Changes in the Value of Sinuosity Index in Komering River Channel, Province South Sumatera Years 1990 - 2016

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Abstract. Komering Watershed has experienced degradation in the quality of environment and ecosystems. This ecosystem and environmental degradation is due to significant deforestation and land conversion in upstream and central areas. Land conversion which led to erosion in the upstream and sedimentation in the downstream causing changes in river channel. This study aims to analyze the deformation (morphodynamics) of river channel of Komering River in 1990, 1997, 2000, 2010 and 2013. The occurred changes are identified using satellite image interpretation and calculation from sinuosity index based on changes in river channel. Satellite image data are obtained from multitemporal Landsat images to identify changes in the river channel, while sinuosity index is used as an indicator of changes in the river channel. The results of this study showed that during 26 years period (1990 - 2016), the channel of Komering River changes in eleven locations. There are five locations that indicate tendencies to be straight and six locations show tendencies to get curved. This conclusion is based on the calculation of the sinuosity index value due to changes in land cover.

1. Introduction
The river is a component of the dynamic fluvial system, that when viewed in spatial and temporal mode, changes in the shape of the river channel can be seen. According to Piegay and Schumm (2003) modelling of the fluvial system concepts are generally divided into two main controls, which are in the upstream (upstream controls) and control in the downstream (downstream controls) [1]. Changes in the form of the river due to the formation of river channel is controlled by various factors such as tectonics, lithology, climate, slope, vegetation, human activity, and baselevel [2]. Listed factors above are classified into two factors that is local control fixed and local control variable. Local control fixed is a factor that is formed naturally by nature and the most influential factor in the early formation of the river. The second factor is local control variable that is most commonly caused by human activity where these factors are factors that play a role in the most dynamic changes in river formations [2].

Sinuosity index is an index that is commonly used in planimetric fluvial geomorphology research to calculate changes in the river channel that occur. Ratio or sinuosity index indicates how the curvature of the river channel can be done by measuring the length of the reach of river flow and dividing by the straight line distance along the valley [3]. Human activity around the river is the result of land conversion from land cover vegetation into non-vegetation land cover (Priatna, 1994). Komering watershed is a watershed in South Sumatra that has experienced changes in environmental quality and land conversion due to human activities [4]. This statement is supported by the results of Musi Watershed Management Center identification in 2009 where the headwaters and the middle decline of ecosystems and the environment. The causes of environmental degradation are due to deforestation and conversion causes natural erosion on the river [5]. This research aims to analyze the deformation (morphodynamics) of river channel that occurred in Komering watershed,
South Sumatra Province in 1990, 1997, 2000, 2010 and 2016 in which changes of the river channel is one of the indicators that has changed environmental quality in a watershed.

2. Area of Study and Data

Komering watershed is geographically located between the 103° 34 '00 " E - 104° 59' 30" E and 30° 30 " S – 40° 59' 30 S. Area of Komering watershed is 806,001 ha or 8,060.01 km². Administratively, Komering watershed passes two provinces which are South Sumatra and Lampung. Districts crossed by Komering watershed covers Way Kanan and West Lampung regency in Lampung Province, while in South Sumatra province across 6 regency namely Ogan Komering Ulu, Ogan Komering Ulu Selatan, Ogan Komering Ulu Timur, Lahat, Ogan Ilir and Ogan Komering Ilir.

This research uses two types of data are primary data and secondary data. The primary data used in this study is the interpretation of digital and digitized on screen remote sensing image is Landsat 1990, 1997, 2000, 2010 and 2016 to obtain the data channel of the Komering River and land cover data and field observations to validate and documentation the channel of the komering river and land cover in the study area. Secondary data used in this study are the river discharge data collection fifteen daily in the period 1998 - 2015 and data distribution quarry C along the Komering River. Imagery from Google Earth

Figure 1. Location of study area

3. Methodology

River channel data obtained through digital interpretation and digitization on a screen using remote sensing data. Remote sensing data used in this study is Landsat imagery. Landsat imagery used is the path row 124/63 and 124/62, and adjusted according to the year. The 1990 – 1997 period used Landsat 5 TM; The 2000 – 2010 period used Landsat 7 ETM; and 2016 period used Landsat 8 OLI / TIRS. Landsat images are selected based on the least cloud cover or the best coverage for the year that has been determined. The next process is the process of digitization of the river flow on a scale of 1: 50,000. Determination of a scale of 1: 50,000 is because Landsat image has a resolution of 30 m x 30 m so if this study follows the Tobler rule (1987) that the map scale = Spatial resolution image (in
meters) * 2 * 1000, then for Landsat images corresponding scale is 1: 60,000 with tolerance scale is between 1: 50,000 to 1: 100,000 [5].

Sinuosity Index calculations performed in this study are done after getting the river channel for each period, namely 1990, 1997, 2000, 2010 and 2016. The channel of the river in 1990 are used as a reference in the river channel to see changes that occur. This calculation is done to see how the changes in the river flow that occurs in the quantitative approach. These calculations look at indexes curvature slope in a segment that is visible changes within five periods. The following equation approach slope curvature index calculation formula according to Langbein and Leopold (1966) [7].

\[ K = \frac{M}{\lambda} \]  

Information:
- \( K \) = sinuosity index
- \( M \) = length channel
- \( \lambda \) = wavelength

The division of the river channel segments are based on the calculation of the index i.e sinuosity river channel, where there are hills and valleys on the flow from the initial formation of the hill until the end of the valley. Here is a classification of the sinuosity index (Table 1) which are classified by Charlton (2008) [3].

### Table 1. Classification of Sinuosity Index

| Type     | Sinuosity |
|----------|-----------|
| Straight | < 1,1     |
| Sinuous  | 1,1 – 1,5 |
| Meandering | > 1,5    |

After doing the calculations of the sinuosity index on Landsat imagery, the next step is to validate sinuosity index value with higher resolution imagery from Google Earth scale 1: 5,000 or ten times larger than a scale of Landsat imagery in the latest year of 2016. The verification process performed in this study is the validation of test calculation sinuosity index by finding massive irregularities that occurred using high resolution imagery of Google Earth imagery. The deviation is calculated by using the equation Root Mean Square Error (RMSE) and Objective Normalized Fungtion (NOF) on Kornecki, et al. (1999) and Hession, et al. (1994) in Arief (2014) [8]. According Kornecki et al. (1999) in Arief (2014) [6], which is ideal for NOF value is in the range of 0.0 to 1.0. Here's the formula in calculating the deviation sinuosity index:

\[ \text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(P_i-O_i)^2}{N}} \]  
\[ \text{NOF} = \frac{\text{RMSE}}{\bar{O}} \]  

Information:
- \( P_i \) = sinuosity index of Landsat Imagery
- \( O \) = sinuosity index of Imagery from Google Earth
- \( N \) = total sample
- \( \bar{O} \) = mean sinuosity index of
The analysis used in this study is the spatial analysis (spatial) and descriptive analysis with quantitative approach. A quantitative approach is used to describe the results of the calculation of changes in the river channel that happen using sinuosity index value. Spatial analysis conducted after the changes are the result of the calculation of the river flow by analyzing changes in the river flow that occur and the factors that influence with the help of descriptive analysis in the form of a map and description of conditions in the field.

4. Result and Discussions

4.1. Land Cover Change

Human activity is one of the factors that influence or control the formation of river channel [2]. In general, land cover change on vegetation classes are fairly stable where the period between 1990 - 2016 comprehensive land cover vegetation decreases only 49.61 km² or shrink by 0.6%. However, this stability is not represented in the sub-class of vegetation where the third sub-class experienced a drastic change mainly in the conversion of forests into plantations and estates into paddy fields. Changes in land cover on the vegetation classes over a period of 26 years is a sub class of the forest where its range reduced by 2,225.51 km² or shrank by 57.26%. Here is table of the land cover area change in Komering watershed.

| Land Cover   | 1990 Area | 1990 % | 2016 Area | 2016 % | Area Change | Area Change % |
|--------------|-----------|--------|-----------|--------|-------------|---------------|
| Water        | 126.63    | 1.57   | 126.63    | 1.57   | -           | -             |
| Settlement   | 84.91     | 1.05   | 164.44    | 2.04   | 79.53       | 93.66         |
| Degraded Land| 70.51     | 0.87   | 40.59     | 0.50   | (29.92)     | (42.43)       |
| Paddy Fields | 638.63    | 7.92   | 2,598.44  | 32.24  | 1,959.81    | 306.88        |
| Forest       | 3,886.59  | 48.22  | 1,661.08  | 20.61  | (2,225.51)  | (57.26)       |
| Farm         | 3,252.74  | 40.36  | 3,468.83  | 43.04  | 216.09      | 6.64          |
| Total        | 8,060.01  | 100    | 8,060.01  | 100    | -           | -             |

4.2 Mining Activities in Komering Riverbank

Based on data from the Department of Mines and Energy of East OKU Regency, in 2013 there were 150 mining sites scattered along the main channel of the Komering river [9]. All mining activities
along the main flow of the Komering river were included into mining activities, mineral C as produced in the form of sand, coral or rock and clay. Mining can significantly increase the clay content (as sediment load) in the river flow, especially the mining of sand and stones that reduces the width and length of the channel or change straight into a meandering channel [2].

Table 3. Total Location Activities Mining in Komering Watershed

| Type of Mines | Number of Location |
|---------------|--------------------|
| Sand          | 69                 |
| Coral/ Rock   | 24                 |
| Clay          | 57                 |
| **Total**     | **150**            |

Figure 3. Distribution Location of Activities Mining in Komering Watershed

4.3 Discharge of Komering Watershed

Schumm (2005) says that the change in river channel can cause growth and shifts in the river flow, especially when large discharge and sediments on the edge is weak then it will rapidly occur in the meandering channel process of change [2]. Based on the results of data processing of discharge in the river, mean daily fifteen years 1998 - 2015 in the post water of Bendung Gerak Perjaya weir under the auspices of the Central River Region (BBWS) Sumatra VIII. The result of data processing shows that the trend of the average - average daily discharge fifteen Ogan River have an upward trend discharge

Figure 4. Discharge of Komering River Graphic Years 1998 – 2015

4.4 Changes in the Value of Sinuosity Index in Eleventh Selection Location

River channel formed by two factors, namely local control fixed and local control variable which are factors that until now continues to change the formation of the river [2]. Based
on the results of observations of Komering river channel using Landsat imagery interpretation and calculation of the value of sinuosity index in the year 1990 – 2016, there were 11 locations that are changing flow of formation is seen in two dimensions. The eleventh location is classified based on the type of sinusitis from Charlton (2008) is the type of meandering, sinuous and straight [3].

**Table 4. Sinuosity Index Changes and Characteristic Location in Eleventh Selection Location**

| No. | Name of Channel | Activity Mining | Type of Rock | Gradient | Type of Channel 1990 | Type of Channel 2016 | Mean SI | ST.DE V. SI | SI Changes |
|-----|-----------------|-----------------|--------------|----------|----------------------|----------------------|---------|-------------|------------|
| 1   | S1              | No              | QTk          | 2 - 15 % | Si                   | Si                   | 1.141   | 0.012       | -0.007     |
| 2   | S2              | No              | QTk          | 2 - 15 % | Sa                   | Sa                   | 1.068   | 0.011       | -0.013     |
| 3   | S3              | No              | QTk          | 2 - 15 % | Ma                   | Ma                   | 1.962   | 0.056       | -0.105     |
| 4   | S4              | No              | Qa           | 2 - 15 % | Ma                   | Ma                   | 2.810   | 0.088       | 0.008      |
| 5   | S5              | Yes             | Qa           | 2 - 15 % | Ma                   | Ma                   | 1.709   | 0.073       | 0.147      |
| 6   | S6              | Yes             | Qa           | 0 - 2 %  | Si                   | Si                   | 1.374   | 0.103       | 0.151      |
| 7   | S7              | Yes             | Qa           | 2 - 15 % | Si                   | Si                   | 1.205   | 0.094       | -0.226     |
| 8   | S8              | Yes             | Qa           | 0 - 2 %  | Ma                   | Ma                   | 1.694   | 0.082       | 0.120      |
| 9   | S9              | Yes             | QTk          | 0 - 2 %  | Si                   | Si                   | 1.099   | 0.047       | -0.004     |
| 10  | S10             | No              | Qa           | 0 - 2 %  | Sa                   | Sa                   | 1.038   | 0.032       | -0.041     |
| 11  | S11             | No              | Qa           | 0 - 2 %  | Sa                   | Si                   | 1.112   | 0.039       | 0.108      |

**Information:**
- Qa : Alluvium
- QTk : Formasi Kasai
- Sa : Straight
- Si : Sinuous
- Ma : Meandering

**Figure 5.** Distribution of River Channel has Changed in Years 1990 – 2016
Based on the validation test sinuosity index value that has been done by taking a sample of 11 sites, obtained RMSE value of 0.0016 and NOF values obtained by 0.00014, then the value of irregularities that occurred at 0.00014. From these results it can be concluded that the data processing sinuosity index using Landsat imagery was well used because of irregularities that occurred only at 0.00014. These results are based on a statement Kornecki et al. (1999) in Arief (2014), which is ideal for NOF value in the range of 0.0 to 1.0 [8].

Based on changes in the value of SI in 1990 - 2016, S7 has decreased the value of Sinuosity Index (SI), which means getting a straight in channel of S7 while the S6 have additional value which means the flow S6 SI increasingly turn. This indicated a significant change caused by changes in land cover in the S6 and S7 edge of the forest into the farm, where this is also the case in the S5, so that it can be said of land cover change from forest to farm the land cover changes cause most of the changes in the value of SI. Land cover change is an important factor in view of changes in channel river, which land cover changes resulted in high rates of erosion in upstream and sedimentation in downstream areas that directly affect river discharge [10]. Komering river discharge shows an upward trend of monthly discharge in every year. The difference this trend led to an imbalance form of rivers, because when the discharge is high then the process will be increased erosion and sedimentation processes weakened when the discharge increases.

Land cover change of forest class in the Komering watershed is very large, especially in the period of 1990 – 1997, Komering watershed lost almost half of its forest area. In the same period the flow changes that occur most of the more straight, is directly contrary to the period 1997 - 2000 is a low deforestation which changes the flow that occurs mostly getting turn. This change is due to a decrease in forest area occurred much lower than the previous period. Forest area changes resulting from converted into farm and paddy fields in the period 1990 - 1997 when land clearing large - scale occurred on the island of Sumatra. Cover the paddy fields are land cover classes of the greatest gain is inversely proportional to the extent and condition of forest land cover classes. Extra spacious paddy significantly occurred in the period 1990 - 1997 where the increase is almost 250%, the addition of this vast obtained from conversion of forest and farm.

5. Conclusion and Recommendation
In a time range of 26 years (1990-2016), the flow of Komering River has undergone spatial changes in eleven locations. Eleven locations that have changed, consists of four meandering types, four sinous types, and three locations with straight flow type. The change of flow that occurs spatially is quite varied, where five locations show an indication to become increasingly straight, and six locations show an indication to become increasingly turned. Temporally, the period of 2000-2010 is the period

![Figure 6. Graph of Relation Change Forest Area with Change in River Shape in Periods of Years 1990 – 2016](image-url)
where many changes occur mainly eight locations from eleven chosen locations that become increasingly straight. In that period, there was a decline of forest area as large as 12.43% and a trend of river discharge rise. So, it can be concluded that there has been a change in the environment of Komering watershed. Therefore, it is necessary to have proper policy development and environmentally friendly in order to preserve Komering watershed.

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