

UDC 528.472

## GEOVISUALIZATION FOR INFORMATION EXTRACTION OF SHORELINE CHANGES IN PADANG CITY 2000–2020

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Received 12 January 2021; accepted 23 May 2022

**Abstract.** This study aims to create a system model that implements the concept of Geovisualization on shoreline changes in Padang city. This implementation is to make it easier to identify shoreline changes. The method used to detect changes is by interpreting satellite imagery with the Modified Normalized Difference Water Index (MNDWI) approach and the Digital Shoreline Analysis System (DSAS). The imagery used is Landsat 7 and Landsat 8 from 2000 to 2020. The model is designed with a Software Development Life Cycle (SDLC) approach. The results obtained are in the form of twenty shorelines per year as well as the amount of abrasion and accretion values from the interpretation. These results are visualized on an online-based map system that allows users to explore, synthesize, present and analyze the interpretation data. In conclusion, the Geovisualization system model is able to make serial data imagery presented dynamically to facilitate identification of shoreline changes.

**Keywords:** geovisualization, shoreline, Landsat, MNDWI, DSAS, SDLC, online-based map.

### Introduction

Poverty alleviation and reducing inequality in the world community are the goals of the initiation of *Sustainable Development Goals* (SDGs). One of the important points to be achieved in the SDGs is to create sustainable cities and communities by adopting and implementing integrated policies towards resource efficiency, mitigation and adaptation to environmental changes and *resilience* to disasters (United Nations, 2015). One of the negative impacts of development of uncontrolled coastal areas is erosion, which causes changes in the shoreline (Fajrin et al., 2016). Most of the population living in coastal areas causes people to be vulnerable to exposure to disasters, especially erosion (abrasion and accretion) so as to change the social structure of the community such as changes in livelihoods.

The city of Padang is the capital of West Sumatra Province, which is on the West Coast of Sumatra, which faces directly to the Mentawai Strait and the Indian Ocean. The total area of the City of Padang is 1,414.96 km<sup>2</sup>. The City has 939,112 inhabitants in 2018. The livelihood structure of coastal communities in Padang City is dominated by fishermen, entrepreneurs and traders who are evenly distributed in each coastal village in Padang City (Haryani, 2016).

To minimize and form coastal communities resilient to climate change and disasters, it is necessary to have digital information readily available in both news and complex spatial data that can be accessed online, and can be easily understood by the general public and the availability of data that can be used for reference or future research on an existing phenomenon.

Spatial data has an important role to play in making decisions related to events on Earth. In the context of disaster emergency response, the main mission of this activity is to save the lives and environment of the victims in a short time (Yulfa et al., 2019). Geovisualization is a process of analyzing geospatial data with visualization that is activated through convergence of information, cartography and geographic methods (Kraak & Ormeling, 2010). Geovisualization is an approach that looks at spatial data from various perspectives to gain new knowledge related to these data (Murasugi, 2019). Geovisualization uses maps as the basic material because maps are key visualizations to make it easier to see the complexity of the relationships between phenomena or object features recorded in them (Laurini, 2017).

Based on the description above, to answer this need, to create a system model that implements the concept of Geovisualization on shoreline changes in Padang city the researcher wants to provide digital information regarding

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the changes in the Padang City shoreline from 2000 to 2020 to see the changes that occur every year whether there is erosion and reduction of the Padang City Beach Lip Area due to abrasion or increase in the coastal area due to sediment deposits.

Therefore, the following research objectives are presented:

1. Facilitating the identification of changes in the coastline in the city of Padang.
2. Giving knowledge related to changes in the physical phenomena of Padang City Beach.

### 1. Methodology

The research location is Padang City, the capital of West Sumatra Province (Figure 1). It is in the West Sumatra Coastal Area. The city faces directly to the Mentawai Strait and the Indian Ocean. The area is about 1,414.96 km<sup>2</sup>. Geographically, the city of Padang is between 0° 44' 00" and 1° 08' 35" south latitude and between 100° 05' 05" and 100° 34' 09" East Longitude. Padang City, which stretches from north to south, has 68.126 km long beaches (PEM-KOPADANG, 2020).

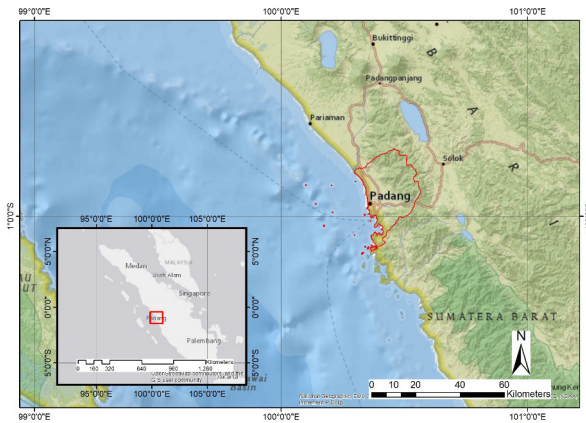


Figure 1. Research location

### 1.1. Data

One form of remote sensing technology use is the detection of coastlines using Landsat satellite imagery. Landsat images that can be used are Landsat 7 and 8. These two images have the same spatial resolution of 30 meters and the wavelength value of the NIR channel is not much different, such as Landsat 7 with a wavelength of 0.772–0.898 μm and Landsat 8 with a wavelength of 0.851–0.879 μm.

### 1.2. Approach

This research approach uses 2 (two) approaches, namely remote sensing and the *System Development Life Cycle* (SDLC).

### 1.3. Remote sensing data processing

This research was conducted with two approaches, namely remote sensing and the *System Development Life Cycle* (SDLC). The initial stages of this research are *pre-processing* Landsat 7 and 8 images, *processing* and *post processing*. The following shows the flow of data processing (Figure 2).

#### 1.3.1. Pre-processing of Landsat data

The initial stage carried out is *pre-processing* of Landsat images. The dynamics of satellite position and the movement of satellites generally cause distortion which results in the geometric position of the image that does not match the actual position. Therefore, it is necessary to repair/correct geometric images. The *root mean square* (RMS) value of 0 indicates no position error, while the RMS value of 1 means that there is a distortion error of 1 pixel. In this case the Landsat image has an error of 30 meters. Geometric accuracy is measured by the value of RMS – *error* (*Root Mean Square Error*) following equation (Schroeder et al., 2011):

$$RMS - Error = \sqrt{(x' - u^0)^2 + (y' - v^0)^2} \tag{1}$$

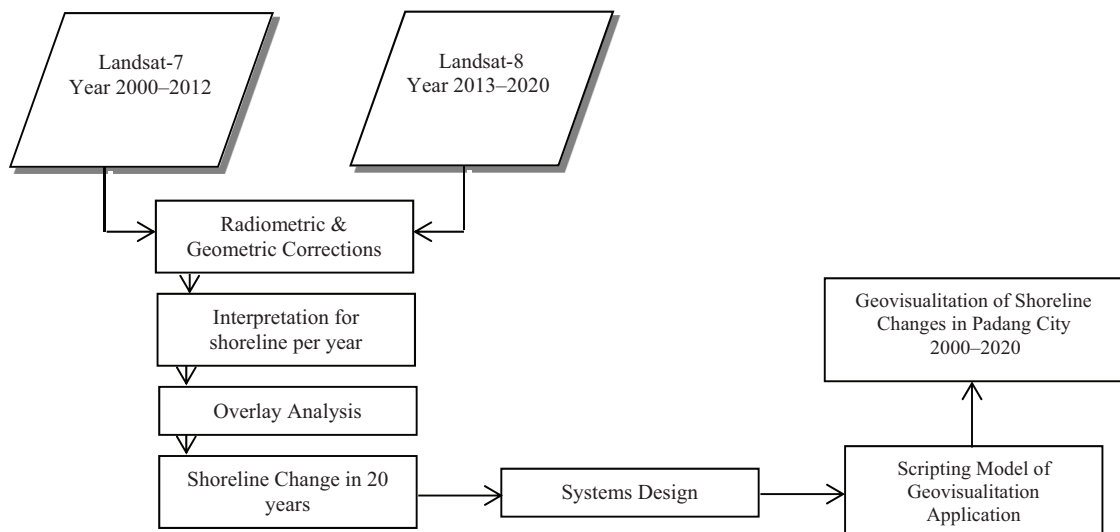


Figure 2. Research flowchart

where:  $x$  – latitude on the map;  $y$  – longitude on the map;  $u$  – row on the image;  $v$  – column in the image.

The next stage *pre-processing* is the improvement *striping* by making a Landsat-7 ETM + SLC OFF data mosaic. This mosaic process is a process of filling the *gap* in the SLC OFF data. Filling the *gap* using Landsat-7 ETM + SLC OFF data which has a different acquisition time with the help of software *Envi 5*.

### 1.3.2. Modified Normalized Difference Water Index

In remote sensing, there are many methods for analyzing shoreline changes, one example of this method is the NDWI or the *Normalized Difference Water Index*. NDWI is an algorithm that is useful for distinguishing between land and water in satellite images. Basically NDWI uses two non-infrared channels, with a wavelength of 0.86  $\mu\text{m}$  and 1.24  $\mu\text{m}$  (Gao, 1996). The latest development of the NDWI method is to modify the algorithm so as to produce a new method, namely the MNDWI or *Modified Normalized Difference Water Index*, this method is efficient enough to emphasize the differences between water areas and urban areas. With the modification of the previous NDWI, some of the limitations such as detecting soil and shapes can be overcome.

The bands used in the MNDWI algorithm are bands with a wavelength of 0.52–0.60  $\mu\text{m}$  and a band with a wavelength of 1.55–1.75  $\mu\text{m}$  (Gautam et al., 2015). MNDWI has an accuracy rate of 99.85% in extracting information from water areas (Xu, 2006). The value of the band wavelength is used as a reference in determining the band to be used.

### 1.3.3. On screen

Digitization is *on screen* carried out using data from MNDWI and Band 5 (Landsat 7), Band 6 (Landsat 8). The results of the MNDWI transformation are useful for seeing the boundaries of sea water with land, assisted by bands 5 or 6 as correction material if the transformation results contain errors or wrong pixels in the coastline boundary classifier. Digitization is carried out following the administration along the coastline in Padang City.

### 1.3.4. Digital Shoreline Analysis Systems (DSAS)

Analysis uses a point as a measurement reference, where a point is generated from a cut between the transect lines created by the user and the coastlines based on time (Himmelstoss et al., 2018). The following is the calculation done with DSAS:

1. *Shoreline Change Envelope (SCE)* is to measure the total change in coastline by considering all available coastline positions and reporting the distance, without reference to a specific date.
2. *The Net Shoreline Movement (NSM)* measures the distance of shoreline change between the oldest and the newest shoreline.
3. *End Point Rate (EPR)* is to calculate the rate of change in the shoreline by dividing the distance

between the longest coastline and the most recent coastline by the time.

4. *Linear Regression Rate (LRR)* is a statistical analysis of the rate of change using linear regression that can be determined using the regression line *least-square* for all points of intersection of the coastline and the transect.

## 1.4. System development life cycle

The *system development life cycle (SDLC)* is a cycle through which a product gradually starts from concept to implementation (Isaías et al., 2015). There are various cycle models that can be selected as references in developing a system. In this study, the prototype model was chosen as a reference because it is more dynamic and responsive to the needs of potential users (Figure 3). The prototype model is based on the idea of creating a whole or part of a system in a pilot version, which is called a prototype (prototype).

The aim of this Prototype model according to (Carr et al., 1997) is to build prototypes with various versions and consistently improve those versions until the final product is reached. There are four stages in this model, namely needs analysis, prototype development, testing, and final product. In the trial phase, user responses will also be obtained which can be used to improve the prototype.

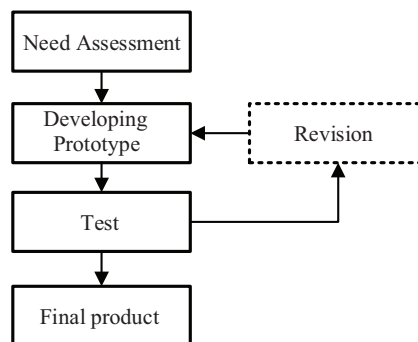


Figure 3. Prototype SDLC model

One of the most popular visual modeling languages used by designers is the *Unified Modeling Language (UML)*. *UML* was created in the 1990s with the main aim of making it easier for designers to create application designs that are easy to human read and executed by computers (Arlow & Neustadt, 2005). This convenience is due to the language *UML* visualizing and documenting stakeholder problems through graphical diagrams (Wazlawick, 2014).

There are several advantages possessed by *UML* (Miles & Hamilton, 2006), namely: (i) it is a formal language so it avoids misinterpretation of the elements being modeled, (ii) the language is simple, (iii) describes all aspects of the system, (iv) is able to manage the design small or large systems, (v) the language is based on the experience of object-based designer communities, and (vi) becomes the standard language supported by open communities.

*Unified Process (UP)* is a method for designing a system by taking into account the system actors, their activities, and the products they produce. There are five main processes in *UP*, namely: the formulation of requirements that must be met by the design, analysis for the requirements and making the structure, the design of the system that embodies these requirements, implementing the design through software, and testing the design. These five processes *UP* can be repeated in order to obtain a system design that meets the requirements that have been formulated (Arlow & Neustadt, 2005). So, *UP* and *UML* are methodologies and languages for designing systems.

## 2. Results and discussion

### 2.1. Pre-processing of Landsat data

The image processing stage includes *image cropping* and *image restoration* in the form of geometric corrections and radiometric corrections. Image cropping aims to limit the area to be processed according to the research location. Geometric correction aims to correct the position or position of objects so that their coordinates match their actual positions on earth. The 2020 image is used as a reference because it has been corrected with the RBI map. Geometric corrections were carried out on images from 2000, 2005, 2010 and 2015 against the 2020 image. GCP positioning was carried out at a location that was considered unchanged during 2000–2020 and could be identified through satellite imagery. Radiometric correction aims to improve pixel values by taking into account atmospheric disturbance, cloud scattering (haze), and scattering other objects that can degrade image quality (BIG, 2018).

### 2.2. Modified normalized difference water index and digital shoreline analysis systems

The results of MNDWI processing show that the shoreline boundary can be observed by formulating an image transformation that is processed on the Envi application device. MNDWI has the advantage of seeing the boundaries of sea water on built-up land. The bands used in the MNDWI formula are bands with

a wavelength range of 0.52–0.60  $\mu\text{m}$  crometers and a band with a wavelength range of 1.55–1.75  $\mu\text{m}$  (Gautam et al., 2015). The wavelength value becomes a reference in choosing the band to be used in carrying out the transformation (Figure 4).

The results of DSAS calculations are useful for seeing the phonemic distribution of abrasion and accretion. In the calculation will show a value that can identify a change occurred. A positive value on the EPR indicates the occurrence of accretion phenomenon and a minus value indicates an abrasion phenomenon. The tendency for abrasion to occur in the northern part of Padang city coastline, while accretion tends to occur in the bay area in the southern part of the Padang city coastline (Figure 5).

### 2.3. System development life cycle

In this case study of Padang City Coastline changes, researchers will build a PHP Framework CodeIgniter 3 Programming Based Geovisualization Application with Binary Admin and Leaflet.JS.

#### 2.3.1. Online survey

This survey aims to capture related information about system design needs and Interface Geovisualization Information System Changes of coastline. In this activity, an online google form is selected for the survey. This survey questionnaire is compiled and presented in the form of 20 questions and each respondent is obliged to give a response to each item. Of the 20 questions divided into 4 sections, namely:

- *Part 1 about self-data and general knowledge*

From the respondents' answers, 90% said they knew about the phenomenon of coastal changes in padang city and another 10% did not know about the phenomenon.

- *Part 2 on the source of information on coastlines*

From the survey results, 75% of respondents were informed about the changes in the coastline from online mass media and online social media and as many as 25% received information from public media such as newspapers, TV and word of mouth conversations.

- *Part 3 concerning respondents' information on geovisualization user interface*

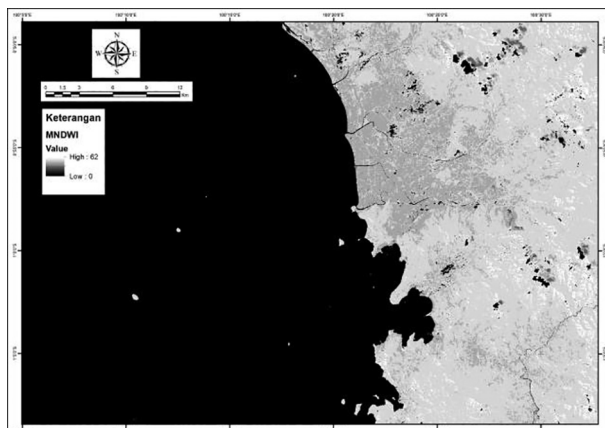


Figure 4. MNDWI transformation

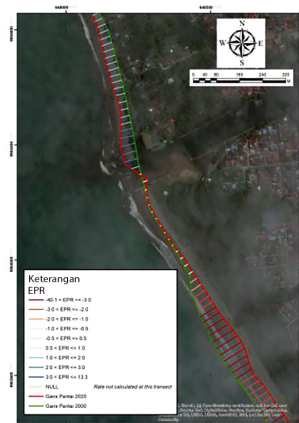


Figure 5. DSAS processing results

From the survey results as many as 70% of respondents chose to get geovisualization information on shoreline changes can be accessed via mobile phones, 25% have access using Laptop devices and 5% choose access using desktop computers. Regarding the design of the user interface displayed, as many as 60% of respondents expressed likes, 15% expressed very likes, 20% expressed quite likes, and 5% expressed dislikes.

– Part 4 concerning an analysis of respondents’ needs for user interface design of geovisualization products

From the survey results, 45% of respondents strongly agreed that geovisualization of shoreline changes using the timeslider menu, 40% agreed, 10% agreed and 5% disagreed.

**2.3.2. Use case diagram of web application geovisualization**

Based on the results of the System Needs Survey through online form media, here researchers try to pour the system plan into the form of a use case diagram that will be made by programming the web application base to be able to describe how the process of coastal change (Figure 6).

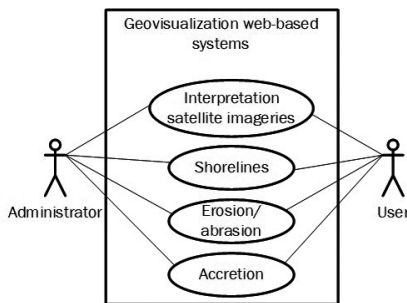


Figure 6. Use case diagram of geovisualization system shoreline changes

The next stage is to create a system design starting from the layout, the information displayed and the application based on the survey results and use case diagram. In Figure 7, the layout is arranged in such a way as to make it easier for users to identify spatial data and attributes. Furthermore, the time slider function makes it easier for users to know changes to the coastline. This time slider refers to the shoreline information that changes per year. Another function is the abrasion and accretion information on the shoreline visualized in the form of a histogram. The aim is to provide comparative data on the occurrence of abrasion and accretion along the coastline.

**2.3.3. Compatibility testing**

This trial uses the Black Box method. It aims to ensure the system can run correctly against various user differences as well as the suitability between inputs and outputs obtained. Starting from PC, Tablet, and smartphone users. The results of compatibility testing are in the Table 1.

Table 1. Compatibility testing matrix

No.	Scenario	Test Case	Expected results	Results
1	Visit the website address	User visits the website address	Browser displays desired functions	Successful
2	Switch to an available menu	User clicks available menu	View the contents of a selected menu page	Successful
3	Observing geovisualization map functions	User using feature on geovisualization web map page	Displaying map data information description	Successful

**2.3.3.1. Browser testing**

This trial was conducted with Google Chrome browser trial and MozillaFirefox. The purpose of the Browser Test to test the results of “Geovisualization Website Creation” such as views, menus and other functions, can run well with different browser engines.

**2.3.3.2. Platform testing**

Platform testing is carried out to ensure that this geovisualization information system can run well and informatively if accessed with different platform devices and dimension sizes. On this occasion, the trial was conducted for 3 types of platform namely Tablet/ipad (Figure 8), smartphone (Figure 9) and Personal Computer (Figure 10).

**2.3.3.3. Performance testing**

Performance testing is a method of testing system capability to serve user requests to the application’s functions. On this occasion, the performance test was done using Apache Jmeter software with a simultaneous system access trial scenario of 100 users at the same time during 10 seconds. After the performance test was executed, the result shows that 100 requests can be served without any failed access and errors. The average response value is 41 ms, and the standard deviation is 22.86.

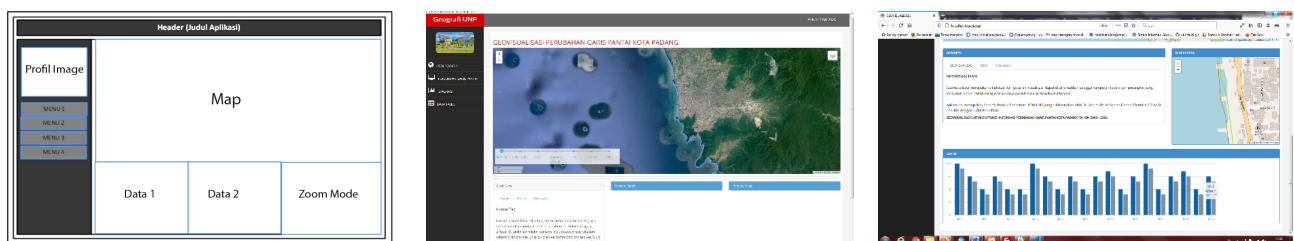


Figure 7. Geovisualization application design layout

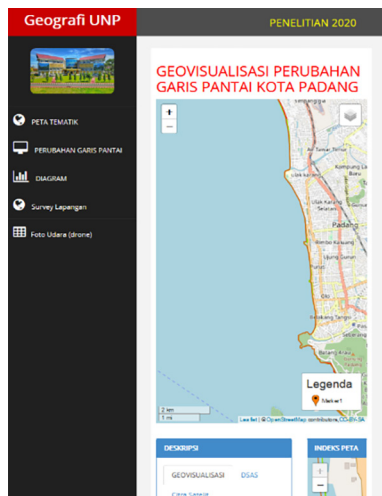


Figure 8. Trials on the Ipad platform

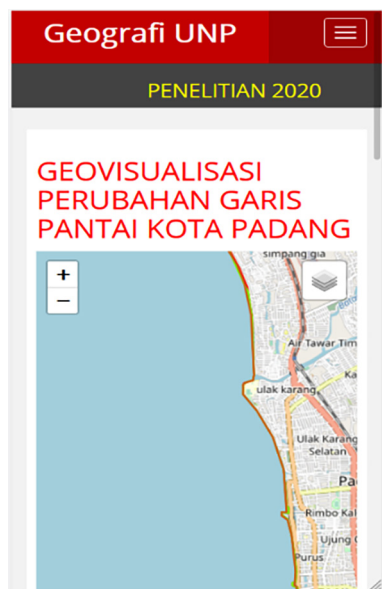


Figure 9. Trial on Iphone/android platform

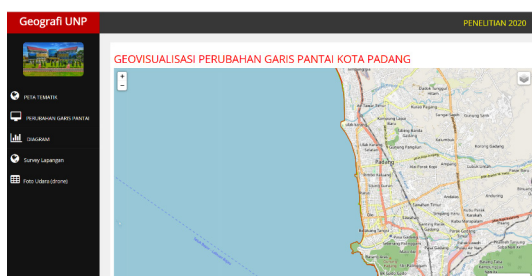


Figure 10. Browser Google Chrome

## Conclusions

Remote sensing is able to detect shoreline changes and see the phenomenon of abrasion/accretion. The utilization of remote sensing in this study uses the MNDWI transformation method to see the boundaries of seawater against the land so that it is able to extract coastline boundaries. In addition to being able to see the shoreline from year

to year with the use of GIS data from remote sensing processing in extracting the shoreline can be calculated the value of the magnitude and see which areas experience the phenomenon of abrasion or accretion by utilizing tools DSAS from USGS.

This information can be input into the designed system to understand the interactive information conveyed through visualization of shoreline movements. The system provides some functionalities for users to explore the data. One of the functions is the time slider. It can help the user to see the shoreline movement based on time. Spatial and attribute data are arranged on the web page layout in a single view to help the user find related information between the data. In conclusion, web-based geovisualization is a convenient method for visualizing shoreline changes and making it easier for users to access.

## Acknowledgements

The authors would like to thank Lembaga Penelitian dan Pengabdian Masyarakat Universitas Negeri Padang for funding this work with a contract number: 1526/UN35.13/LT/2020.

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