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Assessment of River Plan Change using RS and GIS Technique

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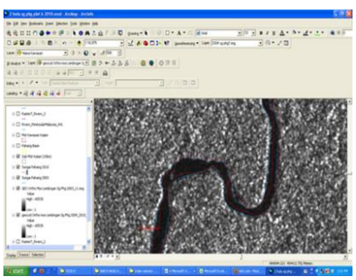
Graphical abstract



Abstract

Rivers is one of the complex natural systems. Classification of the river plan change is very important to know the river problems in early stage, where the classification database can help to understand the behavior of the river in each part. This article discusses about the classification of river plan change at the mainstream of Pahang River, Malaysia. Based on Geographical Information System (GIS) and Remote Sensing (RS) database, analysis of Types Of Lateral Activity (TYLAT) method and Modes of Meander Movement (MOME) method have been used to identify the evolution of the river plan change. The study results indicated, methods of TYLAT are more suitable to use for examining the evolution of river plan change for large and width rivers. While, method of analysis MOME index is more suitable for smaller types of rivers as the upper and middle reaches of the river. From this result, this study can be produced the basic information or database to understanding the characteristics or behavior parts in parts of the main Pahang River. This result also is very important to local authorities to know the early river problems in this area.

Keywords: River plan change, TYLAT index, MOME index, GIS, Pahang River

Abstrak

Sungai merupakan satu sistem semula jadi yang kompleks. Pengelasan perubahan pelan sungai adalah sangat penting bagi mengetahui masalah sungai di peringkat awal, di mana pangkalan data pengelasan sungai boleh membantu untuk memahami tingkah laku sungai di setiap bahagian. Artikel ini membincangkan mengenai klasifikasi perubahan pelan sungai di aliran utama Sungai Pahang, Malaysia. Berdasarkan data dari Sistem Maklumat Geografi (GIS) dan Remote Sensing (RS), kaedah analisis Jenis Aktiviti Lateral (TYLAT) dan Kaedah Pergerakan Meander (MOME) telah digunakan untuk mengenal pasti evolusi perubahan pelan sungai yang berlaku. Hasil kajian menunjukkan, kaedah TYLAT lebih sesuai digunakan untuk memeriksa evolusi perubahan pelan sungai bagi sungai berskala besar dan lebar. Manakala, kaedah MOME lebih sesuai untuk sungai yang lebih kecil atau di bahagian hulu dan pertengahan sungai. Daripada keputusan ini, kajian dapat menghasilkan maklumat asas atau pangkalan data untuk memahami ciri-ciri atau tingkah laku di bahagian-bahagian yang terdapat di aliran utama Sungai Pahang. Keputusan ini juga adalah sangat penting kepada pihak-pihak berkaitan untuk mengenal pasti permasalahan sungai dari peringkat awal.

Kata kunci: Perubahan pelan sungai, Indeks TYLAT, Indeks MOME, GIS, Sungai Pahang

1.0 INTRODUCTION

Study of river plan change is domain of fluvial geomorphology. Traditionally, this approach involves an empirically-based method of enquiry with the focus being on the relationships between forms and processes and between types of channel change and local environmental variables [1-3].

According to Huxley [4], study of river channel change involves integrating field observations of fluvial processes and process-form relationships into a coherent approach to examining rivers within river basins. The key aspect river channel change therefore is change in equilibrium. The use of the equilibrium concept reviews in detail by Montgomery [5], who highlights the problems of incorporating evolutionary change and historical constraints into working definitions of equilibrium. Montgomery also emphasized the difficulties of establishing causality at different spatial and temporal scales.

Central to any understanding of river equilibrium is the notion of stability. In essence, most rivers can be placed into one of three categories in term of stability, namely; a) Stable channels are characterized by beds and banks with little or no significant scour or erosion. Their planform and cross sectional geometry changes very slowly, it at all, with time and even interference with the flow in the channel causes only local changes in channel geometry. b) Dynamically stable channels continually scour and deposit bank material during times of moderate or high flows. Their cross sectional shape does not change progressively, but their planform does change as the channel migrates. Interference to flow due to river works can cause changes in channel geometry for some distance upstream and downstream. A meandering river is usually dynamically stable. c) Unstable channels are characterized by very high rates of erosion and bed material transport during floods and the main channel can shift to follow a different course during a flood. Rivers, which are braided, that is, consisting of more than once channel separated by bars or islands which are mobile during floods, are usually unstable. This type of unstable channel is common in Peninsular Malaysia [3].

Generally, channels that maintain a stable average form are considered to be in a state of equilibrium. According Lewin [6], equates this condition with regime theory which assumes a dynamic equilibrium whereby a channel is adjusted to its discharge regime and although the processes of erosion and deposition continue, the overall form is preserved to produce a dynamic stable pattern. Other workers interpret river equilibrium as being inherently unstable. Hickin [7] was defined the study of river channel changes as "the collection of empirical and theoretical studies concerned with the adjustment of channel cross sectional size, form and pattern shifts in environmental conditions". While there are many techniques used to study river channel change, in this study two major methods will be used for classification the Pahang River channel change with is Types of Lateral Activity (TYLAT) method and Modes of Meander movement (MOME) method [8-10].

2.0 EXPERIMENTAL

Pahang River or in Malay language, Sungai Pahang, is the longest river in Peninsular Malaysia with a length of 459 km and its upstream is located in the main range of Titiwangsa. Sungai Pahang which is located at Pahang River Basin is the main channel responsible for draining the water from this basin into the South China Sea [11-14]. Sungai Pahang is divided into the Tembeling and Jelai Rivers and both rivers meet at a confluence at Kuala Tembeling (Figure 1), which is located 300 km away from the estuary of Sungai Pahang (Kuala Pahang) [15-17].

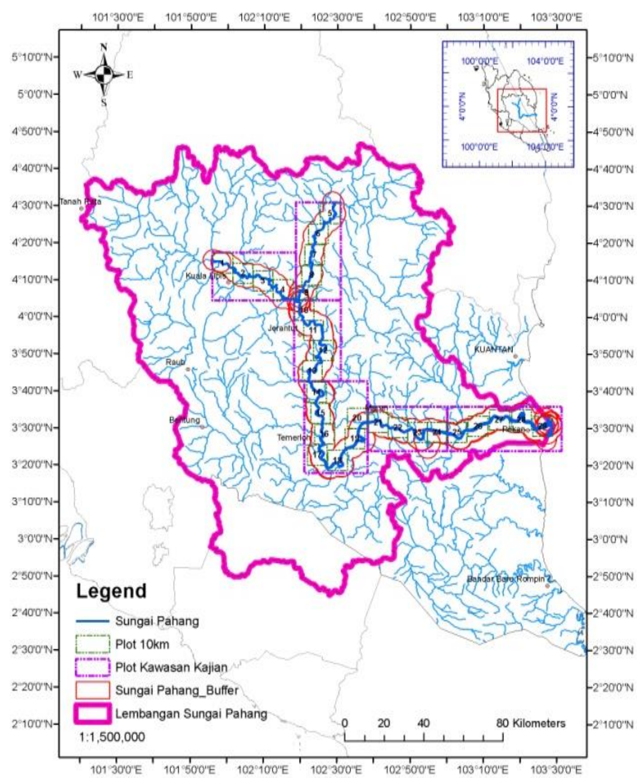


Figure 1 Location of plots at Pahang River, Malaysia

The length of this river thus reflects on the vast size of these basin areas, therefore, various problems arose, faced by the Pahang River and surrounding communities can be example to represent for Tropical River in Peninsular Malaysia. Other reasons why Pahang River has been chosen for investigation are the availability of good database and good maps covering the study areas for river change classification system study. In this study, the main focus is only on main river of Pahang River where, the river classification can be analysis. To facilitate the study was conducted; the main of Pahang River has been divided to sub-plot 1-29, according ±10 km^2, with 6 main plots. Where plot Ua, Ub and Uc represent as an upstream reach, Ma and Mb represent as middle stream reach and Da represent as a downstream reach (Figure 1).

Firstly, in this study, Type of Lateral change (TYLAT) refers to channels that exhibit to change due to lateral activities at main stream of the Pahang River. Six types of TYLAT is Meander progression, Avulsion, Increasing amplitude, Braiding, Progression and cut-off and Irregular erosion. Secondly, a Mode of Meander Movement (MOME) indicates changes in the meander loop at different years on the topographic maps and satellite image. Where, six types of MOME is Extension, Enlargement, Translation, Lateral Movement, Rotation and Complex change. The six types of TYLAT and MOME were illustrated in (Figure 2 and 3).

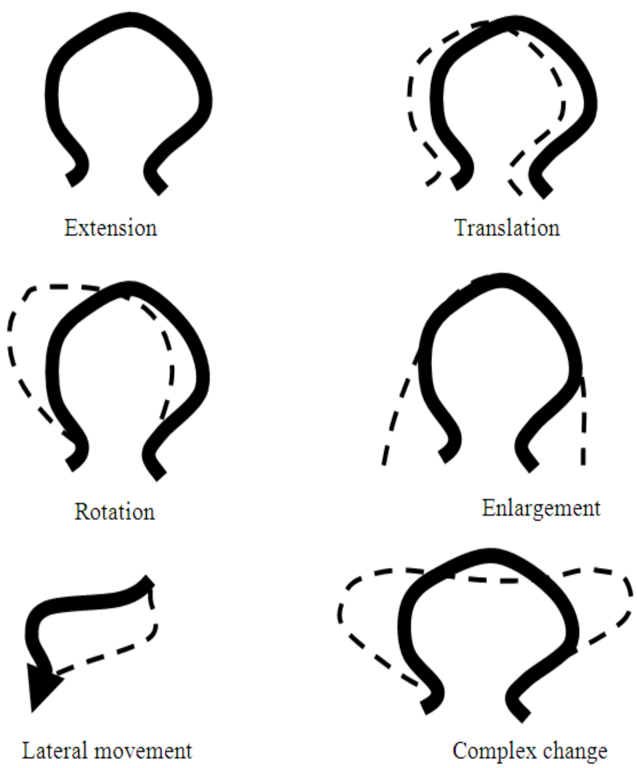


Figure 2 Modes of meander movement (MOME) method

The Geographic Information System (GIS) and Remote Sensing (RS) were used to identify the historical meander changes and produce the main database for the whole Pahang river basin. Where, the topographic maps with a scale of 1:50,000 m, on year 1932 and 1993, and image Satellite Radarsat-1 on 2003 and 2010 has been processed to get the data's. Next, each set of maps and imagery Satellite through the process of geo-reference with Projection: *Kertau_RSO_Malaya_Meters* and digitalization for river using polyline and polygon tool for the basin [11]. As the study requires high accuracy, the validation of the geo-reference process was conducted before the digitalization process was carried out in this process to ensure the total RMS error is minimized and adopted based on the scale used [11, 18].

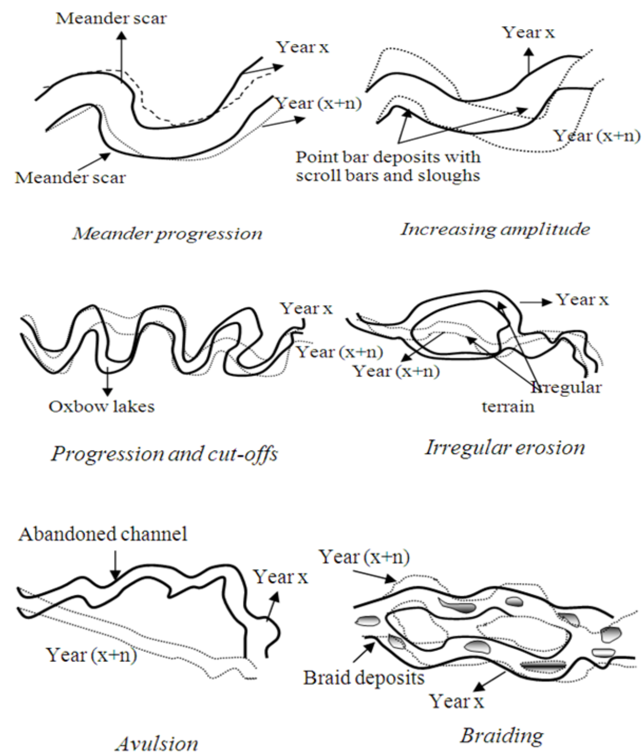


Figure 3 Types of Lateral Activity (TYLAT) method

For the validation of the analyzing of databases in this study, the rectified 1932 and 1993 maps, all maps using similar scale, were superimposed to detect reaches which registered changes. These changes were stored as new themes for the subsequent sinuosity analysis. One of the advantages of using GIS is that highly accurate measurements between points can be obtained.18 It also provides a rapid and convenient technique to compare the rectified map (year 1932) with the base map (year 1993) and 2003 to 2010 for image Satellite. Fixed reference points which could be identified from the two maps were located and their coordinates were noted to the nearest 0.1m. The differences between the coordinates (base map minus rectified map) were determined from X and Y directions. However, errors during the digitizing and rectification processes could still be significant and these can be evaluated using equations (1) and (2). Equation (1) provides the systematic error (s) which is defined as:

$$s = \frac{\sum x}{n} \tag{1}$$

Where, X = error at n reference point If s = 0, then the errors are random. However, if s were introduced, most likely during map rectification, then the value of s indicates the degree of channel 'shift' that has taken place. Secondly, the Root Mean Square Error (RMSE) was calculated as:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n}} \qquad (2)$$

Where:

Xi = The error at n reference point

RMSE = Provides the average error by which coordinates of the same point (or tics) on the two or more maps deviate

Such errors must be considered when measuring a shift in the channel alignment over the observation period. With GIS, the accuracy of the rectified maps could be measured against the base map by fixing several geo-reference points. The differences between the coordinates (base map minus rectified map) were determined in both X and Y directions [11].

3.0 RESULTS AND DISCUSSION

Based on a data analysis study, Table 1 shows the Types of river plan changes based on the TYLAT index for Main Stream of the upstream Pahang River. The highest number of cases on the evolution of the river plan change is the type of Meander progression where 25 cases for the 7 year period from 2003-2010 compared to 17 points cases in year 1932-1993. Meander progression was little changed at the banks of the river. Accuracy with using of the images satellite data on 2003-2010 is why this number changes are obtained (Figure 4). For increasing amplitude type, the river plan changes at Pahang River is 5 cases and one cases is Irregular erosion changes that occurred in year 2003-2010.

Meanwhile, for year 1923-1993, the types of changes are dominated by the Increase amplitude of only 18 cases that reflect the changes occurring as a result of water flow eroded on the river bends. Further, Meander progression type occurring 17 cases, Progression and cut-offs 16 cases, Irregular erosion 1 cases and Avulsion 8 cases. Progression and cut-offs and Avulsion it is a significant change over the river, this show, during the 61 years (1932-1993), the river flow on upstream of Sungai Pahang has undergone tremendous changes and thus will affect other factors such as discharge, plain floods and other [19-20].

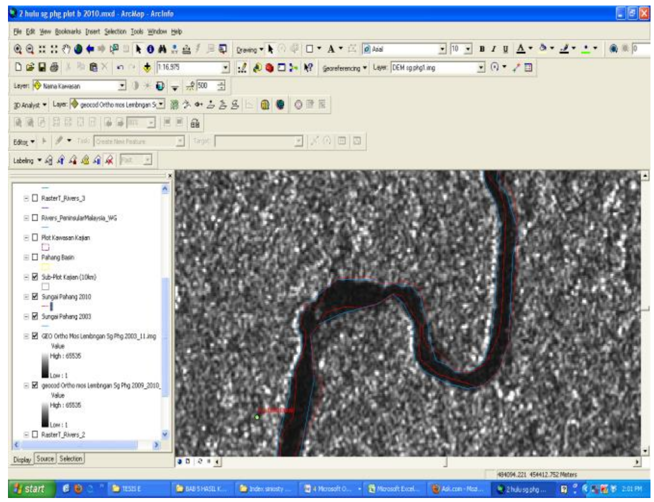


Figure 4 Among the major changes identified in the Meander progression in year 2003-2010 using satellite images at upstream of Pahang River

Table 2 shows the types of river plan changes based on the MOME index for Main Stream of the upstream Pahang River where occurred in 1932-1993 and 2003-2010. Type of Extension and Translation of river plan changes is happened in years 2003-2010 where 16 cases respectively, change of rotation is 6 cases and enlargement type is 2 cases. Pahang River affected by high flow, bank erosion and sedimentation processes that cause to the bay mender river plan seemed to budge [21-24]. This phenomenon can be seen as in Figure 5.

Table 1 Types of river plan change based on the TYLAT for upstream Pahang River

Sub-Plot	Meander progression		Increasing amplitude		Progression and cut-offs		Irregular erosion		Avulsion		Braiding	
	*61	*7	61	7	61	7	61	7	61	7	61	7
Ua1	1	3		1								
Ua2	2	4	4	2	2				3			
Ua3	2	2	1		3				2			
Ua4	2	2	3		3				2			
Ub1	2	5										
Ub2	1	2		1	3							
Ub3		1	1	1	4				1			
Ub4	3	1										
Ub5	1		2									
Uc1	1	2	1		1							
Uc2	1	1	1									
Uc3		1	3				1	1				
Uc4	1	1	2									
Σ	**17**	**25**	**18**	**5**	**16**		**1**	**1**	**8**			

**61 years for 1932-1993 and 7 years for 2003-2010 *datasin = number of cases*

Table 2 Types of river plan change based on the MOME for upstream Pahang River

Sub-Plot	Extension		Translation		Rotation		Enlargement		Lateral movement		Complex change	
	*61	*7	61	7	61	7	61	7	61	7	61	7
Ua1			1	3		1		1				
Ua2		1		2		2		1	4		3	
Ua3		1		2		2			3		2	
Ua4		4		1		1	2		2		2	
Ub1	1	3	2	2								
Ub2		1		2					3		1	
Ub3	1	1		1					3		1	
Ub4		1	1									
Ub5		1	2	1								
Uc1		1	1	1					1			
Uc2		1					2					
Uc3		1	1		1						1	
Uc4	1		1	1	1				1			
Σ	**3**	**16**	**9**	**16**	**2**	**6**	**4**	**2**	**17**		**10**	

**61 years for 1932-1993 and 7 years for 2003-2010 *datasin = number of cases*

Table 3 Types of river plan change based on the TYLAT index for Main Stream of the middle stream Pahang River

Sub- Plot	Meander progression		Increasing amplitude		Progression and cut-offs		Irregular erosion		Avulsion		Braiding	
	*61	*7	61	7	61	7	61	7	61	7	61	7
Ma1	1	3	2									
Ma2	2	1	1					1				
Ma3	1	1	2					1				
Ma4	2	1	1					2				
Ma5	2	1						1				
Ma6	2	1						2		1		
Ma7	1	1								1		
Mb1	1	1	1									
Mb2	1	1	2									
Mb3	2	1										
Mb4	1							1				
Σ	**16**	**12**	**9**					**8**		**2**		

**61 years for 1932-1993 and 7 years for 2003-2010 *datasin = number of cases*

Table 4 Types of river plan change based on the MOME index for Main Stream of middle stream Pahang River

Sub-Plot	Extension		Translation		Rotation		Enlargement		Lateral movement		Complex change	
	*61	*7	61	7	61	7	61	7	61	7	61	7
Ma1	1	1		2	1							
Ma2	1	1		1	1							
Ma3	1	1	1									
Ma4	1	1	1	1			1					
Ma5	2	1	1									
Ma6	1	1		2	1							
Ma7	1	1										
Mb1			1	1								
Mb2			2	1	1							
Mb3	3	1										
Mb4		1	1									
Σ	**11**	**9**	**7**	**8**	**4**		**1**					

**61 years for 1932-1993 and 7 years for 2003-2010 *datasin = number of cases*

Table 5 Types of river plan change based on the TYLAT index for Main Stream of the downstream Pahang River

Sub-Plot	Meander progression		Increasing amplitude		Progression and cut-offs		Irregular erosion		Avulsion		Braiding	
	*61	*7	61	7	61	7	61	7	61	7	61	7
Da1	1	1										1
Da2	1						1	1				2
Da3	1	1	1								1	2
Da4	1	1	1								1	3
Da5			1				1	1			3	4
Σ	4	3	3				2	2			5	12

**61 years for 1932-1993 and 7 years for 2003-2010 *datasin = number of cases*

Table 6 Types of river plan changes based on the MOME index for Main Stream of downstream Pahang River

Sub-Plot	Extension		Translation		Rotation		Enlargement		Lateral movement		Complex change	
	*61	*7	61	7	61	7	61	7	61	7	61	7
Da1	1		1									
Da2			1									
Da3	1	1	1									
Da4	1											
Da5	1											
Σ	4	1	3									

**61 years for 1932-1993 and 7 years for 2003-2010 *datasin = number of cases*

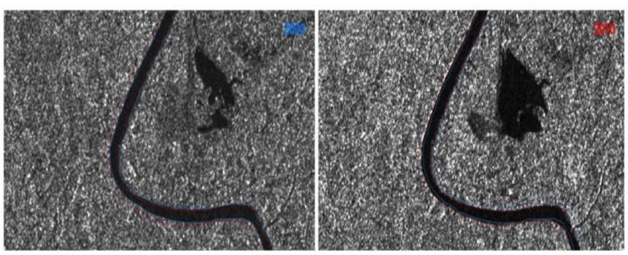


Figure 5 Among the major changes identified with the Extension and Translation using satellite images at the upstream of Pahang River

Evolution of river plan changes for year 1932-1993 showed the highest change is Lateral movement of 17 cases followed by 10 cases of Complex changes, Enlargement with 4 cases, 3 cases of Extension changes and Rotation with 2 cases. This shows that, within 61 years and significant changes have occurred in the upper reaches of Pahang River.

From the result, Figure 6 and 7 showed the evolutionary of the river plan changes in middle stream of Sungai Pahang for plot Ma and Mb on 1932-1993 and 2003-2010. Generally, a significant rather change can be shown for 1932 and 1993 in which the 61-year period, the change in many locations along the river without a significant change in the original plan of the river is not like in the upper reaches of the Pahang River as before. The initial hypothesis shows the flow speed limit in this area starts to slow down and the occurrence of sediment deposition processed products. River plan form also began to stabilize with the occurrence of evolution is not significant.

Table 3 shows the types of river plan changes based on the TYLAT index for the mainstream of the middle stream Pahang River. For the years 2003-2010, the river plan changes that occur only from the type of Meander progression, Irregular erosion and Avulsion were recorded 12, 8 and 2 cases respectively. It shows only the small changes occurred for 7 years. Whereas the type of Irregular erosion and Avulsion is due to the changes that occur to the Sediment Island or Braided in the main stream of the Pahang River as shown in Figure 8. Where in year 2003, the island still exists, but may be due to the process of sedimentation and flooding events that occur during the next seven years, this Island has merged and become a river bank again. For the year 1932-1993, the river plan changes that occur only from the type of Meander progression and Irregular erosion of 16 and 9 cases respectively. Although each type of change is not significant in the plan of the river, but the case is more and can make a major impact on the health of the environment and to the geometric river plan changes.

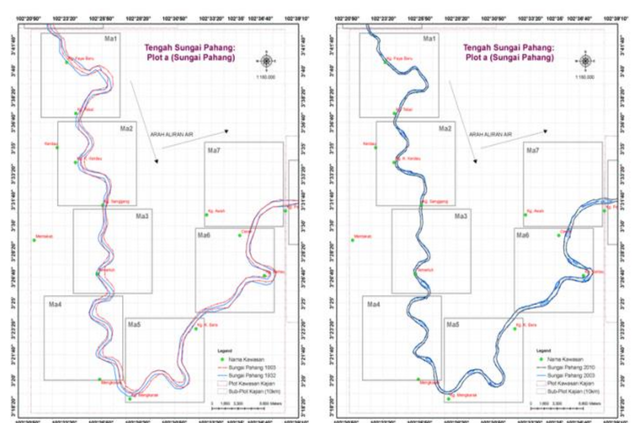


Figure 6 River plan changes for plot Ma on 1932-1993 and 2003-2010

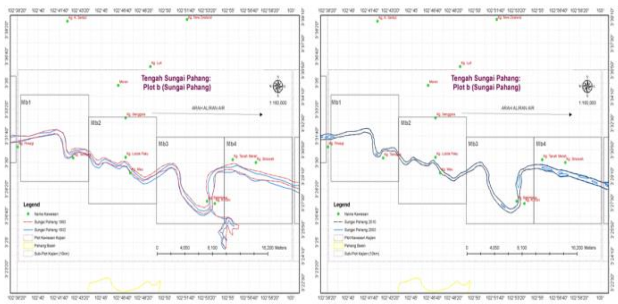


Figure 7 River plan changes for plot Mb on 1932-1993 and 2003-2010

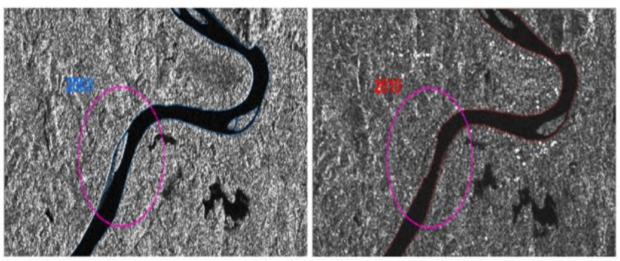


Figure 8 Among phenomenon of *Irregular erosion* and *Avulsion* identified in mainstream of the middle stream Pahang River

Table 4 shows the types of river plan changes based on the MOME index for main stream of the middle stream Pahang River. In year 2003-2010, the river plan changes that occur only from the type of Extension and Translation of 9 and 8 cases respectively. While in year 1923-1993, the type of Extension is dominating this trend by recording 11 cases, followed the Translation by 7 cases, Rotation of 4 cases and Enlargement of 1 case. The evolutionary changes of the river flow in midstream area are viewed are not increasingly significant that shows the flow of the river become more stable in the middle stage.

Figure 9 shows the evolution of the river plan changes in downstream of Pahang River for plot Da on year 1932-1993 and 2003-2010. Generally, the river plan changes can be seen decreasing as compared to the upper and middle reaches of the river. On the other hand, the significant change can be seen in the downstream area on the Pahang River, which is located in the sub-plot Da5.

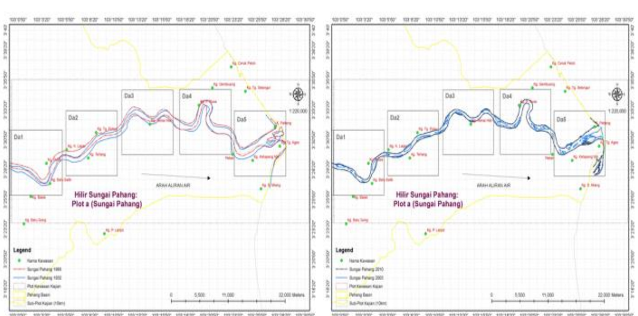


Figure 9 River plan change for plot Da (downstream) on 1932-1993 and 2003-2010

The change type of braiding is seen to dominate area where the islands are formed from the deposition of sediment or braided. The change at estuary shore erosion caused waves can also be seen clearly in the sub-plots (Figure 10). This area is also affected by tides which causes the flow rate to be slow.

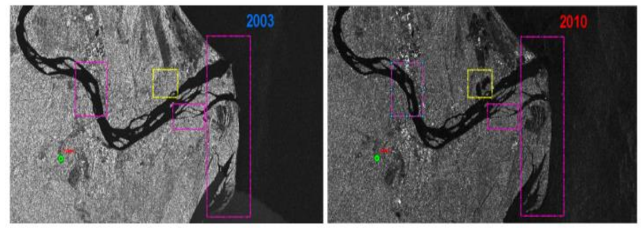


Figure10 The evolution of the Pahang River change at downstream areas on 2003-2010

Table 5 shows the types of river plan changes based on the TYLAT index for main stream of the downstream Pahang River. For the two-year difference that has been identified change the type of Braiding has dominated this area with each recorded 12 cases in 2003-2010 and 5 cases in 1932-1993. This is because these areas are in the estuary area and get the direct impact on tidal from the South China Sea. Further, the type of change that occurred on 2003-2010 is the Meander progression and increasing amplitude with 3 cases respectively and Irregular erosion with 2 cases. For the year 1932-1993, type of change is Meander progression, Increasing amplitude and Irregular erosion with 4, 3 and 2 cases respectively.

Table 6 shows the types of river plan changes based on the MOME index for main stream of the downstream Pahang River. In the year 2003-2007, only one case recorded were types of river plan changes is extension in sub-plot Da3. While, in year 1923-1993, there 4 cases recorded for an Extension and 3 cases of Translation. In this study, Analysis of MOME index is identical more matches to use for upstream reach versus downstream area of the river.

4.0 CONCLUSION

This study tries to be understanding and classify the evolution of the river plan change based on TYLAT and MOME indexes. For overall, based on this study, the methods of TYLAT are more suitable to use for examining the evolution of the river plan change for large and width rivers. While, method of analysis MOME index is more suitable for smaller types of rivers as the upper and middle reaches of the river.

Therefore, this study on river classification hopefully can be contribute to provide better communication among those studying river plan change systems and promote a better understanding of river processes and helping put principles into practice. This study also can be very important to local authorities to make decisions according to the evolution of the river plan change for future study of Pahang River, Malaysia specifically and for Tropical River generally.

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