Oil spill contingency plan (OSCP) by environmental sensitivity index (ESI) analysis at East Barito District, South Barito District and Kapuas District (Tamiang Layang, Buntok and surrounding area), Central Kalimantan Province

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Abstract: The central Kalimantan has involved as new oil and gas industry area where potential impact on environmental need to be anticipated comprehensively for environmental protection from oil spill. The locations are East Barito District, South Barito District and Kapuas District (Tamiang Layang, Buntok and surrounding area), Central Kalimantan Province. The main problem of this study is determining areas of sensitive and vulnerability to oil spill. The aims of study were to identify the factors and components that affect the level of ESI to oil spill and analyse and establish environmental sensitivity rank for oil spill contingency plan. The methodology of study carried out by identifying and assessing each landuse unit and analyse performed by GIS method with ESI formula. Interpretation and classification of landuse used Landsat TM imagery that acquired in 2014 and updated in 2018 and field survey in October 2014. The result of analysis showed environmental sensitivity index divided into four categories, dominated by high sensitive (40.8%) due to the presence of protected and conservation forest, less sensitive (31.9%), moderately sensitive (14.6%), and insensitive (12.8%). General condition of study area is lowland and swamp area and potential to flood. The environmental protection from oil spill should be mitigated and prioritized for sustainable development.

1. Introduction
Central Kalimantan has involved as new oil and gas industry area. There are several oil and gas working areas in the study area, including the Babai Tanjung Block (KE Babai Tanjung Ltd), Tanjung Area-1 Block (PT Pertamina), West Tanjung Block (PT MRI Energy) and Altar Sociade Investindo Imobiliaria, SA [1]. The presence of oil and gas working areas in this area can certainly have a positive impact in increasing Indonesia's oil and gas production and the possibility of the negative impact of oil spills. One of the causes of oil spills is accidental drilling of oil and gas wells (26%). The accidents in the oil gas industry almost certainly have a probably source pollutant in all production stages [2].

One priority of considerably oil spill contingency plan is handling potential contaminated areas that can be executed base on the environmental sensitivity that represents the level of reaction of the environment to recover in the event of an oil spill [3]. A comprehensive information on the sensitivity levels of each category of a susceptible environment is an important requirement for effective oil spill contingency plan. The ESI analysis should be done prior to the oil spills [4], as an essential step in oil pollution preparedness, response, and cooperation efforts. The ESI map a crucial tool to assist responders during an incident [5], an essential components of oil spill contingency planning [6] and one of methods in determining the aspect of landscape planning [7]. Significant effort has been performed in the developing sensitivity mapping components of oil spill contingency plans around the world [8].

Oil spill sensitivity maps are an important tool to develop the best-suited oil spill response strategies [5] and the most efficient application of the available response resources, making the cleanup operation
more effective [9]. Taking into account the various types of the shore and more importantly the most sensitive coastal sites, the oil spill sensitivity maps can also guarantee fast and effective oil spill response operations [5].

This study is conducted to identify the landuse/environmental condition of the study area, and to recognize which area that might be vulnerable from the oil pollution. For that reason, we perform the ESI mapping related to the oil contamination as an oil spill contingency plan.

The study area are focused around oil and gas working block in Kapuas, East Barito and South Barito District, central Kalimantan province (Figure 1).

2. Method

General steps of this study are shown in Figure 2. We used the imagery data from Landsat ETM+ which is acquired in August 2014 from USGS [10] and digitalglobe data from the Google Earth [11]. General condition of the study area was obtained from secondary data, i.e. morphological data and digital elevation obtained from SRTM (Shuttle Radar Topography Mapping) [12] and other map from goverment of Central Kalimantran province.
The ESI analysis was performed by overlaying modeling in GIS method. Data calculation and analysis of ESI were performed by using tabular analysis [14]. The ESI involving three elements, i.e. vulnerability value (VV), conservation value/ecological value (CV) and social value (SV) [15] and the ESI value for polygon unit from overlaying result that has specific environmental character value will be determined by a formula [14], [15], [16], [17]:

\[ ESI = VV \times CV \times SV \]  

Where:
- ESI = Environmental Sensitivity Index
- VV = Vulnerability Value, describing the class of resources that reflect the level of vulnerability of habitat, land use, and land cover affected by an activity.
- CV = Conservation/Ecological Value, describing representativeness, uniqueness, integrity and relationship to other class of resources.
- SV = Social Value, describing the impact of the economy, social and culture from an activity (such as oil spill) to a class of resources.

All components, i.e. vulnerability, conservation/ecology, and social have a range value between 1 to 5. The minimum value (1) indicates not sensitive, and the maximum value (5) refers to high sensitive. The composite value of ESI is a multiplication of these components, where the range value from 1 (insensitive) to 125 (high sensitive). The acquired ESI values from all study area are classified into five (5) classes of sensitiveness based on the value distribution. the classifications of sensitivity index are:

- Highly sensitive, with ESI value: 100 < ESI < 125.
- Sensitive, with ESI value: 75 < ESI < 99.
- Moderately sensitive, with ESI value: 70 < ESI < 74
- Less sensitive, with ESI value: 25 < ESI < 49
- Insensitive, with ESI value: 1 < ESI < 24

Interpretation of landuse/landcover was carried out for identification and assessment of VV, CV and SV by satellite imagery data year 2014 and updated 2018 and guided by map from government of central Kalimantan. Field survey was carried out in October 2014 in order to assist and validate landuse/landcover interpretation.

3. Result

3.1. Land Use and Land Cover
Landuse and land cover identification from guided satellite imagery classification result 16 classes of land use and land cover, are conservation forest, dry land farming, dry land farming and bush, open field, paddy field, plantation, plantation forest, protected forest, mining area, secondary dry land forest,
secondary swamp forest, settlement, shrub, swamp, swamp shrub, water body. The widest area of land use and land cover are protected forest that has 256,774 ha or 22% of the study area, secondary swamp forest: 169,956.3 ha and Swamp shrub: 144,244.6 ha. The total area of three widest area are 626,368.33 ha or more 50% of total study area (Figure 2-Figure 3 and Table 1). Land use conditions based on general forest, without distinguishing functions as protected forest, conservation or other functions are reaching an area of 700,712.18 or 60% of the total area, consisting of protection forest, conservation forest, secondary swamp forest, plantation forest, secondary dry land forest. The study area is also a swampy areas which reaches 28% of the study area or around 331,975 Ha consisting of swamp, lake, river, secondary swamp forest and swamp shrub.

Figure 3. Land use map of the study area

Table 1. Wide of land use and land cover in the study area

| No | Category                        | Area (Ha)  | Percentage |
|----|---------------------------------|------------|------------|
| 1  | Conservation forest (Cf)        | 199,638.0  | 17.1       |
| 2  | Dry land farming (Df)           | 29,590.1   | 2.5        |
| 3  | Dry land farming and shrub (Dfs)| 111,833.7  | 9.6        |
| 4  | Open field (Of)                 | 26,771.2   | 2.3        |
| 5  | Paddy field (Pd)                | 2,941.4    | 0.3        |
| 6  | Plantation (Pl)                 | 10,404.5   | 0.9        |
| 7  | Plantation forest (Plf)         | 9,496.8    | 0.8        |
| No | Category                                      | Area (Ha)   | Percentage |
|----|----------------------------------------------|-------------|------------|
| 8  | Protected forest (Pf)                        | 256,774.0   | 22.0       |
| 9  | Mining area (Mn)                             | 1,108.2     | 0.1        |
| 10 | Secondary dry land forest (Sdf)              | 64,847.0    | 5.6        |
| 11 | Secondary swamp forest (Swf)                 | 169,956.3   | 14.6       |
| 12 | Settlement (St)                              | 7,836.8     | 0.7        |
| 13 | Shrub (Sh)                                   | 114,142.0   | 9.8        |
| 14 | Swamp (Sw)                                   | 814.6       | 0.1        |
| 15 | Swamp shrub (Ss)                             | 144,244.6   | 12.4       |
| 16 | Water body (Wb)                              | 16,959.4    | 1.5        |

**Total area** 1,166,358.53

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3.2. **Morphological Condition**

Generally, the condition of the study area is in the lowlands area with <100 meters above sea level. This lowland area is located in the southern part widely, which consists of swamps with has general height <20 meters above sea level and has an elevation of 0-8%, classified as flat – gently undulating slope. Furthermore, the study area has a watery area that include lakes, swamps, swamp brush and several large rivers. The ground check results also show landuse condition as swampy area (Figure 3). In the north-northeast part of the study area is a hilly area with an altitude between 200-750 meters above sea level and has a slope classification as rolling-moderately steep-steep with slope value between 9-61%. The morphological conditions of the study area are presented in Figure 4 and the slope classification is shown in Figure 5.

![Figure 4](image-url)
Figure 5. General condition of study area (upper row) swamp area, (bottom left) flat and (bottom right) hilly

Figure 4. Morphological condition of the study area (source: SRTM data)
3.3. Sensitivity Index
Factors or components that affect the sensitivity level of a type of resource are different between resources. This depends on the physical condition, the condition of biological resources, habitat and ecology as well as the importance of the area or habitat or ecosystem for the surrounding community. The physical condition of an area which is related to the level of sensitivity or vulnerability of the environment is categorized as the level of natural vulnerability of the region. The condition of biological resources, habitats and ecology related to biological productivity and the role of the existing biological resources in the location to maintain the balance of the surrounding environment referred as a conservation value or ecological value. While the importance of an ecosystem or habitat is related to how important the community utilize resources and habitat so can provide good economic value for the people who live in the vicinity referred to as social values.

Environmental Sensitivity Index (ISL) Analysis was done based on the value of the level of vulnerability (TK), conservation value (NK) and socioeconomic value (NS) of each land use unit in the study area.

3.4. Vulnerability Value
The classification results of the vulnerability level to 16 classes of land resources in the study area indicate the level of vulnerability has very low, moderate/medium and very high value. The low level of vulnerability area are land use in the form of open land and shrubs, with an area of 140,913.21 Ha or around 12% of the total study site. The Land use form of moderate category of vulnerability level are dry land forest, dry land agriculture, settlement and plantation forest and has a wide area 222,604.44 Ha or around 19% of the total area. The high levels of vulnerability land use area are protected forest areas, natural reserve forests, mining areas, plantations, and swampy and watery areas, as a water bodies, swamps, rice fields, secondary swamp forests or other swampy areas. Very high vulnerability level is dominate in the study area and reaching 802,840.88 Ha or around 69% of the total area. Figure 6 shows vulnerability level of the study area.
3.5. Conservation Value (CV)

The conservation level classification results of 16 classes of land resources in the study area indicate the level of conservation value is very low, low, medium and very high value.

Very low vulnerability level has an area of 148,749.399 Ha or an area of 12.7% of total area in the landuse form of open land, shrubs and settlements. Low vulnerability level in the landuse form of paddy field, secondary dryland agriculture, secondary dryland agriculture and bush with an area of 113,775.05 Ha. The moderate level of vulnerability is secondary dryland forest resources, dryland agriculture and plantations with a wide area of 103,933.96 Ha (8.9%). The widest conservation value in the study area is a very sensitive class that reaches 799,899.53 Ha or 68.5%. This area is in the landuse form of mining areas, plantations and swampy areas. Figure 7 shows distribution of conservation value in the study area.
Figure 7. Conservation level of the study area

3.6. Social Value (SV)
The social value classification of land resources in the study location shows the level of social value vary from very low, medium and very high. The very low level of social value is in the landuse form of shrub and open land field with a wide area is 140,913.21 Ha. A moderate level of social value is in the landuse form of secondary swamp forest, plantations. High social value is in the landuse form of residential areas, agriculture, swamps, water bodies/rivers, protected forests, nature reserves with a wide area is 691,343.11 Ha. High social value dominate in the study area (59.2%), due to the presence of natural reserves and protected forests. Figure 8 show distribution of social value in the study area.

Figure 8. Social value distribution map of the study area
3.7. Environmental Sensitivity Index Analysis

Determination of the environmental sensitivity index was done based on formula (1) by calculating VV, SV and CV of each land use unit. Result of level sensitivity in the study area can be divided into four classes, i.e. high sensitive, moderately sensitive, less sensitive and insensitive (Figure 6-Figure 7 and Table 2-3). Table 2 shows a summary of ESI classification that present VV, CV and SC for each unit of land use used in the calculation of ESI value determination.

Figure 9. ESI map of the study area

| Table 2. Summary of ESI classification of study area |
|-----------------------------------------------|
| id  | Landuse             | VV  | CV  | SC  | ESI | Code  | Classification | Wide   | Remark      |
|-----|---------------------|-----|-----|-----|-----|-------|----------------|--------|-------------|
| Cf  | Conservation forest | 5   | 5   | 5   | 125 | 5     | high sensitive | 199,638.02 |             |
| Df  | Dry land farming   | 3   | 3   | 5   | 45  | 2     | less sensitive | 29,590.11  |             |
| Dfs | Dry land farming and shrub | 3 | 2   | 5   | 30  | 2     | less sensitive | 110,833.7 |             |
| Mn  | Mining area        | 5   | 5   | 5   | 125 | 5     | high sensitive | 1,108.16   |             |
| Cf  | Open field         | 1   | 1   | 1   | 1   | 1     | insensitive    | 26,771.21  |             |
| Pf  | Paddy field        | 5   | 2   | 5   | 50  | 2     | less sensitive | 2,941.35   |             |
| Pf  | Protected forest   | 5   | 5   | 5   | 125 | 5     | high sensitive | 256,774    |             |
| Pl  | Plantation         | 5   | 2   | 5   | 50  | 2     | less sensitive | 10,404.45  |             |
| Pff | Plantation forest  | 3   | 3   | 3   | 27  | 2     | less sensitive | 9,496.82   |             |
| Sdf | Secondary dry land forest | 3 | 3   | 5   | 45  | 2     | less sensitive | 64,847.03  |             |
| Sh  | Shrub              | 1   | 1   | 1   | 1   | 1     | insensitive    | 114,142   |             |
| Sl  | Swamp shrub        | 5   | 5   | 2   | 50  | 2     | less sensitive | 144,244.64 |             |
| St  | Settlement         | 3   | 1   | 5   | 15  | 1     | insensitive    | 7,836.78   |             |
| Sw  | Swamp              | 5   | 5   | 5   | 125 | 5     | high sensitive | 814,598    |             |
| Swf | Secondary swamp forest | 5 | 5   | 3   | 75  | 3     | moderate sensitive | 169,956.31 |             |
| Wfb | Water body         | 5   | 5   | 5   | 125 | 5     | high sensitive | 16,959.36  |             |
Table 3. Wide of Area of ESI classification

| No | Category          | Area (Ha)   | Percentage |
|----|-------------------|-------------|------------|
| 1  | High sensitive    | 475,294.14  | 40.8       |
| 2  | Sensitive         | 0           | 0          |
| 3  | Moderate Sensitive| 169,956.31  | 14.6       |
| 4  | Less sensitive    | 372,358.09  | 31.9       |
| 5  | Insensitive       | 148,749.99  | 12.8       |
|    | Total             | 113,587.76  |            |

Figure 10. Graph of ESI classification area width

Generally, the study area mostly has high sensitive category, reaching 475,294.14 Ha or 40.8% of total area study, with ESI value is 125 (Figure 7 and Table 4). Most of the landuse unit that have high sensitive areas category are protected forest (256,774 ha) and conservation forest (199,638 ha), which concentrated in the southern part of study area. Mining, swamp and water body areas are included in this high sensitive ESI category. The existence of water, whether inundated area like swamps, reservoirs or flowing / rivers is used widely by the surrounding community. Mining areas are also included in this category, because the facility may not be compensatory considering the very costly. This ESI class has distribution spread widely most of the study area in the southern part.

The second widest area of ESI classification is less sensitive, reaching 372,358 Ha or 31.9% of total study area. The units landuse in this category are swamp, shrub, plantation, paddy filed, dry land forest and farming. The ESI value of this category vary from 27-50., VV vary from 3-5. CV and SC value also vary from 2-5.

The insensitive classification has ESI value varies from 1-15 and reaching 12.8% of total area study or 148,749.99 Ha with landuse form is open field (226.91 ha), shrub (114,142 ha) settlement (7,836.78 ha). The presence of an insensitive ESI is due very low conservation value, vulnerability value and social value (has value: 1). The existence of shrub and open field in the study location is not used too much by the community. Ecologically, the presence of open fields and shrubs does not have much effect on the surrounding environmental conditions, so it has low VV and CV value.
4. Discussion

The ESI analysis can show the level of environmental sensitivity to oil spills. Generally, most of the study areas are very sensitive. This is due to the existence of the function of the forest as protected forest and conservation forest. This area is a protected area from massive forest exploitation activities and was developed to have a diversity of species. The extent of the areas that are high sensitive compared to the less sensitive and insensitive areas due to the conditions of the study area that is mostly swampy areas. Generally, swampy areas are areas very sensitive to oil spills (Sloan, 1993). In fact, the southern part of the study area is a lowland with an altitude of <20 m above sea level and is a large swampy area. In this area there is also a large river, i.e. the Barito river.

The water area, both ponds and rivers, is widely used by the community to fulfil their needs. The results of the field survey showed that the activities of the floating cage cultivation and aquaculture in ponds. In fact, there are people who use open water areas for domestic activities. River areas are widely used for transportation, including for coal transportion through rivers (Figure 11).

![Figure 11. Using of water area by communities (upper row) for fisheries, (bottom left) domestic purpose (bottom right) coal mining transportation](image_url)

In sensitive and high sensitive areas, the oil spill will affect the sustainability of the surrounding community who rely on livelihood. Serious efforts are needed to prevent an oil spill. Early handling is needed in the event of an oil spill, such as disaster mitigation, localizing the disaster area and giving priority handling [13]. The low topography condition of the study area as a lowland also makes another potential danger, i.e. flooding. Figure 9 shows the potential for flood-prone in the study areas. Low topographic conditions and flood-prone can certainly exacerbate conditions if there is an oil spill in this area. Oil spills can be carried over to large locations and more difficult to clean up and return to normal condition.
Figure 12. Flood prone map of the study area. Insert photo shows flood condition

5. Conclusion
The ESI criterion in this study area shows that more than half of the study area is high sensitive due to the protected forest, conservation forest and swamp area. Therefore, effort of protection are necessary to anticipate since oil spill can damage the environment. Those efforts include the mitigation, localizing and prioritizing the handling of oil spill.

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