Utilization of Vegetation Indices to Interpret the Possibility of Oil and Gas Microseepages at Ground Surface

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Abstract. Microseepages is one way to identify the existence of oil and gas below the surface of the earth. Identification of microseepages could be done using remote sensing approaches. One of the remote sensing data that can be used is Landsat 8. The purpose of this study is to map the potential of microseepages on the ground surface of West Tugu oil and gas field, North West Java Basin, Indonesia. The Landsat 8 data processing were performed including radiometric and geometric corrections, and vegetation indices calculation. The vegetation indices calculated in this study are Normalized Differences Vegetation Index (NDVI), Enhanced Normalized Differences Vegetation Index (ENDVI) and Leaf Area Index (LAI). Based on the vegetation indices, we detected that physical condition of vegetation anomaly served as microseepages location. The results showed that microseepages is identified in the south to the east of the oil and gas field presented by vegetation anomaly. Field survey confirmed the possibility of microseepages is located at yellowish leaf vegetation, high spectral of the leaf at the visible wavelength and low magnetic susceptibility.

1. Introduction

Hydrocarbon seepages are common phenomenon occurs in oil and gas fields. It can cause the land surface vegetation to be stress [1]. Stress in vegetation can be defined as any disturbance that adversely influences growth [2]. The effects of hydrocarbon seepages pollution in vegetation are reducing plant transpiration rate, levels of chlorophyll content, higher levels of foliar water content and leaf structural changes. Cell injury may be the principal cause of photosynthesis inhibition because hydrocarbons tend to accumulate in the chloroplasts, which explains the reduced levels of chlorophyll content in vegetation affected by hydrocarbons. In the soil, interaction between hydrocarbons reduces the amount of oxygen and increases the CO₂ concentration, soils turn acidic and minerals are mobilised [3].

One of the remote sensing methods used in earth exploration is physical vegetation analyses. The spectra of optical wavelength is sensitive to land cover feature such as vegetation conditional at geothermal field [4]. Over the three decades, vegetation analyses has been used to extract specific information of vegetation properties [5]. Vegetation indices is constructed from reflectance
measurements in two or more wavelengths, mainly from visible - near infrared to analyze specific characteristics of vegetation, such as total leaf area, pigments (chlorophyll, carotenoids, anthocyanins), plant structure materials and water content. Vegetation indices represents a single value for converting the reflectance spectrum to measure vegetation properties [6]. Vegetation properties can be divided into three categories: structure, biochemistry and plant physiology or stress condition [6]. Mapping vegetation properties are crucial to estimate the ground and near surface materials related to microseepages or mineral compositions in the rock under tropical conditions [7].

The purpose of this study is to interpret the possibility of microseepages in the surface of oil and gas field in West Tugu, North West Java Basin. In this basin there is a lot of seepages. The distribution of seepages is to the east of the study area and continuously south to Banyumas area. The previous studies explain there is an indication that the oil and gas field is affecting the vegetation conditions around it [8]. This study is a continuation of the previous study by mapping the potential of microseepages around West Tugu oil and gas field. The identification of microseepages in this study by anomaly vegetation mapping as impact of microseepages.

2. Study Area

The study area is in West Tugu oil and gas field located in the border of Indramayu and Majalengka districts. The study area is an anticline oil and gas structure with reservoir rock from Baturaja formation, Parigi formation and Zone 16 from Baturaja formation. In land use/landcover map the study area is characterized by regular rectangular pattern of road that is a sugarcane plantation. The study area is part of the hydrocarbon production basin of North West Java. The first of oil and gas well at West Tugu field was drilled in 1979, the namely TGB-1. it's an exploration well that reached a depth of 2545 m. TGB-1 produced gas from the equivalent layer of Baturaja formation [9]. In 1992, seven developments well have been drilled and one well reached Baturaja formation with a depth of 2758 m and more than 300 m of formation thickness [10]. then one well drilled in that year was the TGB-25 that produced oil [11]. The area of study is in Figure 1.

![Figure 1](image-url)  
**Figure 1.** Study area as part of North West Java Basin presented by landuse/landcover map overlaid with oil and gas well-head in red dots.
3. Data
Remote sensing data used were Landsat 8, with acquisition date at September 25, 2015 and path/row 121/165. Landsat 8 is a new generation of Landsat series that was launched. Landsat 8 system are consistent and comparable with the previous system. Landsat 8 has two sensor, the operational land imager (OLI) and the thermal infrared sensor (TIRS). The OLI and TIRS spectral remain broadly comparable to the Landsat 7 ETM+. But Landsat 8 in the OLI has two additional wavelength: a new shorter wavelength blue band (0.43-0.45 μm) and a new shortwave infrared band (1.36-1.39 μm). The TIRS senses emitted radiance in two 100 m thermal infrared bands, compared to the high and low gain single thermal infrared 60 m ETM+ band. The reduced TIRS spatial resolution is not optimal but was necessitated by engineering cost restrictions. However, the two thermal TIRS bands enable thermal wavelength atmospheric correction and more reliable retrieval of surface temperature and emissivity [12]. The Landsat data is in Figure 2.

4. Methods
The image processing of Landsat 8 includes radiometric correction, geometric correction and band ratio. A radiometric correction was a multi-step process, from radiometric calibration that is done by calculation the digital number to Top of Atmosphere (ToA) radiance value and then atmospheric correction. Atmospheric correction was used FLAASH method to change the radiance value of ToA into surface reflectance and undertake atmospheric correction [13].

Geometric correction is conducted by the image to image correction. Ikonos imagery and supporting by topographic map are used as the references image. This correction is conducted to minimize the bias of locations (Spatial displacement) [14]. The results showed that Landsat 8 Imagery has similar position in the study area.

More than 150 vegetation indices have been published in scientific literature, but only a small subset have the substantial biophysical basis or have been systematically tested [15]. In this study, there is three vegetation indices used: Normalized Difference Vegetation Index (NDVI), Enhanced Normalized Difference Vegetation Index (ENDVI) and Leaf Area Index (LAI). NDVI is the most popular of vegetation index [16]. It has been used in a wide application of vegetation studies [17]. It can be used to estimate vegetation canopy, fractional vegetation cover, vegetation condition, and biomass [18]. NDVI is also had relation with the fraction of photosynthetically active radiation that absorbed by vegetation. It’s a key parameter in crop biomass and yields as well net primary
productivity models. But in greater values, NDVI is having a problem with saturation [19]. NDVI is defined as follows:

\[
N = \frac{(\rho_{\text{nir}} - \rho_{\text{red}})}{(\rho_{\text{nir}} + \rho_{\text{red}})}
\]  

(1)

where \(\rho_{\text{nir}}\) is the near infrared band reflectance and \(\rho_{\text{red}}\) is red band reflectance. The ENDVI is modification of NDVI. It’s calculated for low altitude monitoring systems, such as UAVs [20]. ENDVI is an indicator of live green vegetation and can be used for crops in all growth stages [21]. In a normal health, plant reflects both visible green and near infrared light accommodated by ENDVI as follows [20]:

\[
E = \frac{(\rho_{\text{green}} + \rho_{\text{red}})}{(\rho_{\text{green}} + \rho_{\text{red}}) + (2 \times \rho_{\text{red}})}
\]  

(2)

where \(\rho_{\text{green}}\) is green band reflectance and \(\rho_{\text{blue}}\) is blue band reflectance. The leaf area index (LAI) is usually defined as the one-sided area of leaves per unit ground area [22]. LAI is an important vegetation parameter, which used widely in many applications [23]. Accurate measurement of LAI is important to characterize plant canopies linking to primary production [24]. Remote sensing is an attractive technique for estimating LAI. LAI is calculated by the enhanced vegetation index (EVI) basis [25]. EVI was developed to optimize the vegetation signal by improving sensitivity in high biomass regions and vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences [26]. The LAI was calculated as follows:

\[
L = 3.618 \times \left(2.5 \times \frac{(N - R)}{(N + R - 7.5 \times B + 1)}\right) - 0.118
\]  

(3)

Interpretation of microseepages is conducted by three stages. The first stage identifies the vegetation cover based on the LAI. The next step maps the vegetation index based on NDVI and ENDVI, then the results are overlaid with LAI to produce vegetated areas but have low NDVI and ENDVI values. These results were interpreted as vegetation stress. The last step is to overlay the second results with oil and gas fields for identifying microseepages. The final results is a possibility of microseep that is a region dominated by stress vegetation around the oil field [27][28][29][30].

5. Results and discussion

The results of LAI shown that area around of oil and gas field is covered by vegetation from rare to medium. The LAI total value range from -0.80 to 2.85 Its value was given the explanation that the study area is not totally covered by vegetation. The previous study showed that 100% area that covers by vegetation has LAI value 10 [18], LAI value in the edge of oil and gas field is 0.1 to 1.1. Based on LAI results, vegetation anomalies are detected in the edges of oil and gas field. LAI is functionally linked to the canopy spectral reflectance. The problems of LAI are vegetation index approach a saturation level asymptotically when LAI exceeds 2 to 5, depending on the type of vegetation index; and there is no unique relationship between LAI and a vegetation index of choice, but rather a family of relationships, each a function of chlorophyll content and/or other canopy characteristics [31]. So that we only want to show the distribution of leaf area using LAI. The LAI result can be seen in Figure 3a.

The result of NDVI value range from -0.4 to 0.8. Figure 3b shows that the low NDVI values form a circular pattern on the edge of the oil and gas field. This pattern is estimated as a possibility of microseepages that tends to occur in the edge oil and gas field. it caused the vegetation abnormal growth [30], affects the health of vegetation [32] and increases the spectral reflection in areas that are supposed to be absorbed in electromagnetic waves [33]. Linear regression analysis between LAI and NDVI were obtained \(R^2 = 0.8715\). The NDVI is affected by dense and multilayered canopies, soil background, canopy shadows, illumination, atmospheric conditions and variation in leaf chlorophyll concentration [31].
The result of ENDVI value range from -0.014 to 0.71. The ENDVI map result is more clearly the difference of low value with high value than NDVI. The comparison of NDVI and ENDVI using the linear regression were obtained $R^2 = 0.6806$. But the comparison of ENDVI and LAI using linear regression were obtained only $R^2 = 0.8715$. NDVI and ENDVI provide similar information only at high values, but somewhat different information at low values [20]. The vegetation anomalies appearance in the edge of oil and gas field same as NDVI, the pattern follows the boundary of oil and gas field. The ENDVI results show in Figure 3c.

![Figure 3. Vegetation indices were extracted from Landsat 8; a. LAI, b. NDVI and c. ENDVI](image)

The overlay between LAI, NDVI and ENDVI showed vegetation anomaly occurs in 0.1 to 1.1 values of LAI, 0.20 to 0.25 values of NDVI and 0.21 to 0.35 values of ENDVI. The results of the three vegetation indices show the surface conditions of oil and gas field is similar, but the ENDVI is more clear than LAI and NDVI. The overlay between anomalous results shown that the possibility of microseepages is happening on the edge of oil and gas field. The location is in the south to the east of the field.

The problem in the interpretation of the possibility of microseepages is the different growth phases of the vegetation condition. In the locations that are predicted as microseepages, the sugarcane plants are in germination phase and tillering phase, so in this area have a low vegetation index values. A field survey has evidenced that possibility of microseepages caused the vegetation is not growing well, making yellowish leaf vegetation, high spectral of the leaf at the visible wavelength and low magnetic susceptibility. Figure 4 showed the vegetation anomaly is not growing well. The sugar cane condition grows in the south is less fertile and not much clump. While the sugar cane in the east looks yellowish. This is thought to be a possibility of vegetation anomalies and suspected as the effect of microseepages.
Figure 4. The appearance of vegetation indices calculation in study area interpreted as a microseepages location and presented by red dashed lines. Photographs showed the vegetation cover and condition at interpreted microseepages with low susceptibility values in this area.

6. Conclusion
The results of this study indicate that the LAI does correlate well with NDVI and ENDVI. The LAI, NDVI, and ENDVI provide similar information for mapping possibility of microseepages, but ENDVI is better than LAI and NDVI. Based on the results shows that on the edge of the field there are vegetation anomalies. The pattern formed on the anomaly that occurs in the form of the circular pattern. The anomaly is thought to be a microseepages that reach the surface. The existence of microseepages is proved by rare vegetation conditions with a yellowish color and low magnetic susceptibility. Further research is needed with the uptake of the chlorophyll content in the leaves to identify the vegetation stress affected by microseepages.

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