Assessment of river bank erosion at Kilim River, Langkawi using geospatial technique

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Abstract. In Malaysia, the reduction of mangrove area is very serious which urges government to take appropriate and stern action to solve this problem. The study area is in Kilim River, Langkawi, one of the most attractive tourist spots in Malaysia. This area is now under the threat of significant river bank erosion caused by intensification of tourism that visited this wonderful mangrove area. In this study, geospatial technique is used for assessment of river bank of Kilim River, Langkawi, Kedah. It is one of the main tourist attraction in Malaysia with UNESCO recognition since 2007 as Kilim Geoforest Park. It is well known as nature reserve that consist of various amazing flora and fauna in the mangrove area. In this area, the tourists hired boat to visit the surrounding area. However, there are too many boats used, many trips and uncontrolled speed boat that caused river erosion. The aim of this research is to assess river bank erosion using remote sensing image and GIS tools in analyzing the impact that caused river erosion by the tourist speed boat. In order to determine the rate of changes of river erosion occurred along the river bank, Digital Shoreline Analysis System (DSAS) software is used in this research which highlight two main statistical analysis of Net Shoreline Movement (NSM) and End Point Rate (EPR) of both sides of the river bank. The output of this study shows significant changes of river erosion and also accretion along the river bank which can be seen by the extraction or river line. Also in this study, the migration of mangrove trees is also examined. In conclusion, the impact towards the migration of mangrove trees and riverbank erosion can be identified and predicted based on several epochs of observation using remotely sensed data.

1. Introduction

River bank erosion in Malaysia is one of the impulsive and major threats and may cause sediment accumulation that will lead to intensification of river pollution problems [1]. Kilim River, Langkawi is one of the main tourist attraction and river bank erosion are apparent along the river and over a decade the development had caused the mangrove ecosystem degraded [2]. Mangrove forest deterioration caused a great deal of ecological and economic loss [3]. Various coastal hazards like coastal erosion, seawater erosion and others happened due to various development projects made along the coastal area [4]. Mangroves migrate at considerable speed with current distribution of forests a legacy of the Holocene according to geological perspective [5]. Impacts can be seen through loss of life and property, harbour security, change of the coastal socioeconomic environment and decreases of coastal land resources [6].

The study investigate the role of coastal development activities in the degradation of Kilim River, Langkawi, Kedah as mangrove ecosystem is important in the coastal zone [2]. A halt on further development and agriculture activities in estuaries within 400m of the coastline that should be left untouched were announced by the Malaysian Government in late 1996 to further support the conservation [3]. Nevertheless, the development of touristic location and expansion of built environment surrounding and near touristic locations created pressure on lands [7]. Langkawi Department Authority (LADA) is concern about the problem of river bank erosion along Kilim River will give impact to the ecosystem and thus the status of Kilim Geoforest Park could be withdrawn. Therefore effective conservation and sustainable resource utilization need to be formulated to ensure dynamic link in between scientific work occurring in the field and the living community of the community [8]. One approach is to document forest dynamics which employs remote sensing imagery.

The objective for this study is devote for modelling of river bank erosion and affected mangrove area using geospatial technology. Small scale river bank erosion can be measured using Real-Time Kinematic (RTK) GPS. Large area erosion mapping can be done by means of aerial photogrammetry. For assessment of mangrove habitat, integrated analysis between aerial photogrammetry which utilised UAV and shoreline evolution is employed. Also Digital Elevation Model (DEM) is used to simulate water levels in GIS environment and model the shoreline evolution for the projected scenarios. There are numerous studies that describe temporal changes in spatial extension of mangrove ecosystems such as shifts in species composition, changes in mangrove cover before and after natural hazards, and dynamics of mangrove forest types [9].

2. Materials and Methods

The assessment of river bank erosion is analyze using geospatial technique with the extension of Digital Shoreline Analysis System (DSAS). DSAS is free software used to calculate shoreline change statistics through vector data. This software is intended for use on coastal environments but it is useful in other environments that display boundaries like snowlines, land cover and vegetation lines [10]. The shorelines extracted from the satellite images are analyzed using DSAS software for measurement of erosion rate and retreating along the coastal area [10]. The main application of DSAS is in utilization a range of statistical change measures based on the comparison of shoreline positions through time [11]. Short-term and long-term periods of shoreline variation was mapped to provide an immediate insight of trend in shoreline evolution and help decision makers to report coastal issues more efficiently within a reasonably shorter time [12].

DSAS introduced numerous statistical analysis based on the rate of change of river bank. In this paper, there are two main statistical analyses were used which is Net Shoreline Movement (NSM) and End Point Rate (EPR). The distance in between oldest and the youngest shoreline for each transect were calculated as NSM, meanwhile EPR is a product of dividing the NSM by the number of years elapsed between the two shoreline, negative NSM or EPR indicate erosion while positive indicate accretion [13].

This method requires the extraction of river bank positioning based on multi-temporal high spatial resolution remote sensing imagery. The uses of Very High Satellite Imagery (VHSI) compared to aerial photogrammetry provide image with similar spatial resolution and many studies been using the VHSI to map vegetation communities [14].

2.1. Description of Study Area

The study area for this research is at Kilim River, Langkawi, Kedah, Malaysia. This area is selected because Kilim River is declared as Kilim Geoforest Park by UNESCO in 2007. It is well known nature reserve with various amazing flora and fauna of mangrove area. The approximately 100 square kilometers covered by mangrove area is one of the tourists' attraction. The whole area is administered and protected by the Peninsular Malaysia Forestry Department. It is part of the larger Langkawi

Geopark and one of the biggest hot spots of Eco tourism in the entire region. Through the Kilim River, there are dense green mangroves also known as wetland mangroves that protect the shorelines. On some areas of the study area there are gigantic limestone rock rising from the river bed. Figure 1 depicts the study area in red polygon.

Figure 1. Study Area of Sungai Kilim, Langkawi, Kedah

2.2. Data Sources

The data used in this research are high spatial resolution remote sensing imagery of Quick Bird and World View 2. Projection used in this study area is WGS84 Universal Transverse Mercator (UTM) 47North. Table 1 shows the satellite image used in determining river bank boundary.

Table 1. Data sources information used in the study

Type of Data	Year	Resolution
Quick Bird	2005	0.6m-panchromatic 2.0m-multispectral
World View 2	2012	0.5m-panchromatic 2.0m-multispectral

3. Results and Discussion

The Digital Shoreline Analysis System (DSAS) is used as a tool extension in analyzing the rate of shoreline changes based on digital images. DSAS can be used to execute the rate of change of river estuaries in determining any changes occurred along the river bank. There are two types of analysis involve in measuring the rate of change of river bank, which is Net Shoreline Movement (NSM) and End Point Rate (EPR). There are two major baseline across the river named as Transect 1 and Transect 2. The results and analyses are as follows. Transect 1 covers area of 2440m from Bat Cave up to the first corner after the jetty (Figure 2). While Figure 3 depicts the NSM of Transect 1.

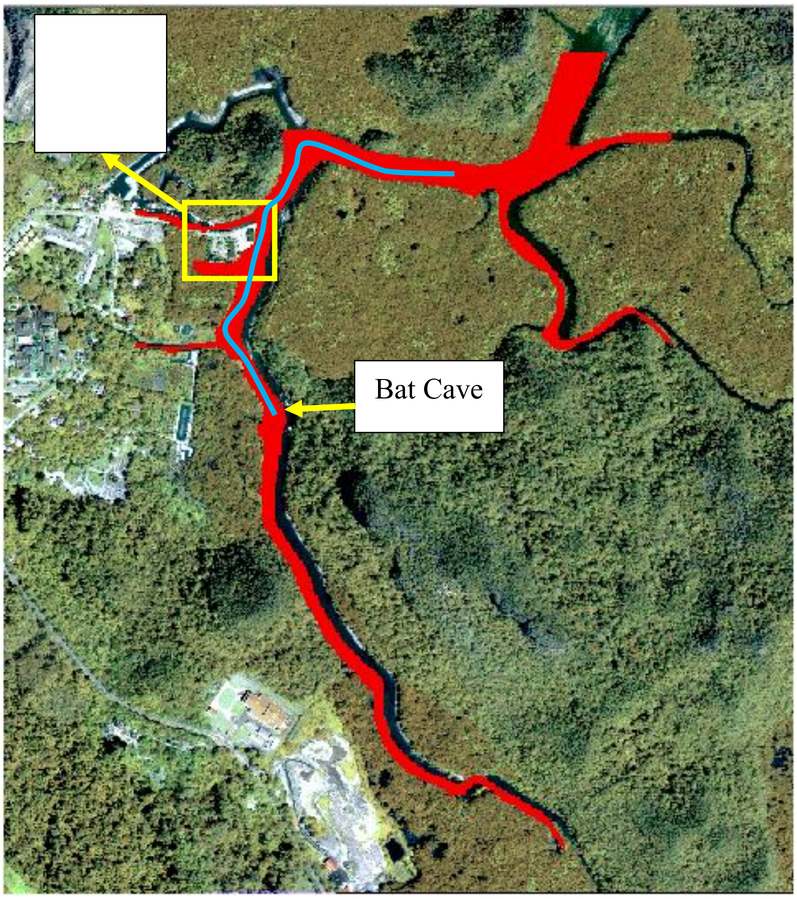

Figure 2. Area of Transect 1

River bank rate of change analysis are conducted in two different period of year 2005 and 2012. The distance in between two years are measured separately for the left and right side of the riverbank. Then both side of riverbank were merge together to be analyzed. The result shown in Table 2 indicate the rate of erosion and accretion along the river using NSM and EPR analysis. The percentage of erosion is 23.67% with maximum erosion of 9.135m. The area which is undisturbed area before the jetty indicate tremendous accretion from analysis obtain which indicate 76.33% of accretion along the river with maximum accretion of 24.25m.

Table 2. Transect 1 rate of change using NSM and EPR analysis

	Erosion		**Accretion**	
Analysis	NSM(m)	EPR(m)	NSM(m)	EPR(m)
Maximum	9.135	1.335	24.250	3.55
Minimum	0.055	0.005	0.085	0.01
Mean	4.595	0.67	12.168	1.78
Percentage %	23.67		76.33	

The maximum erosion EPR from Table 2 is 1.335m which indicate the rate of erosion per year throughout the 7 consecutive years from 2005 to 2012. The value is obtain from the NSM value divided by years in between those two years of data. While the maximum EPR of accretion is 3.55m per year.

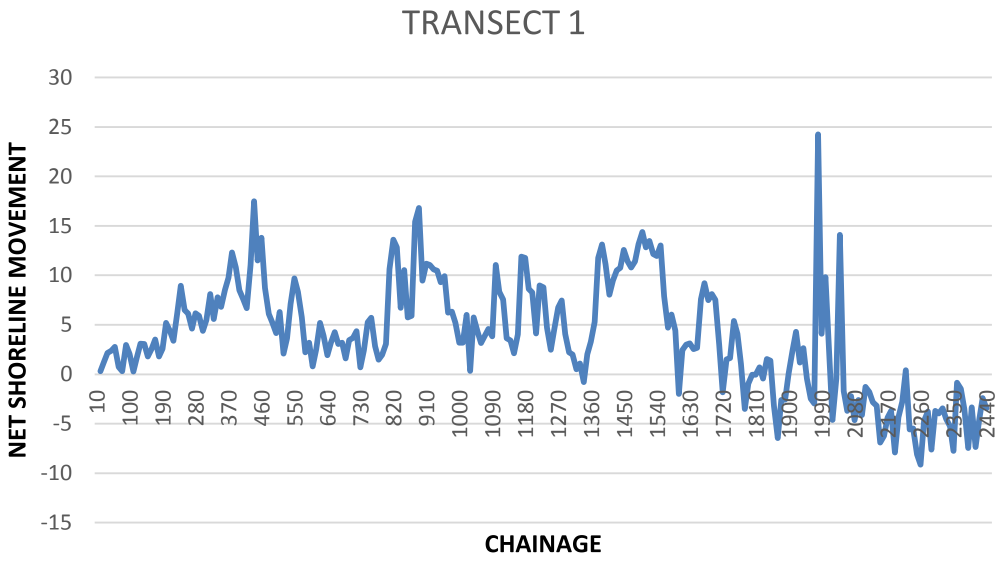

Figure 3. Net Shoreline Movement (NSM) of Transect 1

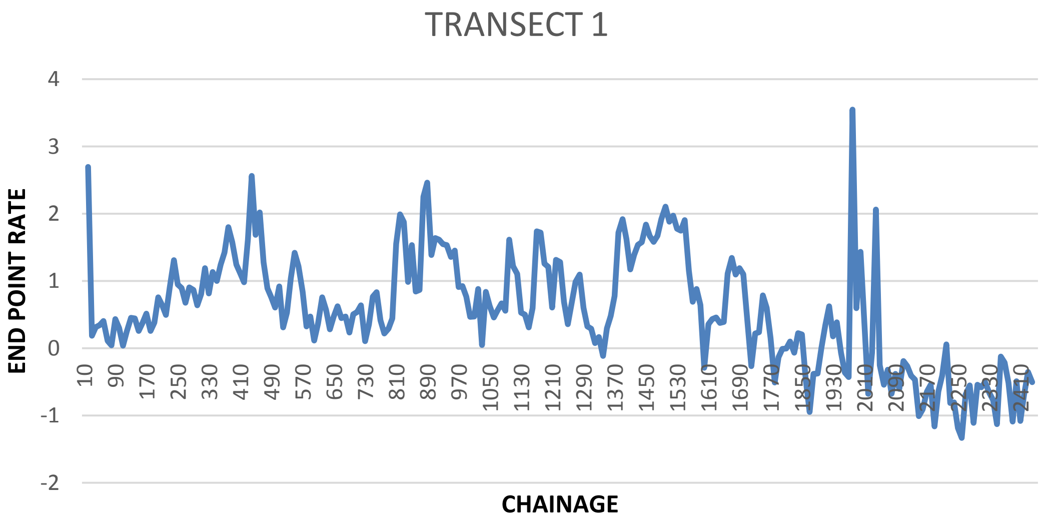

Figure 4. End Point Rate (EPR) of Transect 1

Figure 3 and Figure 4 above show a line graph of rate of change along transect 1 for NSM and EPR respectively. From the above graph, the results show that the first segment of the graph indicate accretion while towards the end of transect the graph start to decline which indicate the erosion. The Kilim River data are spatially interpolate using Inverse Distance Weightage (IDW) to produce raster distribution analysis for better data interpretation. From the raster distribution shown in Figure 5 and Figure 6, the most intense erosion is indicated by red colour which can be seen at the first corner after the jetty and toward the river mouth.

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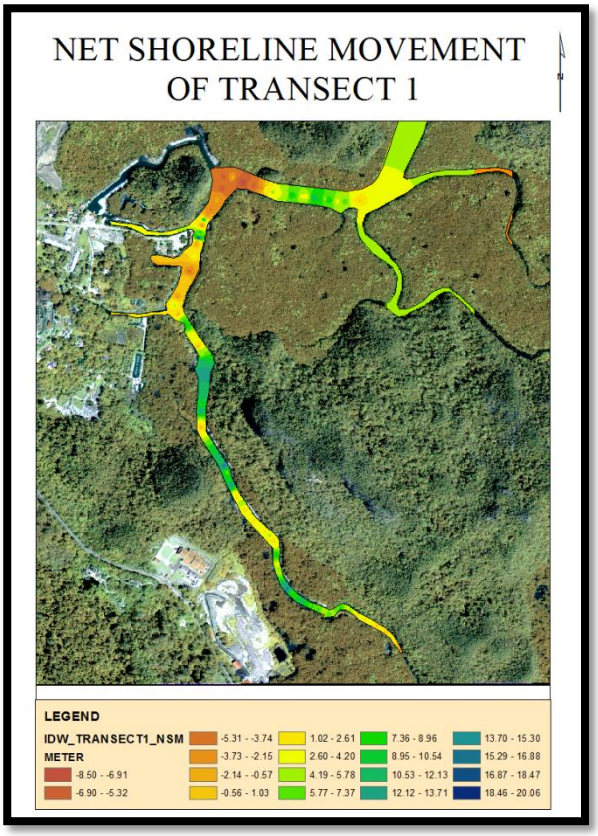

Figure 5. Spatial Interpolation of Transect 1 Net Shoreline Movement Analysis

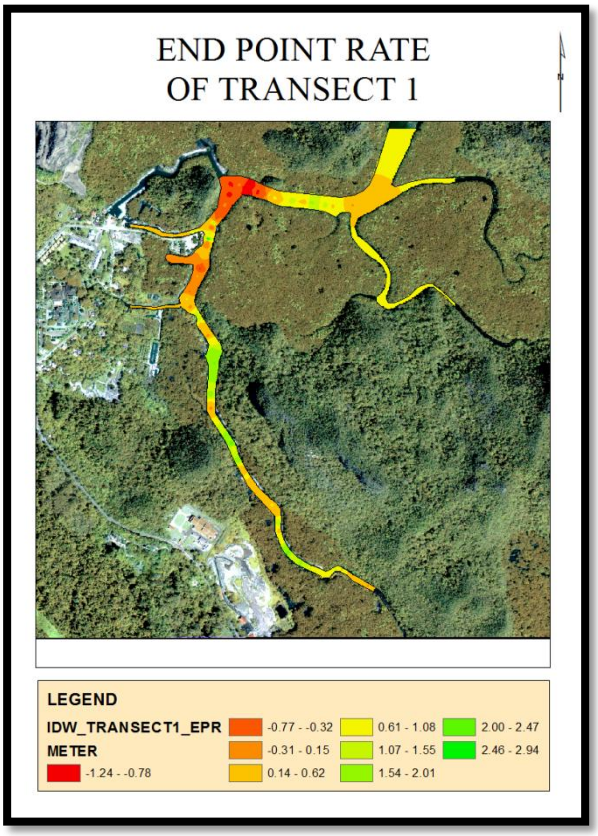

Figure 6. Spatial Interpolation of Transect 1 End Point Rate Analysis

For transect 2 (i.e blue line), it covers an area of 1290m after the corner of severe river bank erosion up to the river mouth. Toward the river mouth, this area is the route for tourism activities, where tourist could explore the nature by using speed boat (Figure 7).

Table 3. Transect 2 rate of change using NSM and EPR analysis

	Erosion		**Accretion**	
Analysis	NSM	EPR	NSM	EPR
Maximum	9.98	0.580	17.7	0.075
Minimum	0.01	0.005	0.07	0.010
Mean	4.995	0.293	8.885	0.043
Percentage %	66.43		33.57	

The results show 66.43% of erosion with maximum erosion of 9.98m (Table 3). The accretion of transect 2 is 33.57% with maximum accretion of 17.7m. The rate of erosion per year is 0.580 and rate of accretion per year is 0.075. This result indicate that toward the river mouth the rate of erosion is increasing while the rate of accretion is decreasing.

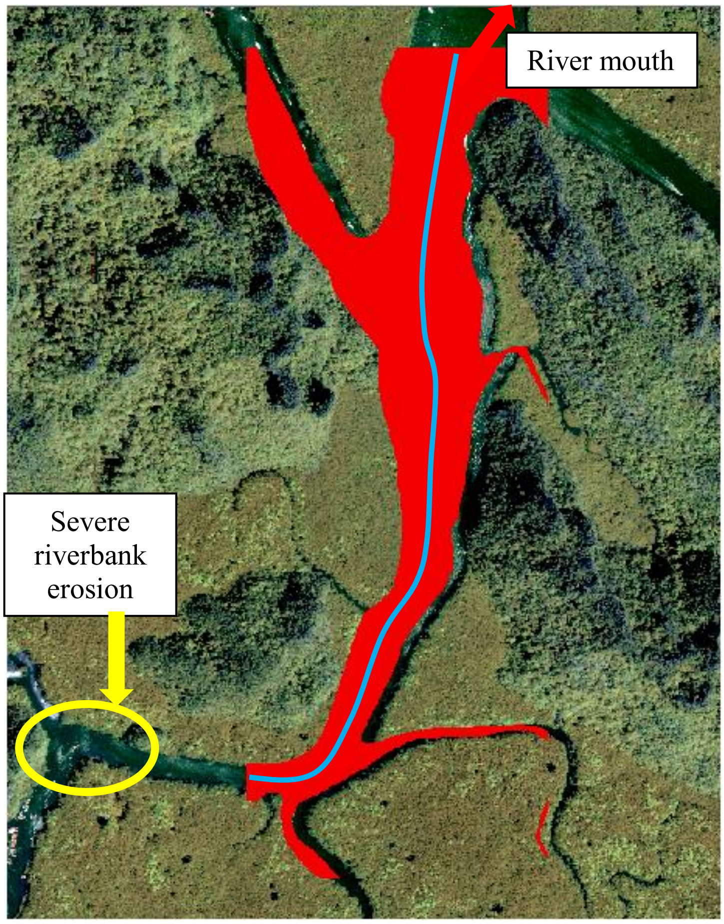

Figure 7. Area of Transect 2

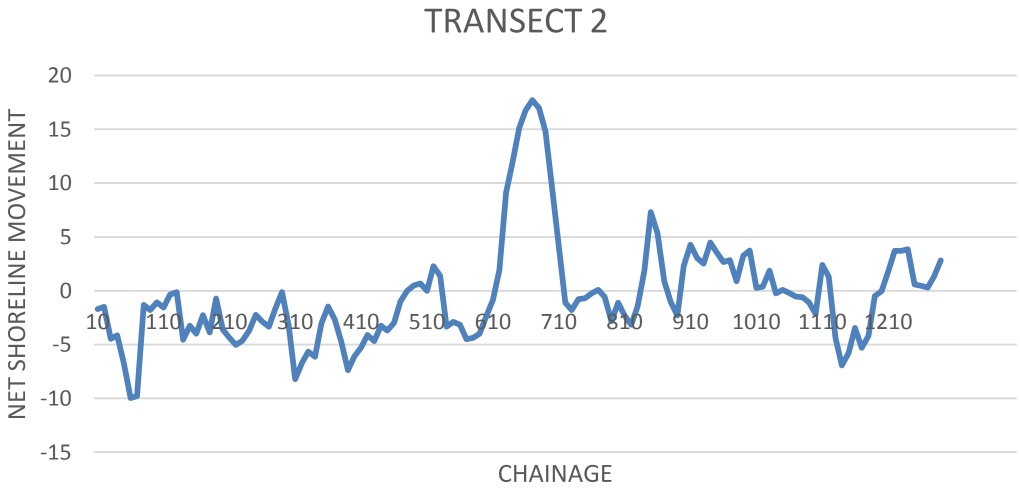

Figure 8. Net Shoreline Movement (NSM) of Transect 2

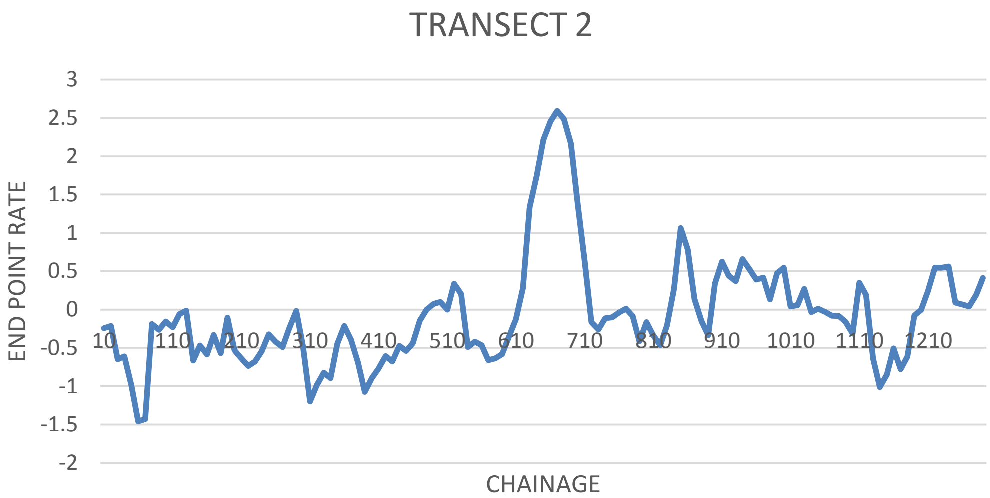

Figure 9. End Point Rate (EPR) of Transect 2

Figure 8 and Figure 9 above show a line graph of rate of changes along transect 2 for NSM and EPR respectively. The graph show that after the jetty the trend is decreasing which indicate erosion towards the river mouth

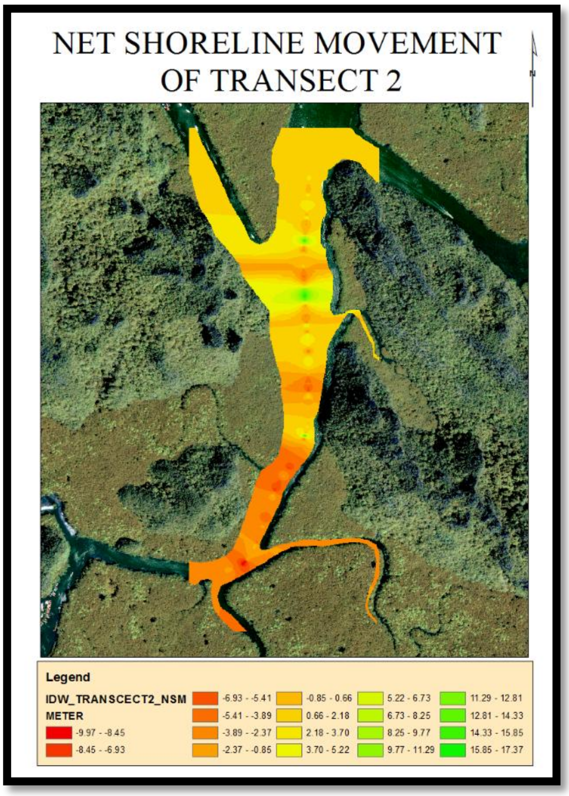

Figure 10. Spatial Interpolation of Transect 2 Net Shoreline Movement Analysis

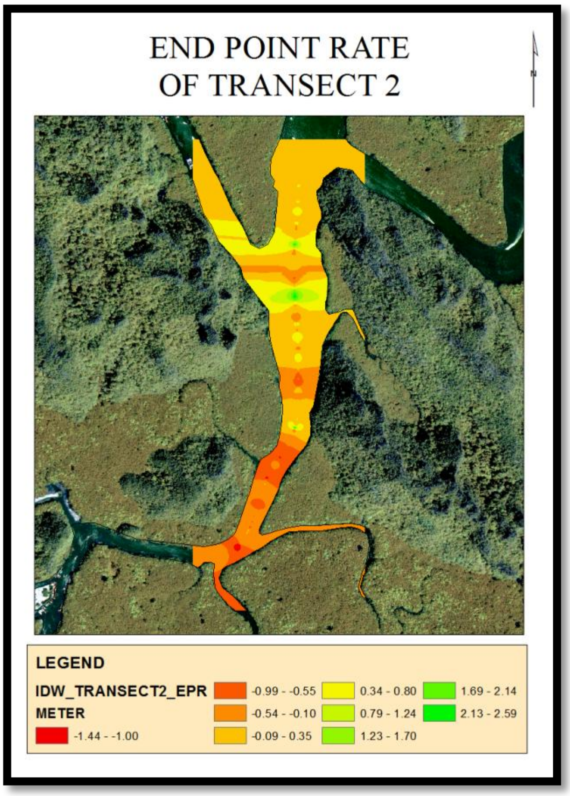

Figure 11. Spatial Interpolation of Transect 2 End Point Rate Analysis

Better interpretation of data are portrayed in Figure 10 and Figure 11 where red colour indicate erosion while the yellowish to green colour indicate accretion along the river. These results also pointed out the statistic previously discussed in Table 3.

4. Conclusion

Kilim River is one of the main attraction in Langkawi. It is also known as Kilim Geoforest Park declared by UNESCO in year 2007. Thus, it has attracted many tourists and the intensification of tourism activities had caused the physical environment to change immensely throughout the year. This study provided a statistic of rate of change using geospatial technique of DSAS with high spatial resolution satellite image. The result obtain from two different timeline of year 2005 and 2012 had shown that there are more accretion for undisturbed area of transect 1 and there are more erosion of transect 2 towards the river mouth which is mainly the tourist main route for tourism activities. Transect 1 shows 76.33% of accretion which indicate the true nature a river should be as the area was not disturbed by tourism activity. Meanwhile transect 2 show 66.43% of erosion as the impact of tourism activity. Therefore further research are needed to make sure the sustainability of Kilim River ecology system.

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