principle, objects can be recognized based on different

characteristics on the image so that they can be the characteristics of these objects to be distinguished from other objects. The geological structure in the image is clearly visible as a straight line and is indicated as a join or fault. The results of the interpretation of the surface and subsurface geological structures are then overlapped to enable identification of the potential for heavy oil. The characteristics of the presence of heavy oil use a proven reference to the heavy oil field, namely the Duri field. The results of this analysis are expected to be an indication basement high in the Central Sumatra basin that potentially may contain heavy oil.

RESULTS AND DISCUSSION

Vegetation Index

Band ratio processing has been carried out using Landsat 8 OLI on vegetation index, clay mineral index, iron oxide index and surface temperature. The vegetation index is an algorithm used for vegetation analysis so that potential vegetation stresses can be identified due to the presence of oil and gas. The determination of this vegetation index uses the Normalized Difference Vegetation Index (NDVI) approach which is generally good for modeling vegetation, does not really have an effect on atmospheric effects and is able to respond to vegetation signals in areas that have different topographic variations (Sudarsono, *et al.*, 2016).

The NDVI value is generally divided into three (3) classes, where water cover has a value of <0 , vegetation cover > 0 and open land is close to 0 (Danoedoro & Zukhrufiyati, 2015). The results of NDVI calculations in the onshore area of the Central Sumatra basin are as follows: (1) NDVI Landsat 8 path / row 126/059 values indicate dominance between 0.62 - 0.88, with histogram peaks at 0.82 to 0.87; (2) NDVI Landsat 8 path / row 126/060 value shows a dominant between 0.75 - 0.88 with a peak histogram of 0.87; (3) The NDVI Landsat 8 path / row 127/059 values were dominant between 0.68 - 0.89 with a histogram peak of 0.86; and (4) The NDVI Landsat 8 path / row 127/060 value is dominant between 0.70 - 0.88 with a peak histogram of 0.85. The NDVI value at the top of the histogram is the dominant NDVI value that is in each path / row of image data which is a vegetation category with dense cover. The map of the NDVI analysis results can be seen in Figure 2.

Based on the NDVI value, the Central Sumatra basin tends to have vegetation cover with moderate density towards dense. This is consistent with the explanation of van der Werff, *et al.* (2008) which states that a high NDVI value indicates dense vegetation cover and a low value indicates reduced vegetation. Muhammad and Saepuloh (2016) state that the NDVI value with dense vegetation is around 0.8. This is the result of analysis on vegetation observations on Gunung Malabar, Gunung Bedil, Gunung Wayang and Gunung Windu. The condition of the vegetation cover which tends to be dense is an obstacle to the mapping of vegetation stress due to the presence of oil and gas underneath. Moreover, the vegetation in the study location based on field observations is cultivated vegetation with the dominant oil palm plantations.

Observation of the NDVI value on the surface of the Duri Oil and Gas Field which is proven to contain heavy oil shows that the oil and gas field has a lower NDVI value compared to plantation areas or other vegetation. However, the existence of settlements around the Duri field causes NDVI analysis to be less usable in the initial identification of oil and gas

exploration. Where dense settlements have a lower NDVI compared to areas where there are oil and gas sources (Figure 3).

Clay Mineral Index

One of the important compositions in the source rock and reservoir rock is the presence of clay minerals. Where its existence greatly affects the physical and chemical properties of the sandstone, carbonate and unconventional shale properties (Jiang, 2012). On the surface of the oil and gas field, the presence of clay minerals sometimes undergoes alteration as a result of oil and gas seeping up to the surface or near the surface (Susantoro, *et al.*, 2020). Analysis of the clay mineral index using Landsat 8 OLI in the Central Sumatra basin has been carried out and has resulted in a low index value. In general, the clay mineral index for the 4 scenes Landsat 8 OLI ranges from 0 - 1. Based on the comparison of the results of the research by Susantoro *et al.* (2020), the clay mineral index in the South Sumatra basin is low. Where the research results show mineral clay is greater than 1.

The results of calculating the clay mineral index at 4 scenes Landsat 8 OLI in detail are as follows (1)

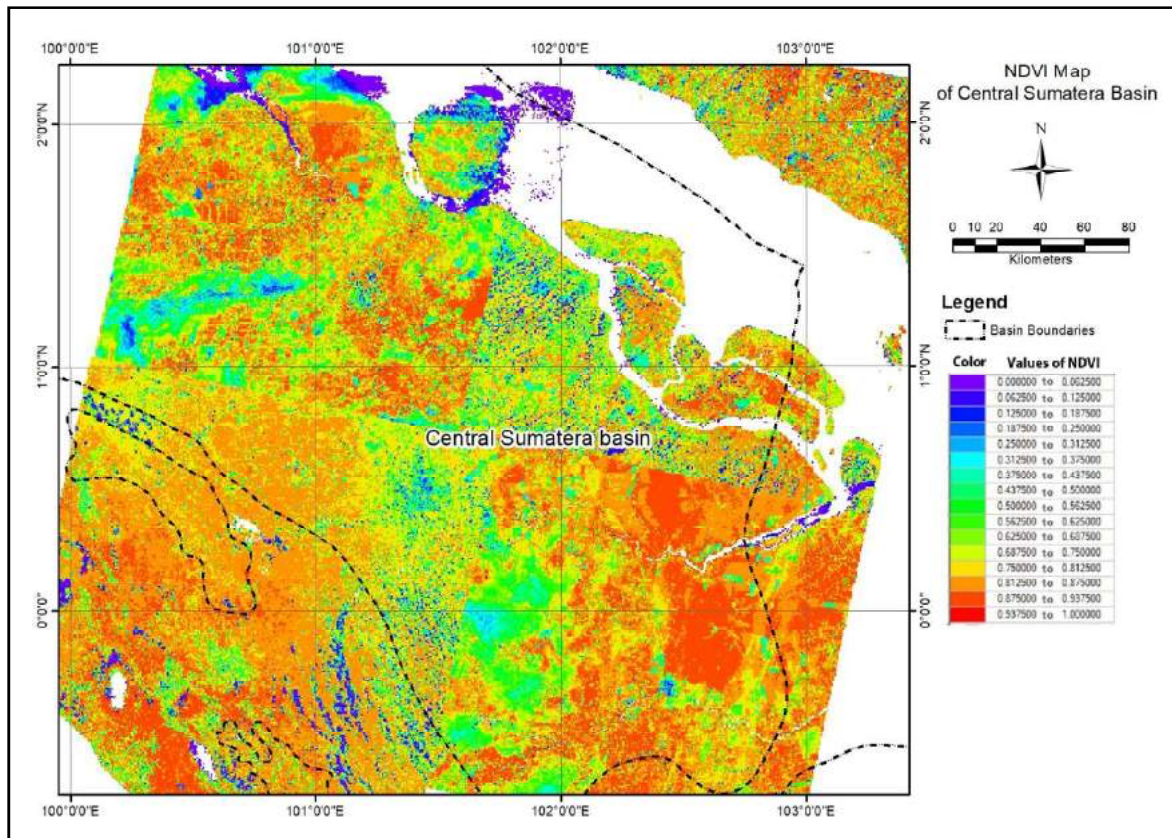


Figure 2
Vegetation index, NDVI result in Central Sumatera Basin, no anomaly detected on heavy oil fields.

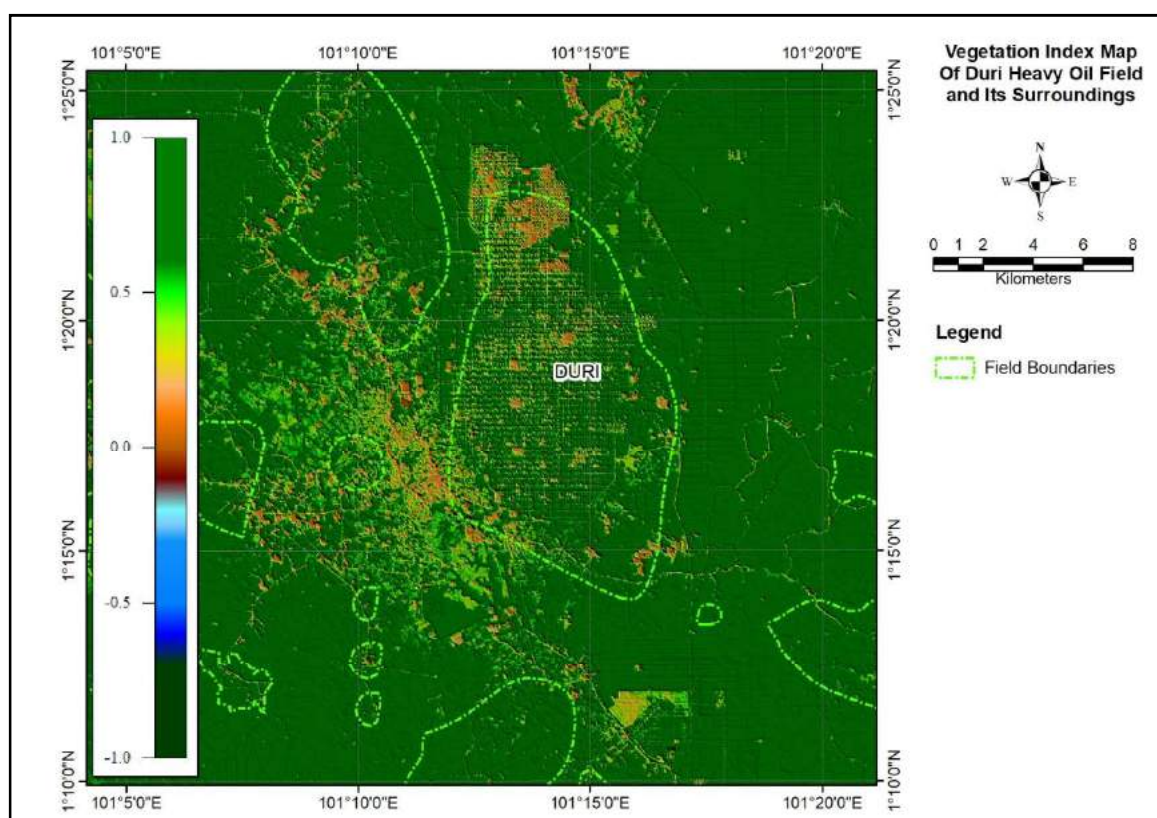


Figure 3

Vegetation index, NDVI result in Duri heavy oil field, the index showed that Duri field has the low vegetation canopy, but not clear anomalous caused by the settlements around the field.

the clay mineral index of Landsat 8 OLI path / row 126/059 for the onshore area ranges from 0.313 - 0.605 with the peak histogram (the highest number of pixels) is 0.375; (2) the clay mineral index of Landsat 8 OLI path / row 126/060 ranged from 0.293 - 0.816 and with a histogram peak with a value of 0.393; (3) the clay mineral index of Landsat 8 OLI path / row 127/059 ranges from 0.293 - 1.05 and with a peak histogram of 0.385; and (4) the clay mineral index of Landsat 8 OLI path / row 127/060 ranged from 0.341 to 0.895 and with a peak histogram of 0.390. Based on these results, it is indicated that the Central Sumatra Basin tends to have a low clay mineral index. This is thought to be related to the condition of the vegetation at the study site. Where there is vegetation cover that tends to be dense, the ability of remote sensing to detect clay mineral content is not optimal. The results of the clay mineral index mapping can be seen in Figure 4.

Visual observations on the Duri field show that in general the field has a higher clay mineral index than non-oil and gas fields. However, the presence of settlements and dense vegetation makes it difficult / unclear to change the clay mineral index in

distinguishing surface anomalies in structures containing heavy oil. In residential areas, the clay mineral index tends to be higher than the clay mineral index in the oil and gas field (Figure 5).

Iron Oxide Index

Iron oxides are generally the second group of minerals associated with alteration rocks due to their hydrothermal effects. Remote sensing for iron oxide is described by Ouattara, *et al.* (2004) with research in White Mountain, Beaver Co., Utah, USA using channel 3 linkage with Landsat TM channel 1. The results depict areas where high iron oxide appear lighter. This is because iron oxide absorbs the blue wavelength, so the reflection is low, while at the red wavelength the reflection is high. In rocks that have ferromagnetic minerals, they can cause absorption at wavelengths close to 1.0 μm (Hunt, *et al.*, 1974; Hunt & Salisbury, 1976). Iron oxide analysis on Landsat 8 OLI was carried out to detect potential iron mineral anomalies as an indication of a microseepage.

The results of calculations of the iron oxide index that have been carried out at 4 scenes Landsat 8

A Preliminary Study on Heavy Oil Location in Central Sumatera
 using Remote Sensing and Geographic Information System (Suliantara, *et al.*)

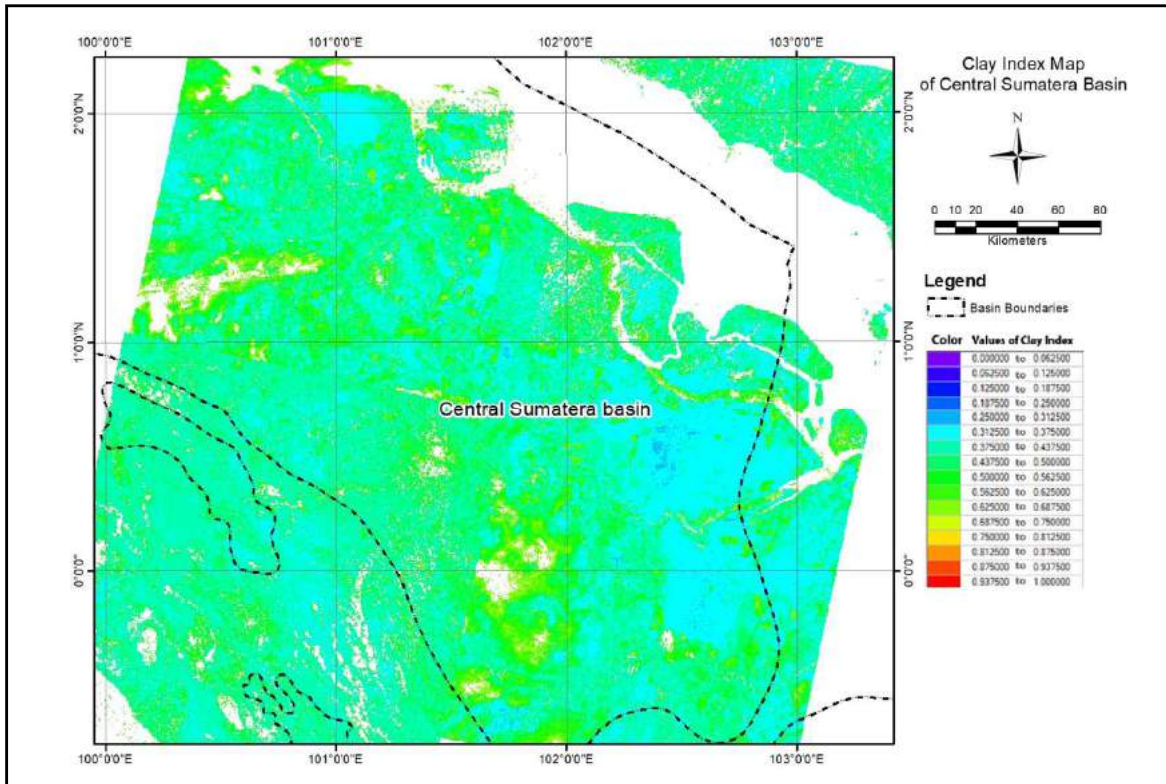


Figure 4
 Clay index map of Central Sumatra Basin, no anomaly of clay mineral detected on heavy oil fields.

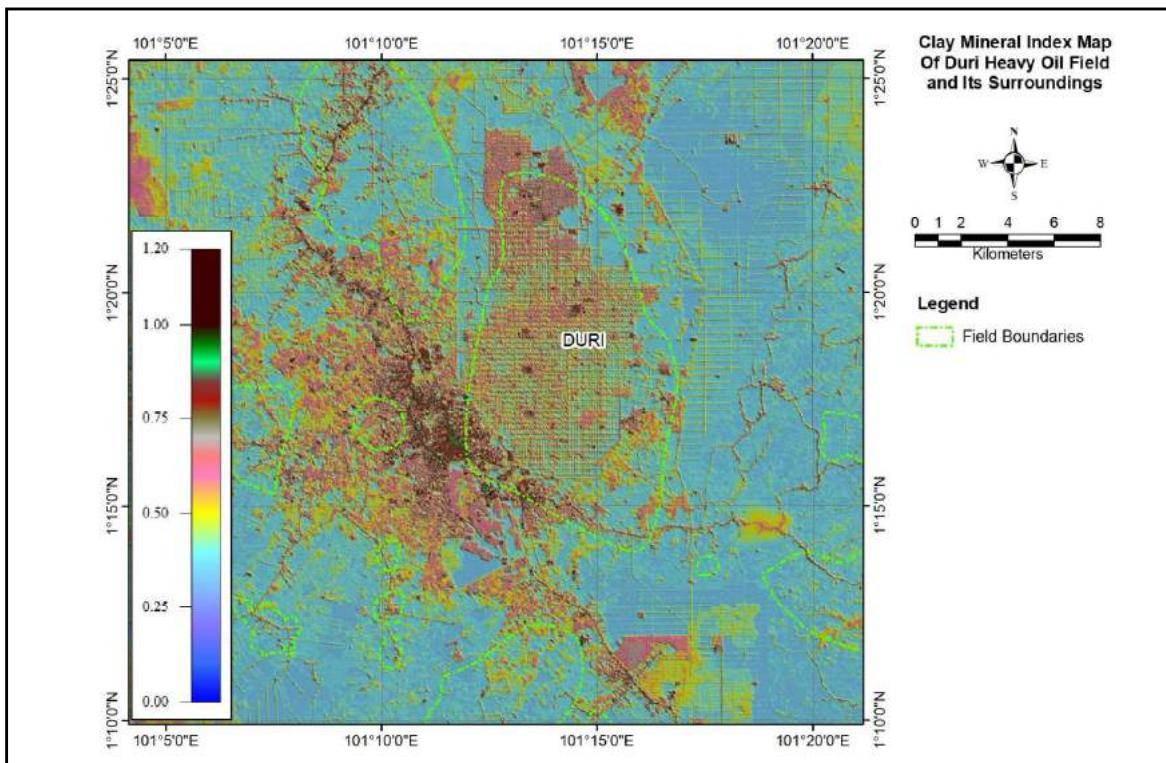


Figure 5
 Clay index result in Duri heavy oil field, the index showed that Duri field has the high clay index, but not clear to detect the anomalous caused by the settlements or baren areas around the field.

OLI covering the Central Sumatra basin show that the values range from 0 - 1,400. In detail, it is described as follows: (1) The index value of iron oxide on the Landsat 8 OLI path / row On the Landsat 8 OLI path / row 126/059 ranges from 0 - 0.787 and with a histogram peak at the index value of 0.497; (2) Iron oxide index values on Landsat 8 OLI path / row On Landsat 8 OLI path / row 126/060 ranged from 0 - 0.656 and with a histogram peak at an index value of 0.417; ; (3) The iron oxide index value on the Landsat 8 OLI path / row On the Landsat 8 OLI path / row 127/059 ranges from 0 - 0.657 and with a histogram peak at the index value of 0.495; (4) The iron oxide index value on the Landsat 8 OLI path / row on the Landsat 8 OLI path / row 127/060 ranges from 0.278 to 1.380. The iron oxide index value was dominant in the range 0 - 0.844 with a peak histogram of 0.495 (Figure 6).

Based on the results of processing at the 4 scenes Landsat, in general, it has a low iron oxide index value. This is based on the comparison of the iron oxide index value in the Tugu Barat oil and gas field in West Java, which ranges from 0.74 to 1.52. The low vegetation index value is possible as a result

of the relatively dense vegetation covering the soil surface. This causes the ground's spectral reflection to decrease. This has been explained by Rajesh (2004) where in the tropics limitations in mapping rock alteration due to the high density of vegetation is sometimes experienced. Observations in the Duri Field show that the iron oxide index value in the middle of the field is higher than that of the field edge (Figure 7). However, the existence of settlements that have a high iron oxide index value causes difficulties in detecting the boundaries of the oil and gas field.

Surface Temperature

Surface temperature is a state on the earth's surface which is controlled by the energy balance of the surface, atmosphere, surface thermal properties and subsurface materials. Surface Temperature is the temperature of the surface of the earth's surface which is the result of temperature emission from the surface of the object recorded by satellite imagery at a certain time. Surface temperature can be identified through multispectral satellite image data extracted from the infrared thermal band or infrared thermal imagery. According to Sabins (1996) in Kuenzer (2013), the infrared thermal

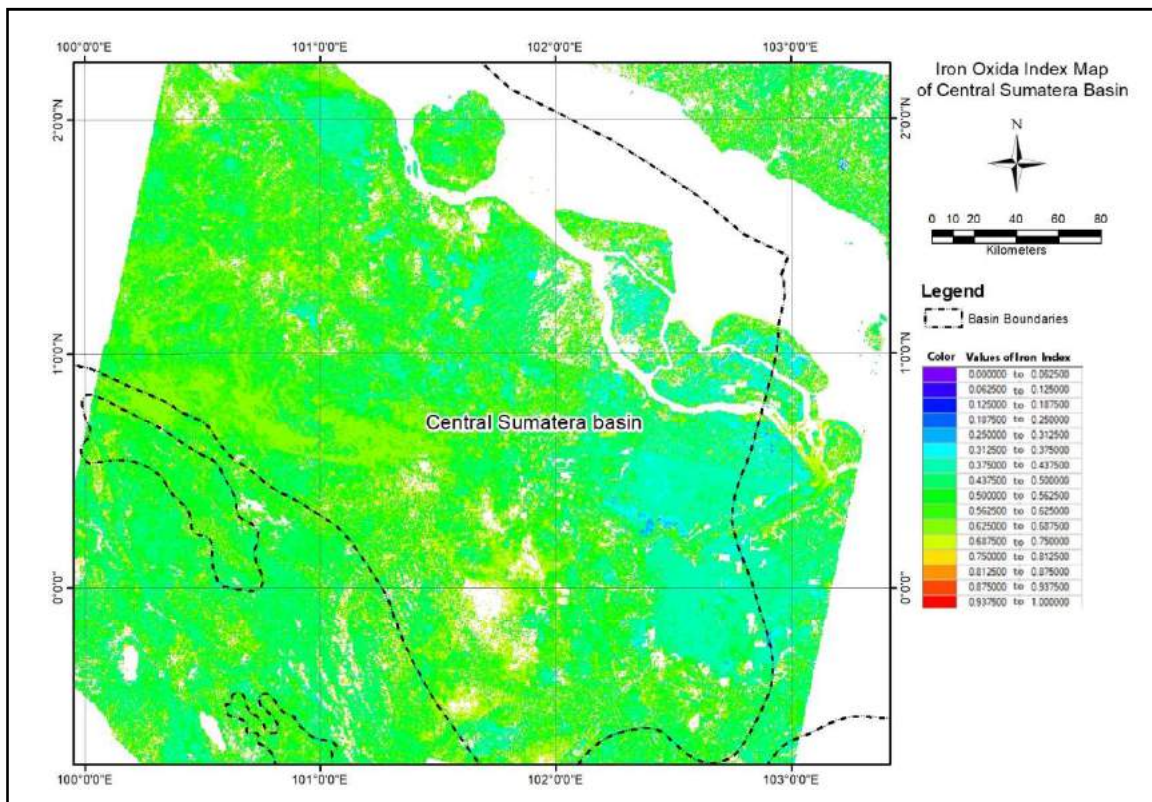


Figure 6
Iron oxide index map of Central Sumatra Basin,
no anomaly of iron oxida index detected on heavy oil fields.

wavelength is around 3 to 14 μm . In this range, surface temperature mapping is possible using remote sensing images due to the presence of a band in the 8-14 μm range.

The results of surface temperature calculations in the Central Sumatra basin show values between 20 - 45°C. In detail, it can be described based on the recording of 4 Landsat 8 OLI images as follows: (1) In the Landsat 8 OLI image path / row 126/050 060 the surface temperature at the study location ranges from 20 - 35°C with a histogram peak of 26°C; (2) In the Landsat 8 OLI image path / row 126/050 060 the surface temperature at the study location ranged from 20 - 33.87°C with a peak histogram of 22.75°C; (3) On path OLI image 8 path / row 127/059, the surface temperature at the study location ranged from 20 - 35°C with a histogram peak of 25.32°C; and (4) On path OLI image 8 path / row 127/060 the surface temperature at the study location ranged from 20 - 35°C with a histogram peak of 24.79°C (Figure 8).

In general, temperature can be used as an indicator of oil and gas under the surface. Previous studies have shown that surface temperature is related to subsurface conditions and can be the key in oil and

gas exploration. Thermal information on the surface shows a relationship with the presence of faults underneath, which is influenced by the convection of geothermal energy propagating to the surface. The thermal difference on the surface can also be influenced by presence of hydrocarbons, where in general the surface of the oil and gas well has a tendency to be higher than the surrounding area (Magdic, 2016). The intertie thermal oil and gas fields also have a higher value compared to areas outside the oil and gas fields. However, conditions become difficult if there are settlements around areas that contain oil and gas. Where settlements generally have higher thermal intertie than oil and gas fields. This is evidenced in the Duri field which contains heavy oil. The observations show that the Duri field has a higher temperature than the forest, plantation and shrub areas. However, the residential area has a higher temperature than the Duri field (Figure 9).

Structural Geology Interpretation

Interpretation of lineaments on the surface of the Central Sumatra basin has been carried out using a combination of Landsat 8 OLI data, Landsat 8 OLI merger with DEM data and DEM data independently.

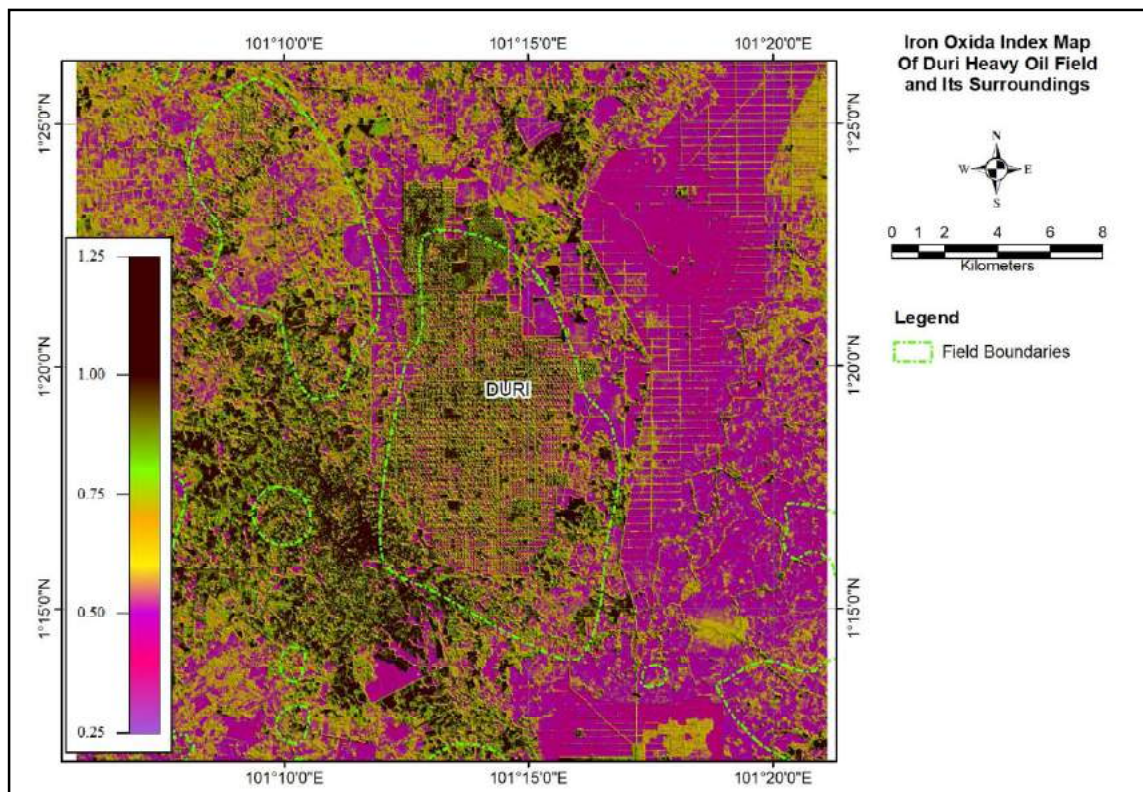


Figure 7

Iron oxida index result in Duri heavy oil field, the index showed that Duri field has the low iron oxida index, but not clear anomalous caused by the settlements or baren areas around the field.

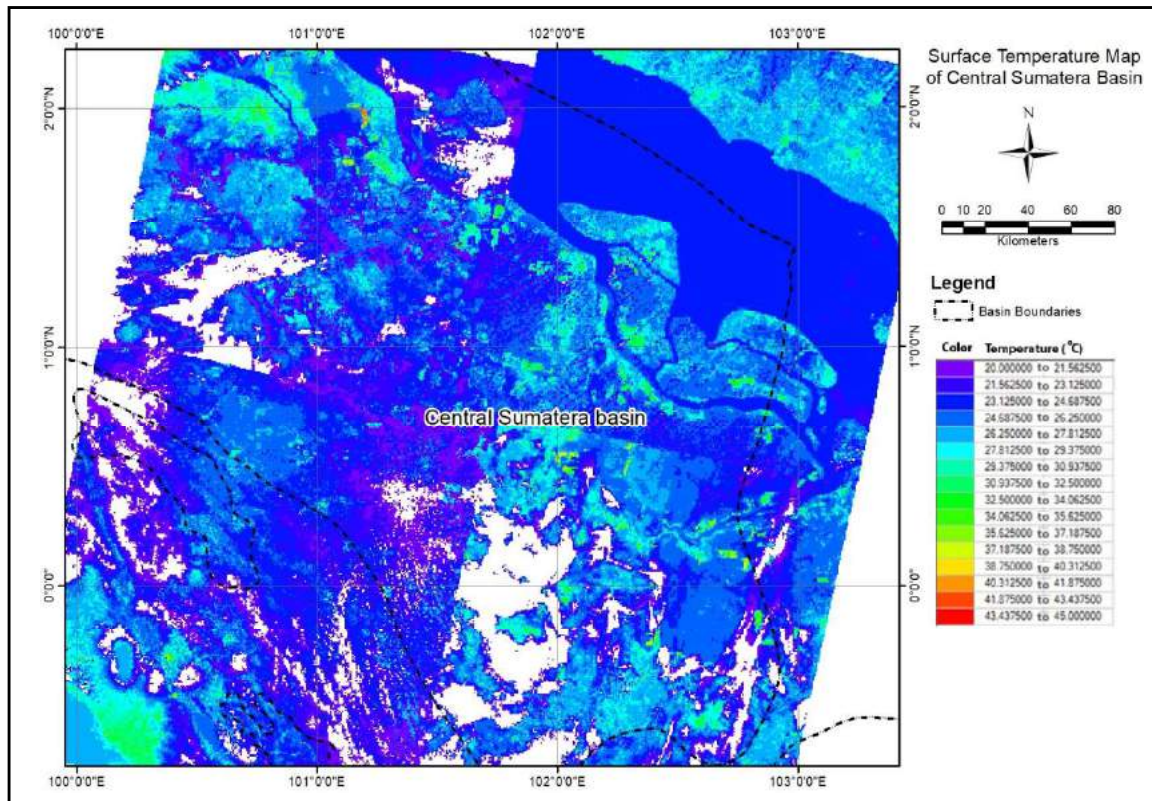


Figure 8
Surface temperature map of Central Sumatra Basin, no anomaly of surface temperature detected on heavy oil fields.

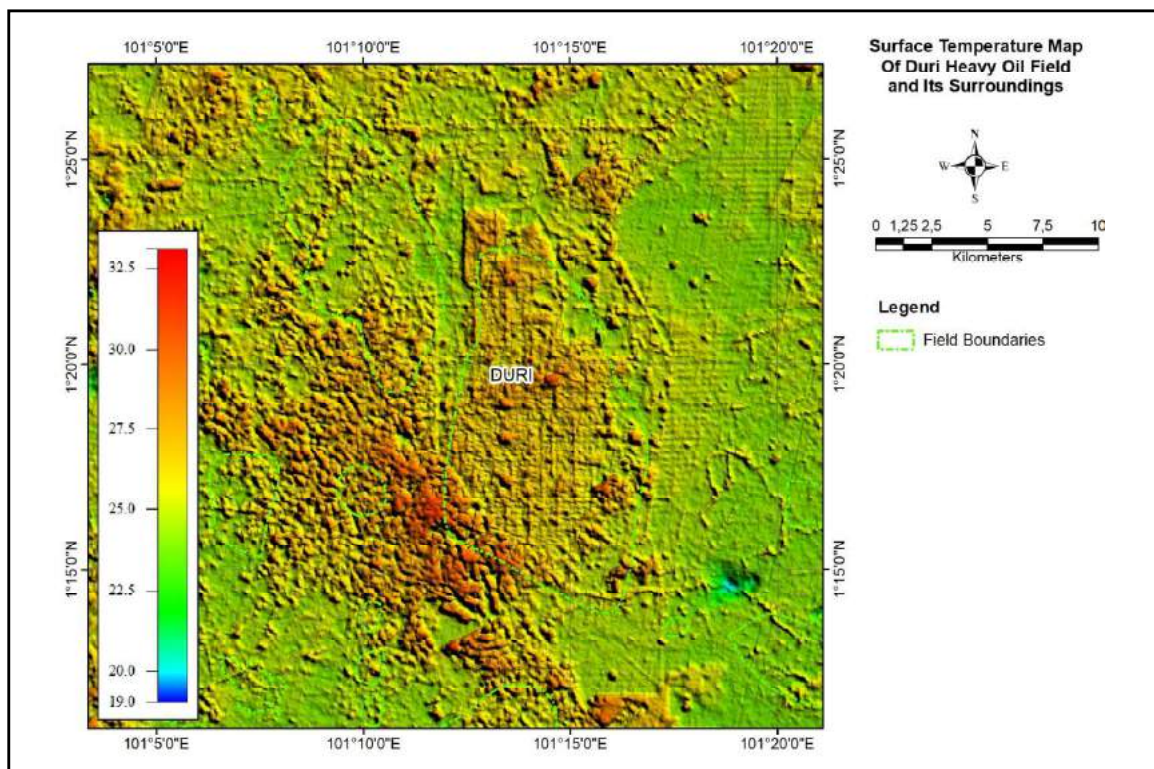


Figure 9
Surface temperature of Duri heavy oil field, the surface temperature showed that Duri field has the high temperature, but not clear anomalous caused by the settlements or barren areas around the field.

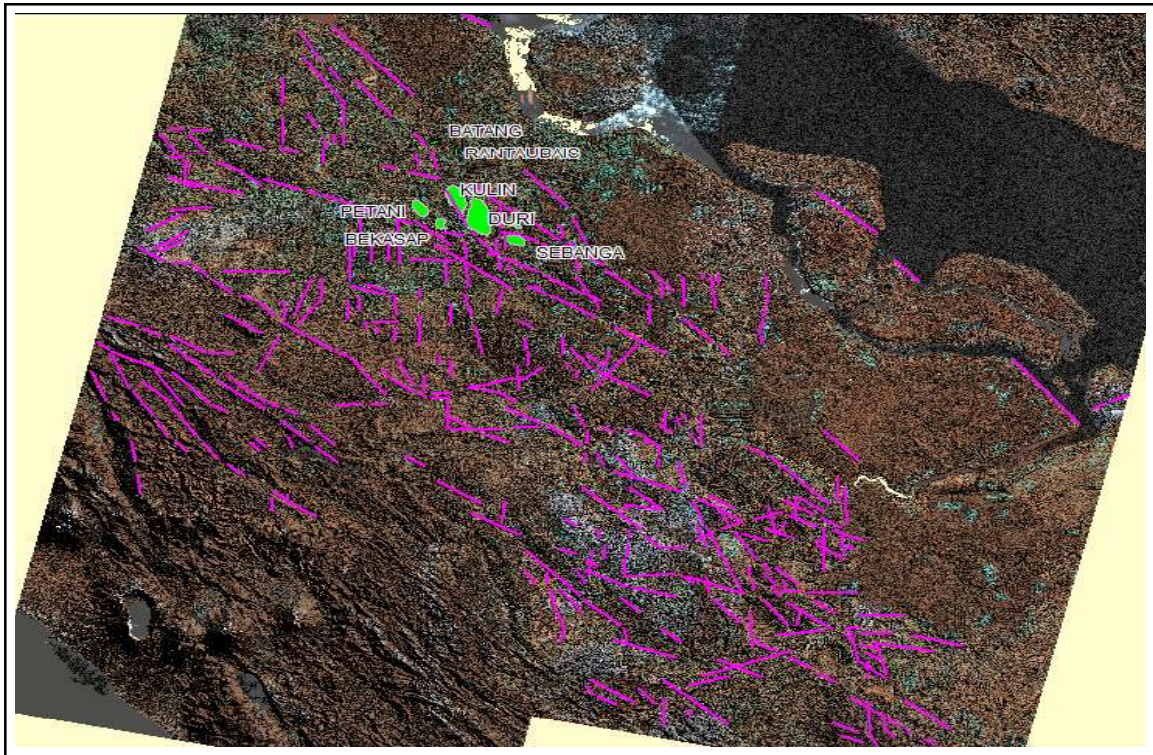


Figure 10
Map of the interpretation of lineaments on the surface in the Central Sumatra basin.
The background is Landsat 8 OLI - DEM Fusion Image which is overlapping with the main heavy oil fields.

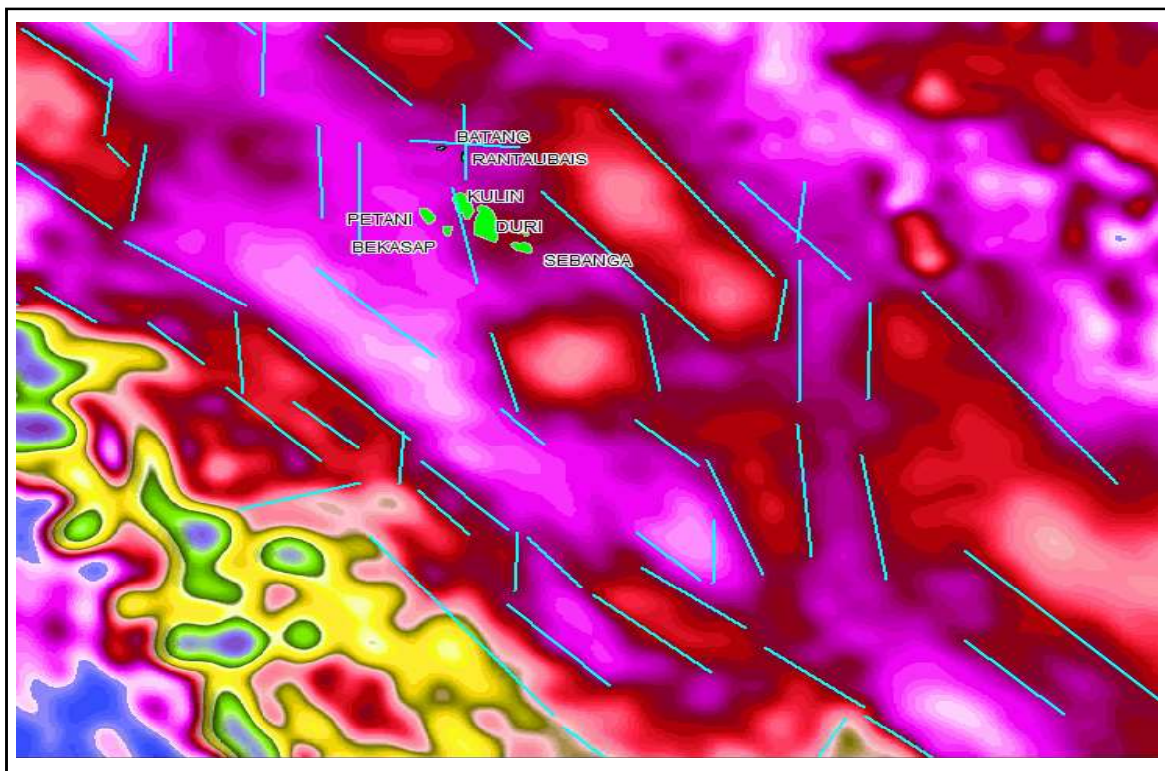


Figure 11
Lineaments interpretation on the gravity map and selected oil and gas field.

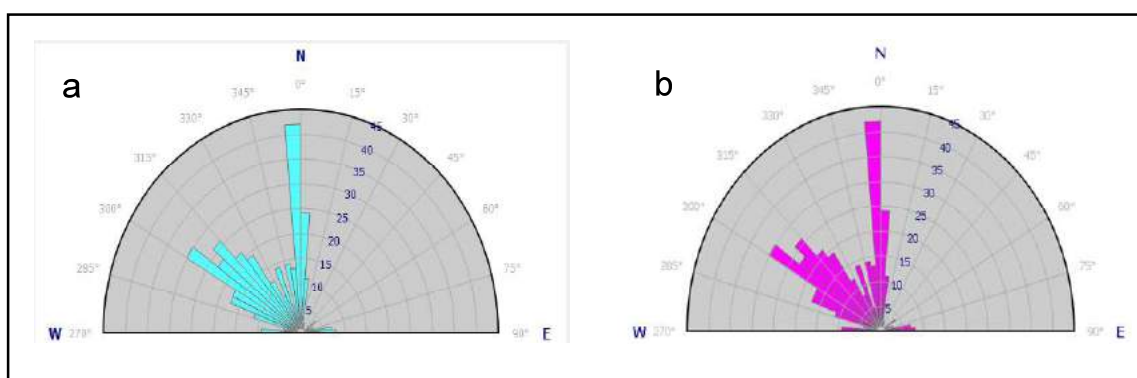


Figure 12
Rose diagram of the subsurface lineaments (a) and subsurface lineaments (b).

Lineament interpretation is also performed on subsurface data using gravity. Interpretation is done visually by digitizing on screen. The results of this interpretation are then carried out overlay to produce suspect areas or locations that are related to the presence of heavy oil. These results are expected to be an early indication or initial screening in assessing heavy oil in the Central Sumatra basin. Landsat imagery with a combination of 547 channels is commonly used for surface geological interpretation. In this combination, it can be recognized that there are different types of rock units, such as igneous, limestone, sandstone and claystone as well as alluvial deposits. Combined with digital elevation model (DEM) data, the image will show topographic contrast which can be interpreted as lineament. These lineaments in geology are known as joint or fault structures. The results of lineament element interpretation and Landsat 547 - DEM fusion imagery are shown in Figure 10. Visually the developing structure is NW - SE and N - S direction. The results of subsurface interpretation based on gravity data can be seen in Figure 11. Similarities in trends of surface and subsurface structures is then analyzed using a rose diagram so that the population and direction of the existing straightness elements can be identified (Figure 12). Results of subsurface interpretations show that the lineaments that exists below the surface is similar to the lineaments that develops on the surface with the dominant in the NW - SE and N - S directions. This is in accordance with Sakti's opinion (2009) which states that oil has a relationship closely related to the fault zone as a basin-forming and sediment-forming system, so knowing the subsurface structure pattern including the existing fault system is important in petroleum exploration.

Analysis of Heavy Oil Potential Area

The use of Landsat series data to distinguish rocks that have undergone alteration has been successfully carried out in arid and semi-arid areas. This condition is useful for detecting the presence of petroleum under the surface. However, tropical areas sometimes experience limitations due to the high density of vegetation for mapping rock alteration (Rajesh, 2004). This problem occurs in the mapping of rock alteration (clay mineral and iron oxide) in the Central Sumatra Basin. Where the mapping of clay mineral and iron oxide index is less able to describe the presence of oil and gas, especially heavy oil due to dense vegetation cover. The existence of dense vegetation is evidenced by the presence of a high NDVI vegetation index value at the study location. This causes the spectral reflection from the ground to be not maximally received by the Landsat 8 OLI satellite imagery. In addition, the limitation of spectral and spatial resolution is thought to be a constraint on mineral alteration mapping. Noomen (2007) explains that in vegetation index analysis, remote sensing data with high spectral resolution in visible and NIR are needed and high spatial resolution so that it can be used as an indicator of oil and gas seepage. Vegetation index analysis is also not suitable for use in regional studies, but should be used to complement the analysis of prospects that are ready to be drilled so as to increase the chance of geological factors. Several cases of studies on the use of remote sensing for oil and gas mapping tend to be carried out on a single oil and gas field structure and not a large structure consisting of several fields. This condition also affects the surface temperature mapping. Where endogenous factors that affect soil

surface temperature cannot be mapped properly due to dense vegetation. In addition, atmospheric conditions do not support this study, due to the absence of cloud-free Landsat imagery.

A follow-up analysis was carried out to assess the relationship between the presence of heavy oil and existing lineaments. The analysis was carried out using the overlay method between surface lineaments, subsurface lineaments and the existing heavy oil field. Based on the overlay, it can be analyzed that the oil and gas fields containing heavy oil are located on the high edge. This can be especially identified around Duri Field where the surface and subsurface structures are relatively identical. Accordingly, based on this, the potential locations for structurally heavy oil trapping are located on the edge of the high area and controlled by identical surface and subsurface structures. Based on this analysis, the locations that have the potential for heavy oil and gas traps are on the northeast edge, namely Dalu-dalu High, the edge of Kampar High, the west edge of Kuantan High, the southwest edge

of the Beruk High, the southwest edge of Sembilan High (Figure 13).

The results of interpretation based on remote sensing data and gravity show suitability with existing heavy oil fields and well data which are indicated to contain heavy oil. The Rokan High is a major producer of heavy oil with main fields covering the Duri, Kulin, Bekasap, Bekasap South, Pinggir, Pungut and Rantau Bais Fields; while the Dalu-Dalu High has an existing heavy oil field i.e. Kotalama, Kumis, Kasikan, and Langgak Fields. At the Dalu-Dalu High there are also several exploration wells which are indicated to contain heavy oil, but they have not yet been developed. These wells include Batu Kecil-1, Ngaso-1, Kepanasan-1, Bacang-1, Ladang-1 and Paitan-1. At Sembilan High in the North, it is known that there is a Pusing Field which is indicated to contain heavy oil. In Beruk High, there are fields that contain heavy oil, including Melibur, Kurau and Selatan Fields. Mean while, in the Kampar and Kuantan High, no heavy oil was found.

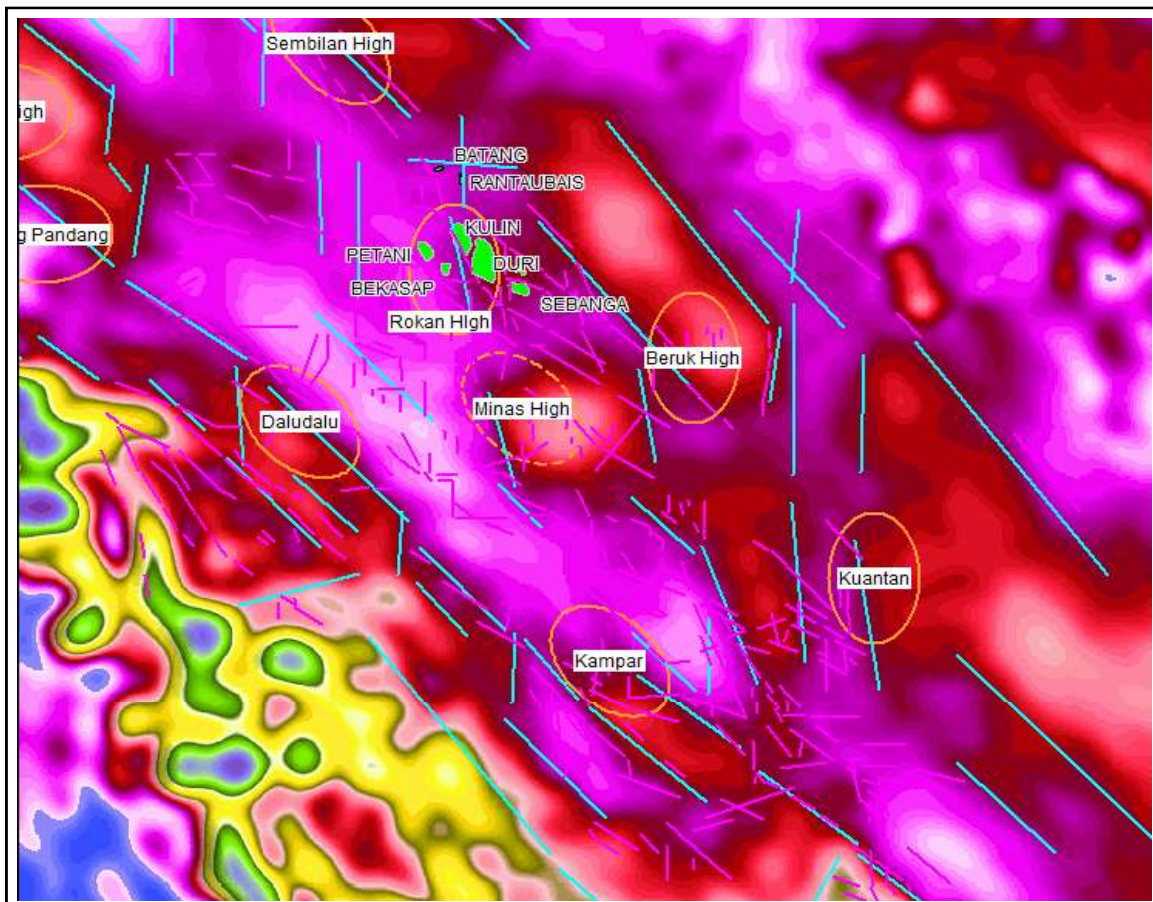


Figure 13
Potensial area for heavy oil trap within Sumatra central basin that marked by red circle (Lemigas, 2020).

CONCLUSIONS

Some surface analyzes, such as mineral clay index, vegetation index, iron oxide index and surface temperature for regional studies for oil and gas exploration activities are not used properly. Constraints in the form of unfavorable atmospheric conditions in the Central Sumatra Basin and dense vegetation make this interpretation less optimized. Satellite image data processing for mapping the clay mineral index, vegetation index and iron mineral index in the Sumatra Basin has not succeeded in finding a good formula for identifying the presence of heavy oil. However, to optimize the use of remote sensing data, it can be done through the interpretation of surface and subsurface geological structures using Landsat 8 OLI and gravity. Geological interpretation in areas with dense vegetation is recommended to use fusion images between optical data and DEM data. Combining surface data and gravity data improves the accuracy of geological recognition of the study area. In this interpretation, indications of the presence of heavy oil can be found at several heights, namely Dalu-dalu High, the edge of Kampar High, the west edge of the Kuantan High, the southwest edge of the Beruk High, the southwest edge of the Sembilan high.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
Anticline	geological structure; are folds in which each half of the fold dips away from the crest.	
Band ratio	the very simple and powerful technique in the remote sensing. Basic idea of this technique is to emphasize or exaggerate the anomaly of the target object	

Symbol	Definition	Unit
Basement High	is a portion of the basement in a sedimentary basin that is higher than its surroundings.	
Clay Mineral Index	a ratio of the SWIR1 and SWIR2 bands. This ratio leverages the fact that hydrous minerals such as the clays, alunite absorb radiation in the 2.0–2.3 micron portion of the spectrum	
Color Composite Image	displaying images in three primary colours (RGB = red, green and blue). When we combine these three images, the result is a colour image with each pixel's colour determined by a combination of RGB of different brightness.	
DEM	Digital Elevation Model; computer model that represent terrain elevation.	
Geographic Information System	a framework for gathering, managing, and analyzing data that tied on geographic position.	
Heavy Oil	is oil that has an API gravity of less than 20°API or greater than 0.93g / cm3 or with a viscosity greater than 100-cP	
Iron Oxide Index	a geological index for identifying rock features that have experienced oxidation of iron-bearing sulfides using the red and blue bands.	
Landsat 8 OLI	an American Earth observation satellite launched on 11 February 2013 carries the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) instruments	
Lineament	is a linear feature in a landscape which is an expression of an underlying geological structure such as a joint or fault	
NDVI	a measure of the state of plant health based on how the plant reflects light at certain frequencies (some waves are absorbed and others are reflected	
NIR	near infrared at 0.85–0.88 μ m wavelength (band 5 in Landsat 8 OLI	

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using Remote Sensing and Geographic Information System (Suliantara, et al.)

Symbol	Definition	Unit
N-S	North – South direction	
NW-SE	North west – South East direction	
Overlay analysis	combining information from one GIS layer with another GIS layer to derive or infer an attribute for one of the layers	
Red	0.64–0.67 μm wavelength (band 4 in Landsat 8 OLI)	
Remote Sensing	as a data acquisition method without physical contact with the areas being explored	
Surface Temperature Index	the radiative skin temperature of the land surface, as measured in the direction of the remote sensor. It is estimated from Top-of-Atmosphere brightness temperatures from the infrared spectral channels	
SWIR1	shortwave infrared 1 at 1.56–1.66 μm wavelength (band 6 in Landsat 8 OLI)	
SWIR2	shortwave infrared 2 at 2.08–2.35 μm wavelength (band 7 in Landsat 8 OLI)	
Vegetation Index	spectral transformation of two or more bands designed to enhance the contribution of vegetation properties and allow reliable spatial and temporal inter-comparisons of terrestrial photosynthetic activity and canopy structural variations.	

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