A morphometric analysis for investigation climate impact on settlement in Lengkiti, Ogan Komering Ulu Regency, Indonesia

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Abstract. The change in morphological patterns upstream of Ogan River were investigated to analyze land-use and climate change impact on the river meandering. This study aimed to investigate morphological changes of Ogan River in Lengkiti area between 1996 and 2019. Two sets of Landsat areal (1990 and 2016) were used to identify the morphological changes during flood periods. Data analysis used the maximum likelihood approach, t-test and Spearman correlation analysis. The morphometric indicators such as river width (W), meander neck length (L), axis length (A), curvature radius (R), water flow and sinuosity of meander (C) were extracted to identify the morphological pattern of river meandering. Analysis of land-use change used Support Vector Machine (SVM) and kernel function method to interpret the meander parameter change. Ogan River in Lengkiti, such as Batu Kuning and Marga Jaya segments, which have rice field and settlement cover from 1996 to 2019, had been cut off. Cut-off occurred due to landslides that entered river’s body and narrowed riverbed. This fasted river flow even though river discharge was same, caused intensive erosion and sedimentation. The increase in water velocity increased flow power, shortened flow distance and cut-off caused reduced meander’s sinuosity (C).

1. Introduction
Increased atmospheric humidity affects global warming (climate change) which affects the intensity and frequency of rainfall as well as extreme events in the hydrological cycle [1]. Indonesia is a country with a tropical climate that has high rainfall in several regions. The high rainfall causes frequent hydrometeorological disasters. One of the hydrometeorological disasters is a natural disaster due to climate change such as floods, landslides and drought [2]. River is one of the geomorphological aspects directly affected by climate change due to precipitation and evaporation [3]. These changes affect the sedimentation rate, rock layer composition and elevation, river system and flow pattern. Geomorphic analysis approach of river change can be done using a Geographical Information System (GIS) which can analyze the change in river morphology after a flood event [4].

Lengkiti is an area in the upper of Ogan River Watershed in of the fluvial system. Sedimentation affects Ogan River development in this area, which has implications for hydrometeorological disasters, especially flooding. Lengkiti lies at elevation ± 300 m above sea level (m asl) with area 700 km² and population 25,369 people. Most of the population works in agricultural sector that affects land cover changes. These changes play a role in erosion and sedimentation in Ogan River system development.
Therefore, it is necessary to conduct a river morphometric analysis to determine river changes and its impacts such as flooding for spatial planning, settlement, and infrastructure in the future.

2. Study method

2.1. Data
This morphometric analysis study used data as shown in the research flow diagram (Figure 1) which was processed using a Geographic Information System (GIS).

![Research methodology diagram](image)

Figure 1. Research methodology.

Landsat data can display satellite record images that are quite high resolution starting from 15 meters, 30 meters and 100 meters [5]. In this study, Landsat 5 TM, and Landsat 8 OLI/TIRS were used to visualize Ogan River's appearance in the past (retrieved 23 July 1996) and present (retrieved 9 September 2019).

2.2. Meander parameters
The use of meander parameters in river morphometry changes analysis was referred to Hooke [6] and Hooke [7]. This identification used data visualization displayed by Landsat. The parameter aspects were measured based using parameters, namely (Figure 2): neck length (L), axis length (A), length of water flow (S), river width (W), curvature radius (R) and sinuosity (S) was calculated based on equation (1) [6][7]. The length of the winding neck is the lowest distance between the two winding loops, the length of the axis is the distance between the internal arc of the meander and the winding neck, the length of the water flow is the length of the river flow in two winding aspects, the width of the river is the average of the lowest distance between river banks, and the radius of curvature is the maximum radius of the interior in the winding circle.

\[
C = \frac{S}{L} \tag{1}
\]

Where, \( C \) is meander's sinuosity, \( L \) is neck length, and \( S \) is water flow length.

The loop meander changes were divided into several types of changes. These changes were either simple or combined: translation, rotation, extension, expansion, cut off, redevelopment, lateral movement, and irregular changes (Figure 3). Evaluation of the river meander morphometry results was calculated statistically using T-test and Spearman Correlation Test.
Figure 2. Meander morphometric parameter curve model (A is axis length, S is water flow length, W is river width, R is curvature radius and L is neck length). Source: [6][7].

Figure 3. Meander change model. Source:[4][5].

2.3. History rainfall and land cover data
Rainfall and land cover data were supporting parameters in analyzing morphometric changes. For rainfall data, this was obtained from the SiBiaS application with historical data between 1974-1989 and 1990–2005 [8]. Meanwhile, the land cover data were used data from WebGIS on the Ministry of Environment and Forestry (MOEF) website, namely 1996 and 2019.

3. Results
Landsat data were visualized using composite false-color where the Landsat 5 TM data was using a band combination of 4, 3, 2 while Landsat 8 OLI/TIRS data used band combination of 5, 4, 3. On composite false-color appearance, vegetation distribution appeared dark red, settlements were grayish blue, open land was brown and rivers were dark blue. For detailed analysis, the upstream of Ogan River was divided into several segments based on changes in the river direction (10 segments) were obtained from A to J (Figure 4). Almost all segments of the upstream of Ogan River changes indicated that the evolution of river meander occurred over time with different intensity levels.
Figure 4. The change of meander at the upstream of Ogan River

The calculation of each meander morphometric element was carried out to determine the meander's change according to Hooke [6] and Hooke [7] as shown in Table 1. Rainfall is one of the factors controlling morphometric changes and was obtained from SiBias. Rainfall analysis was carried out by calculating 5 daily rainfall which accumulated every month and was divided into 1974–1989 and 1990–2005. This was because the probability of flood was most likely due to extreme rainfall in 5 days. The rainfall map is shown in Figure 5 that the lowest rainfall was in the range 100-200 mm and the highest was in the range 800-900 mm.
Figure 5. Means of rainfall in 1974–1989 (a) and 1990–2005 (b)

Table 1. Result calculation of morphometric change of meander

| Section | L (m) | A (m) | S (m) | W (m) | R (m) | C  | Sec. | L (m) | A (m) | S (m) | W (m) | R (m) | C  |
|----------|-------|-------|-------|-------|-------|----|------|-------|-------|-------|-------|-------|----|
| A        | 2496  | 669   | 3013  | 25    | 875   | 1.21| A    | 2419  | 722   | 2867  | 26    | 866  | 1.20|
| B        | 2683  | 973   | 3133  | 26    | 1112  | 1.17| B    | 2730  | 857   | 3227  | 33    | 1165 | 1.20|
| C        | 5015  | 2015  | 6393  | 37    | 1522  | 1.27| C    | 5121  | 1579  | 6564  | 60    | 1782 | 1.28|
| D        | 3374  | 767   | 4094  | 28    | 1146  | 1.23| D    | 3387  | 776   | 4140  | 53    | 1148 | 1.24|
| E        | 3020  | 514   | 3330  | 33    | 909   | 1.09| E    | 3002  | 437   | 3475  | 51    | 947  | 1.15|
| F        | 7175  | 2024  | 11886 | 28    | 2420  | 1.69| F    | 7152  | 2045  | 11746 | 41    | 2451 | 1.68|
| L        | 1902  | 1033  | 2839  | 28    | 782   | 1.51| L    | 1934  | 1004  | 2861  | 41    | 801  | 1.50|
| K        | 2060  | 776   | 2580  | 32    | 573   | 1.25| K    | 2047  | 779   | 2597  | 33    | 551  | 1.26|
| J        | 2750  | 940   | 4597  | 19    | 945   | 1.67| J    | 2765  | 990   | 4697  | 34    | 956  | 1.70|
| I        | 2356  | 1482  | 5607  | 31    | 1443  | 2.38| I    | 2339  | 1438  | 5543  | 24    | 1417 | 2.37|
| Mean     | 3283  | 1119  | 4747  | 29    | 1173  | 1.45| Mean | 3289  | 1063  | 4772  | 40    | 1208 | 1.46|
| Min      | 1902  | 514   | 2580  | 19    | 573   | 1.09| Min  | 1934  | 437   | 2597  | 24    | 551  | 1.15|
| Max      | 7175  | 2024  | 11886 | 37    | 2420  | 2.38| Max  | 7152  | 2045  | 11746 | 60    | 2451 | 2.37|

Note: Neck length (L), axis length (A), length of water flow (S), river width (W), curvature radius (R) and sinousity (S) with equation \( C = S/L \)

Figure 6. Land use change in Lengkiti area in 1996 and 2019.
Based on MOEF land cover data in 1996 and 2019, there were 8 land cover types identified in Lengkiti, consisting of bushland farming, dryland agriculture, secondary dryland forest, plantations, shrubs, rice fields, settlements, and mining (Figure 6).

4. Discussion
Analysis of changes in the Ogan River's morphometry was carried out using T-tests and Spearman Correlation. T-test was used to determine significant changes from the same parameter, while Spearman Correlation was used to determine the relationship between the formed values by the relationship between two variables [9]. Table 2 shows that all parameters (L, S, W, R and S) increased (p <0.05), while axis length (A) decreased between 1996 and 2019. The river width (W) was an aspect of significant change. It also proved the widening of river body due to river walls’ erosion that led to cause landslides. River system is structurally interconnected. Changes in curvature radius are caused by an increase in water flow length, the neck length and the axis length [10] as shown in Table 3.

Batu Kuning area, Lengkiti Regency, represented a high erosion associated with high rainfall (Figure 7). High rainfall caused abundant water discharge which caused an increase in flow velocity due to water volume and riverbed slope. This increased erosion of river walls which form the foundation of the road.

Land cover change influenced the morphometric development of Ogan River. The dynamics of land change also affected erosion. Land without vegetation on the surface results in weak soil resistance [11]. Removing vegetation and plowing rice fields make the soil lose its resilience and affect river degradation, such as riverbed deepening and riverside widening [12]. The residential areas played a major role in erosion due to human activities. This was indicated by changes in river morphometry that occurred in settlements and rice fields areas.

**Table 2. Result of T–test in morphometry of Ogan River.**

| L (m) | A (m) | S (m) | W (m) | R (m) | C |
|-------|-------|-------|-------|-------|---|
| Pearson Correlation | 1.00 | 0.97 | 1.00 | 0.52 | 0.99 | 1.00 |
| Hypothesized Mean Difference | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| df | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| t Stat | -0.41 | 1.25 | -0.70 | -3.42 | -1.36 | -1.49 |
| P(T<=t) one-tail | 0.35 | 0.12 | 0.25 | 0.00 | 0.10 | 0.08 |
| t Critical one-tail | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 |
| P(T<=t) two-tail | 0.69 | 0.24 | 0.50 | 0.01 | 0.21 | 0.17 |
| t Critical two-tail | 2.26 | 2.26 | 2.26 | 2.26 | 2.26 | 2.26 |

*Neck length (L), axis length (A), length of water flow (S), river width (W), curvature radius (R) and sinousity (S)*

**Table 3. Result of Spearman correlation**

| L | A | S | W | R | C |
|---|---|---|---|---|---|
| 1.00 | | | | | |
| 0.75 | | | | | |
| 0.76 | | | | | |
| 0.92 | 0.82 | 1 | | | |
| 0.92 | 0.89 | | | | |
| 0.17 | 0.29 | 0.05 | 1 | | |
| 0.44 | 0.05 | 0.18 | | | |
| 0.90 | 0.83 | 0.96 | 0.10 | 1 | |
| 0.92 | 0.88 | 0.95 | 0.26 | | |
| 0.04 | 0.45 | 0.41 | -0.16 | 0.39 | 1 |
| 0.02 | 0.54 | 0.39 | -0.47 | 0.32 | |

*Length of the axis = 0.75 Ogan River in 1996; *Length of the axis = 0.76 Ogan River in 2019.*
Figure 7. Road cracks and landslides in Batu Kuning, Lengkiti Regency. (a) road crack due to erosion, (b) detail road crack, (c) landslides caused by river erosion, (d) bird view location of landslides caused by river erosion.

Figure 8. The cut off process occurred in the Marga Jaya area, Lengkiti District.

Cut-off in the river segment was caused by landslide entered river body and narrowed riverbed. This happens when the same water flow discharge has a faster current [13]. River currents that increased lead to the river flow to shortened flow distance. Google Earth appearance in Marga Jaya area represented cut-off (Figure 8). Residential areas and rice fields dominated this area and cut-off occurred due to erosion and sedimentation.
Figure 9. Changes in meander trends in the Lengkiti area (a) and Current region view via Google Earth (b).

The river system responded to several processes that occur in the watershed, especially Ogan River. Rainfall and land cover changes became spatial planning study about the forming of river system. River morphometric analysis could be an effort to predict future meander development. In Google Earth appearance (Figure 9), river that was near residential areas were seen moving away from residential areas. On the next meander, the river was seen approaching the road. If it is uncontrolled, the road will collapse due to erosion of the foundation and it is required to study about river morphometric analysis before building an infrastructure.

5. Conclusion
Understanding the response of river systems is important in predicting the effects of human and climate activities on the fluvial system. Morphological changes occurred with high intensity in almost every segment, whether it was influenced by climate change or land cover change. Meander morphometric analysis is useful in predicting the morphological and meander evolutions of Ogan River. A better understanding of river management can reduce the impact of damage caused by these changes.

References
[1] Wardoyo W and R Jayadi 2009 Analysis to extreme hydrology parameter on Mt. Merapi area to justify the effect of climate change in International Seminar on Climate Change Impact on Water Resources and Coastal Management in Developing Countries Manado.
[2] Qodriyatun S N 2013 Bencana Hidrometeorologi dan upaya adaptasi perubahan iklim Jurnal Kesejahteraan Sosial 5 9-12.
[3] Verhaar P M, P M Biron, R I Ferguson and T B Hoey 2008 A modified morphodynamic model for investigating the response of rivers to short-term climate change Geomorphology 101 672-82.
[4] Kidova A, M Lehotsky and M Rusnak 2016 Geomorphic diversity in the braided-wandering Bela Rive, Slovak Carpathians, as a response to flood variability and environmental changes Geomorphology 272 137-149.
[5] Archarya T D and I Yang 2015 Exploring Landsat 8 International Journal of IT, Engineering and Applied Research (IJIEASR) 4 4-10.
[6] Hooke J M 1984 Change in river meandering - a review of techniques and results of analysis," Journal Physics Geography 473-508.
[7] Hooke J M 2013 River Meandering Treatise on Geomorphology 260-288.
[8] Faqih A 2017 A statistical bias correction tool for generating climate change scenarios in Indonesia based on CMIP5 Datasets Journal Earth and Environmental Science.
[9] Setiawan A 2017 *Analisis Data Statistik* (Salatiga: Tisara Grafika Salatiga).
[10] Lagasse P R, L W Zevenbergen, W J Spitz and C R Thorne 2004 *Methodology for Predicting Channel Migration* (Colorado: Transportation Research Board).
[11] Lang A, H R Bork, R Mackel, N Preston, J Wunderlich and R Dikau 2003 Change in sediment flux and storage within a fluvial system: some examples from Rhine catchment *Journal of Hydrologic Processes* 17 3321-34.
[12] Guneralp I, J D Abad, G Zolezzi and J Hooke 2012 Advances and challenge in meandering channel research *Geomorphology* 1-9.
[13] Yanan L, Q Yuliang and Z Yue 2011 Dynamic monitoring and driving force analysis on river and lakes in Zhuhai City using remote sensing technologies *Journal Environmental Science* 10 2677-83.