Impact of oil and gas field in sugar cane condition using landsat 8 in Indramayu area and its surrounding, West Java province, Republic of Indonesia

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Abstract. This study tried to monitor sugar cane condition surrounding of oil and gas field area. The spectral approaches were conducted for mapping sugar cane stress. As an initial stage Landsat-8 was corrected radiometrically and geometrically. Radiometric correction is an important stages for spectral approaching. Then all pixel values were transformed to the surface reflectance. Several vegetation indices were calculated to monitor vegetation stress surrounding of oil and gas field. NDVI, EVI, DVI, GVI, GRVI, GDVI and GNDVI were applied for generating tentative sugar cane stress images. The results indicated that sugar cane surrounding of oil and gas field has been influenced by oil and gas field.

1. Introduction
The presence of oil and gas beneath the earth can be identified through their seepage. There are three types of seepage; gas seepage, oil seepage and mudvolcano [1]. All types of seepage sometimes are associated each other. In mudvolcano sometimes contained gas and or oil seepage and also in oil seepage sometimes contained gas seepage [2]. Based on the appearance, seepage divided into macroseep and microseep. Macroseep is oil and gas seepage that can be seen by eye directly on the surface [3]. Macroseep in the surface can be seen as asphalt, oil pond or gas bubbles when associated with water or mudvolcano. Microseep is seepage that occurs vertically or nearly vertically from the reservoir to the surface, but can not be seen directly by eye [3].

Macroseep and microseep are common phenomenon occurs in oil and gas fields. More than 75% of oil and gas basin occur macroseep [4]. Around of 85% of oil and gas occur in the shape of microseep to the earth surface. Microseep could cause “hydrocarbon altered column” and hydrocarbon alteration halo” on the earth surface in over hydrocarbon reservoirs [5]. Microseep is basically pervasive to the earth surface. Hydrocarbon gas blows spread of the earth resulting from the migration of natural gas from reservoirs [6]. The presence of both, macroseep and microseep may affect to the vegetation and soil surface conditions. Stress on vegetation can occur which is characterizatized by slower growth and reduced chlorophyll [7] [8]. It is also reduce the vegetation density as the oxygen in the soil is reduced [9].

Remote sensing has the ability to detect the vegetation condition, whether healthy or stressed. This is because vegetation spectral reflectance is dependent on the chlorophyll and water absorption in the
leaves, which get altered by oil and gas impact [10]. Healthy vegetation possess high spectral reflectance pattern at wavelengths near infrared (800-1100 nm). Healthy vegetation is characterized by high absorption of blue (450 nm) and red (670) wavelengths. A decline of the health vegetation due to interference from accumulation of seepage or other obstruction will change the spectral pattern. The near infrared spectral shows a drop value due to decreasing chlorophyll in the leaves [11] [7]. In addition, this will increase spectral reflection at red wavelength [12].

The purpose of this study is to identify the impact of the oil and gas fields on the sugar cane condition, Indramayu Regency and surroundings, West Java, Republic of Indonesia. Remote sensing data used were Landsat 8. It is a new generation of Landsat series that was launched. Initially known as the Landsat Data Continuity Mission (LDCM), it took the name Landsat 8 when handed over to the U.S. Geological Survey (USGS) for operational work on May 30, 2013 [13]. Spectral bands of Landsat 8 has high similarities with Landsat 7ETM+, except the three parameters as follows: the Landsat 8 had higher values of the near infrared band for vegetative landcover types, lower values for the shortwave infrared (2.11–2.29 µm) band for all land cover types and higher values for the shortwave infrared (1.57–1.65 µm) band for non-water land cover types [14].

Several vegetation indices namely Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Difference Vegetation Index (DVI), Green Vegetation Index (GVI), Green Ratio Vegetation Index (GRVI), Green Difference Vegetation Index (GDVI), Green Normalized Difference Vegetation Index (GNDVI) are used to monitor the condition of sugar cane plantations (Table 1).

### Table 1. Several Vegetation Indices used in the study

| No | Veg. Index                             | Algorithm                                                                 | References |
|----|----------------------------------------|---------------------------------------------------------------------------|------------|
| 1  | Normalized Difference Vegetation Index (NDVI) | (NIR-Red)/(NIR+ Red)                                                      | [21]       |
| 2  | Enhanced Vegetation Index (EVI)         | (NIR-Red)/(NIR+6*Red-7.5*Blue+1)                                          | [22]       |
| 3  | Difference Vegetation Index (DVI)       | (NIR-Red)                                                                 | [23]       |
| 4  | Green Vegetation Index (GVI)            | (-0.2848*TM1)+(-0.2435*TM2)+(-0.5436*TM3)+ (0.7243*TM4)+(0.0840*TM5)+(-0.1800*TM7) | [24]       |
| 5  | Green Ratio Vegetation Index (GRVI)     | (NIR/Green)                                                               | [25]       |
| 6  | Green Difference Vegetation Index (GDVI) | (NIR-Green)                                                              | [25]       |
| 7  | Green Normalized Difference Vegetation Index (GNDVI) | (NIR-Green)/(NIR+ Green)                                                  | [26]       |

### 2. Study Area

The study area is located in Indramayu and Majalengka Regency, West Java Province, Republic of Indonesia (Figure 1). Sugar cane plantation is part of Jatitujuh Company. The area is around of 11,921.56 hectares in Indramayu Regency and 5,673.04 hectares in Majalengka Regency [15].
Figure 1. Study area presented by red rectangles with subset of 653 RGB of Landsat 8 overlaid with oil and gas well-head in red dots

3. Material and Method
Landsat 8 data used were collected from Indonesian National Institute of Aeronautics and Space (LAPAN). Landsat 8 data was acquired on September 25, 2015. The ancillary data used include: oil and gas well obtained from Research and Development Center for Oil and Gas Technology “LEMIGAS”, Topographic Map from Geospatial Information Agency (BIG) and IKONOS Imagery from Ministry of Agriculture. The methods implemented in this study for observing the condition of sugar cane plantation is shown in Figure 2. The following tasks were performed: image pre-processing, NDVI, EVI, DVI, GVI, GRVI, GDVI and GNDVI calculation and analysis.

Figure 2. Work flows of analyzing vegetation condition at oil and gas field at Indramayu and Majalengka Regencies
3.1 Digital Image Processing
Radiometric calibration is done by calculation the digital number to Top of Atmosphere (ToA) radiance values. Calculation of at-sensor spectral radiance is the fundamental step in converting image data from multiple sensors and platforms into a physically meaningful common radiometric scale. Radiometric calibration of Landsat 8 sensors involves rescaling the raw digital numbers transmitted from the satellite to calibrated digital numbers which have the same radiometric scaling for all scenes processed on the ground for a specific period [16]. Converting digital number to ToA is very important because the light energy that comes from the sun, the radiance is often normalized into a reflectance values. Then FLAASH method was used to change the radiance values into surface reflectance and undertake atmospheric correction [10].

Geometric correction is done by image to image using IKONOS imagery and supporting by Topographic map. This correction is conducted to minimize bias of locations (Spatial displacement) [17]. Interpolation method of spectral values is using nearest neighbour [18]. Transformation of pixel positions is using polynomial order 2. The minimum GCP of this method are 6 GCP. Consideration of using this method is based on the area condition that has undulating topography [19]. Residual Mean Square Error (RMSE) maximum of this correction is 0.5 X pixel resolution [20].

3.2 Analysis of Vegetation Index
Several vegetation indices is used in this study to extract information related to sugar canes vegetation stress (Table 1). NDVI is a measure of healthy and green vegetation. The combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions [21]. EVI was developed as a standard of MODIS product to improve the NDVI by optimizing the vegetation signal in LAI regions. It uses the blue reflectance region to correct for soil background signals and to reduce atmospheric influences, including aerosol scattering [22]. DVI used to distinguish between soil and vegetation [23].

GVI minimizes the effect of the background soil while emphasizing green vegetation. It uses global coefficients that weigh the pixel values to generate new transformed bands. It is also known as Tasseled Cap Green Vegetation Index [24]. GRVI is sensitive to photosynthetic rates in canopies [25]. GDVI was originally designed to predict nitrogen requirements for corn in color-infrared photography [25]. GNDVI is more sensitive to chloropyll concentration than NDVI [26].

Analysis of vegetation stress is based on the vegetation indices results. The vegetation index values will reflect the health of the vegetation condition. Low vegetation indices values can describe the condition of vegetation stress or dominated by soil and or water underneath. Buffer of oil and gas wells conducted to assess the change of vegetation index results as an indication of stress. Buffer is done with a distance of 100 meters, 250 meters and 500 meters.

4. Result and Discussion
The results of several vegetation indices in sugar cane plantations in Indramayu and its surroundings can be seen in Figure 3. NDVI maximum value is 0.59. This NDVI values is considered as moderate category [22]. At the location where there is no vegetation, NDVI value will be close to 0 to 0.1. It values typically occurs in baren land [27]. Based on growing phase of sugar cane, this condition occurs in post-harvest and or early planting (phase-1).

NDVI values describe the sugar cane condition in oil and gas field has no high density canopy. This should occur in three phases, namely stem elonging phase. This phase occurs in 4 to 9 months ages after planting. In this phase, especially after 9 months, sugar cane condition has no less than 12 of tillers, 3.8 meters of height, 3.2 cm of diameters and 20 segments [28]. NDVI with a high bulk density has values close to +1 or 0.6 to 0.9. But the dominant NDVI value in sugar cane ranges from 0.11 to 0.35 (95%) of the total area. The value is in low to moderate categories.

DVI value in sugar cane ranges from 0 to 0.4. The dominant values is ranging between 0 to 0.184. This index distinguishes between soil and vegetation. But it does not account for the difference between reflectance and radiance caused by atmospheric effects or shadows. Lower DVI value which means
sugar cane condition is not dominant vegetation cover the area. It is assumed as impact of oil and gas field and or sugar cane plantations dominated by phase-1 and or post-harvest phase. GVI value ranges from 0 to 0.0674. This indicates that the green level of sugar cane is very low. GVI maximum values is 0.02 (2%). GNVDI values are almost equal to the NDVI values. The maximum value is 0.5382 and dominant value ranges from 0.1339 to 0.3361 (83%). GNDVI function almost the same as the NDVI, but more sensitive to chlorophyll concentration.

EVI value ranges from 0 to 0.2901. The dominant value is between 0.058 to 0.174. Based on EVI values, sugar cane vegetation signal is very low. Actually this index is used to estimate foliage cover and to forecast crop growth and yield. GRVI used to assess the sensitivity of photosynthetic process. On sugar cane plantations GRVI values range from 0 to 3.5. However GRVI values is dominant at 1.25 to 2.5 which reached 98%. Based overlaying with NDVI values, GRVI in dominant values has low NDVI values. It means the photosynthetic rates is low. GDVI value ranges from 0 to 0.3. The dominant GDVI value ranges from 0.0376 to 0.1681. It means, the level nitrogen in sugar cane is low. Based on the analysis of EVI, DVI, GVI, GRVI, GDVI and GNDVI values tends to be low and correlated with NDVI values (Table 2).

Figure 3. Vegetation indices were extracted from Landsat 8, Namely: NDVI, GNDVI, DVI, EVI, GDVI, GRVI and GVI
Table 2. Vegetation index results and their areas

| NO | DVI VALUES | AREA (M²) | NDVI VALUES | AREA (M²) | GNDVI VALUES | AREA (M²) | EVI VALUES | AREA (M²) |
|----|------------|-----------|-------------|-----------|--------------|-----------|------------|-----------|
| 1  | -0.0461 to -0.0000 | 874.800 | -0.2181 to -0.0000 | 879.300 | -0.0000 to -0.0000 | 942.300 | -0.0526 to -0.0000 | 879.300 |
| 2  | 0.0000 to 0.0612 | 25.483 | 0.0000 to 0.1181 | 941.200 | 0.0000 to 0.1339 | 2.646 | 0.0000 to 0.0580 | 17.091 |
| 3  | 0.0612 to 0.1224 | 58.519 | 0.1181 to 0.2363 | 52.874 | 0.1339 to 0.2350 | 32.053 | 0.0580 to 0.1160 | 76.552 |
| 4  | 0.1224 to 0.1836 | 38.133 | 0.2363 to 0.3544 | 65.103 | 0.2350 to 0.3361 | 51.752 | 0.1160 to 0.1741 | 28.467 |
| 5  | 0.1836 to 0.2448 | 769.500 | 0.3544 to 0.4725 | 3.831 | 0.3361 to 0.4371 | 36.071 | 0.1741 to 0.2321 | 793.800 |
| 6  | 0.2448 to 0.4000 | 156.600 | 0.4725 to 0.5906 | 291.600 | 0.4371 to 0.5382 | 459.000 | 0.2321 to 0.2901 | 143.100 |

Analysis of all vegetation indices showed low to moderate. This is presumably due to the oil and gas beneath that affect to vegetation in the surfaces [29]. Oil and gas beneath the earth precipitated to bring carbonates, pyrite, sulfur, pyrhotite, uranium, radon and others to the surface. In addition there is also oxidation process that forms microseeps in the surface [30] [31] [12] [32]. These conditions resulted vegetation anomaly that causes slow growth and the vegetation becomes sparse [11]. The presence of excess carbon dioxide gas (increased carbon content) will reduced chlorophyll content of leaves and the leaves become yellowish [8].

In healthy vegetation, near infrared reflectance will occur significantly spectral ranges from 0.7 to 1.2 μm. Only few are absorbed by the leaves. Healthy vegetation have 40 to 60% of reflectance, 40 to 60% of transmission and only 5 to 10% of absorption. The biggest adsorption is in blue and red channels. The presence of vegetation damaged/unhealthy will indicate the minimum of vegetation index values, but will be very high in healthy vegetation [33]. Vegetation may be affected by natural gas in many ways. The gas may be taken in the vegetation by the root system where it metabolized or passed in the transpiration stream [34]. Vegetation anomaly (stress) may exist in area where the soil contain unusually high concentration of the certain elements or compounds [35].

Based on buffer analysis of wells at a distance 100 m, 250 m and 500 m seen that sugar cane plantations around the wells has a NDVI, EVI, DVI, GVI, GRVI, GDVI and GNDVI values are likely to be low. Those values begin to rise at 50 m, but not significant (Figure 4). This indicates that the presence of oil and gas is expected to affect the sugar cane plantation. This is due to the long-term presence of oil and gas seepage continuously cause anomalies mineral and chemical changes in the surface [36]. These condition altered the biophysical and chemical characteristics of vegetation. The biophysical and biochemical characteristics changes in vegetation induced by oil pollution would affect the spectral signature of vegetation in visible and near infrared wavelengths [10]. Hence the vegetation cover is affected by gas in the soil and it can be a key to predict hydrocarbon seeps [37]. The vegetation growing in areas of gas production have a different spectral signature from vegetation growing off-gas field. Vegetation growing off-gas field have higher reflectivity in the 750-1250 nm spectral region and an absorption feature at 1200 nm is much stronger in off-gas field [38]. The model of vegetation change condition of oil and gas field described where the vegetation at the center of field will grow up stunted and abnormal, as for getting away from center will get better and grow normally [11] (Figure 5).
**Figure 4.** NDVI, EVI, DVI, GVI, GRVI, GDVI and GNDVI values around of oil and gas wells.

**Figure 5.** Conceptual model of vegetation change condition in oil and gas field that vegetation will grow up stunted and abnormal in the center of field and away from center will get better and grow normally [11].
5. Conclusion
This study was conducted to analyze the impact of oil and gas beneath the earth to sugar cane plantations. The analysis was conducted by processing and reviewing NDVI, EVI, DVI, GVI, GRVI, GDVI and GNDVI values. Based on its vegetation indices values, oil and gas beneath the earth are affecting the condition of sugar cane plantations. The effect is analyzed based on NDVI, EVI, DVI, GVI, GRVI, GDVI and GNDVI values that has dominant low values in all of sugar cane plantations. Results of buffer analysis around of oil and gas wells of several vegetation indices tends to be low values and then increase away from the well. It can be concluded that, the seven vegetation indices from Landsat 8 corresponded to vegetation condition at oil and gas field and agreed with previous published references. Ground checking is crucial to validate the obtained vegetation indices for next step.

Acknowledgement
We would like to express our thank to head of Remote Sensing Technology and Data Center-LAPAN for supporting Landsat 8 Data, Geospatial Information Agency (BIG) for supporting Topographic Map and Ministry of Agriculture for supporting High Resolution Data for making this paper.

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