MORPHOLOGICAL CHANGE OF AYEYARWADY RIVER FROM CHAUK TO MAGWAY

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Abstract

The Ayeyarwady River is the main artery and an important source of multipurpose. Compared to its historical condition, the Ayeyarwady River's morphology has undergone significant changes as a result of erosion and deposition. These natural processes have shaped the river's landscape, altering its course and creating new land formations along its banks. Of all river sections, the Ayeyarwady River from Chauk to Magway area is the most affected by human impacts. Remote Sensing (RS) and Geographical Information Systems (GIS) are widely used for change detection in rivers caused by erosion and deposition. Digital image processing techniques and GIS analysis capabilities are used for detecting temporal variations in erosion and deposition characteristics of the Ayeyarwady River from Chauk to Magway areas during the years 1990, 2011, and 2022. The study aims to assess spatial variation in the Ayeyarwady River in the periods 1991, 2011, and 2022. Landsat satellite images for the years 1990, 2011, and 2022 were processed to investigate the erosion and deposition areas, patterns, and sedimentation conditions of the Ayeyarwady River. In the study, NDWI and MNDWI were used to create the delineation of the water area. Among these two indices, MNDWI results are a more differentiated open water area that has greater positive values than NDWI, as it absorbs more shortwave-infrared (SWIR) wavelengths than near-infrared (NIR) wavelengths. Built-up features have negative values and soil and vegetation also have negative values, as soil reflects more SWIR wavelengths than NIR wavelengths. Along the left bank, there is mainly deposition than on the right bank because of the elevation and geological structure. The derived results of channel pattern changes were validated by comparing them with the Sediment Transport Index (STI), and Stream Power Index (SPI). Integration of remote sensing data with GIS is an efficient and economical technique to assess land losses and channel changes in large rivers.

Keywords*: River channel; migration; NDWI; MNDWI; erosion and accretion*

Introduction

Rivers and streams are natural watercourses on the surface of the earth and are of great importance in geomorphology. Naturally, rivers are dynamic and their shapes and sizes vary in space and time because of erosion and deposition. A firm understanding of channel migration and associated processes of erosion and deposition will allow for the management of river behavior and decision-making processes (Alam et al. 2007). River channel forms and their dynamics over time have long been a major subject of study in geomorphology (Petts 1995). Channel forms are classified into three basic types: straight, meandering, and braided (Leopold & Wolma 1957; Lewin & Brewer 2001; Schumm & Khan 1972). Meandering rivers shift their courses across the valley bottom by depositing sediment on the inside of bends while simultaneously eroding on the concave side of the meandering banks. Meandering is a natural geomorphic feature in rivers that results in the gradual migration of the river’s course and erosion of its banks. Most rivers in the world are subject to meandering due to natural and human activities (Ayman & Ahmed Fawzi 2011). Monsoon runoff is known to affect river bank erosion rates (Darby et al. 2013). By using RS and GIS technology, river profiles at certain periods are developed and the rate of erosion and deposition is quantified. The temporal satellite images

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show how the river and its floodplain dynamics move. Also, these images help to predict how mobility continues or which kind of measures need to be considered to restore stability. The advantage of remote sensing techniques is the use of synoptic data covering both spatial and temporal aspects. These advantages could be maximized by using ground information and other geographical data, all of them integrated into a Geographical Information System (Rogan & Miller 2007).

Study Area

Two-thirds of Myanmar's surface rivers drain into the Ayeyarwady which ranks as the most important Myanmar river system. The Ayeyarwady River is a life artery and a major waterway. It passes through the heart of the dry zone which receives rainfall between 508mm (20 inches) and 1016mm (40 inches). The study area is located between north latitudes 19° 40' and 21° 00' and between east longitudes 94° 35' and 95° 15'. According to F. Bender (1983), the Ayeyarwady has a length of 2010 kilometers (1246.2 miles) and a catchment importance area covering 415700 sq. km (162123 sq-ml). The study area defines the Ayeyarwady River from Chauk to Magway and is about 203 km long.There are folds of rock formation older than sand. These folds are of importance because of their association with oil. The Ayeyarwady River wanders irregularly in this zone where it is bordered by alluvium, and the banks are low and fringed with sandbanks.

Figure 1. Location of the Study Area

Source: Landsat 8 (30 m)

Aim and Objectives

Aim

- To assess spatial variation in the channel migration in the Ayeyarwady River with the periods of 1990,2011, and 2022.

Objectives

- To investigate the erosion and deposition areas, patterns, and sedimentation condition of the Ayeyarwady River.
- To address the impact of the channel pattern changes of the study area.

Materials & Methods

Remote Sensing has been used by scientists for more than thirty years for investigating the surface of the earth (Bato et al. 2011). In order to quantify the changes in channel morphology of the Ayeyarwady River, satellite images of the study area were acquired and processed. There are a variety of satellite data source such as Landsat, Spot, Ikonos, Orbview and Quickbird. A selection of data mainly relates to its spatial, temporal, and spectral characteristic, time availability and most importantly its price (Hussain et al. 2011). For assessment of river channel temporal changes Landsat 5 TM, Landsat 8 OLI images with 30 m resolution were acquired for the months of November 1990, 2011 and December 2022. Images of November and December were chosen because of minimum discharge in the study area. The acquired images were already geo-rectified with the assigned parameters of projections and coordinate system. Parameters were WGS 84, zone 46N and Transverse Mercator's projection.

Landsat TM and OLI images actually consists of 7 bands and 11 bands but only three were required for information to be extracted. After atmospheric and radiometric correction of the images, a final binary image was obtained by applying the two techniques. The comparison of the channel pattern at different dates shows that the channel migration during 1990, 2011 and 2022 due to the erosion and deposition processes. Moreover, NDWI and MNDWI create for the delineation of the water area. Of these indices, MNDWI results is more differentiate open water has greater positive values than NDWI because it absorbs more shortwave-infrared (SWIR) wavelengths than near-infrared (NIR) wavelengths. And also, built-up features as well as soil and vegetation have negative values, as soil reflects more SWIR wavelengths than NIR wavelengths. The binary images were processed in ArcGIS10.8 software to extract the channel pattern. Firstly, each image was converted from raster to vector (feature class) with two main polygon features; water and land. Secondly, the two polygon layers were overlaid to estimate erosion and deposition pattern of sand areas in each period 1990, 2011 and 2022 along the Ayeyarwady River. As classified images were in raster format, they were converted into vector format by using Arc Map technique namely Raster to Polygon conversion. As a result of Vectorization all channel area of images were converted into polygon shape files. Flood plain boundary from the images was digitized by using Arc Map 10.8 meanwhile the vector layers of flood plain boundaries were produced for year 1990, 2011 and 2022. In order to integrate with topographic data, topo values were extracted from USGS SRTM DEM create a relief map. And also geological formation is used for erosion and deposition condition. NDWI and MNDWI band ratio method using Landsat images of LT5 and LC8 for 1990, 2011 and 2022 are as follows:

$$NDWI = \frac{\text{P Green} - \text{P NIR}}{\text{P Green} + \text{P NIR}}$$

$$MNDWI = \frac{\text{P Green} - \text{P SWIR}}{\text{P Green} + \text{P SWIR}}$$

Where, P Green, PNIR and PSWIR are the reflectance values of Landsat 5 TM Band 1, Band 2, Band 4 and Band 5 respectively. Moverover, Sediment Transport Index and Stream Power Index methods are used for data validation. Sediment Transport Index and Stream Power Index are as follows:

$$STI = (m + 1) \times (A_s / 22.13)^m \times \sin(B / 0.0896)^n$$ (Moore and Burch (1986))

Where A_s is the specific catchment area (i.e. the upslope contributing area per unit contour length) estimated using one of the available flow accumulation algorithms in the Hydrology toolbox; B is the local slope gradient in degrees; the contributing area exponent, m, is usually set to 0.4 and the slope exponent, n, is usually set to 1.4. Notice that *As* must not be log-transformed prior to being used; *As* is commonly log-transformed to enhance visualization of the data. The slope image can be created from the base digital elevation model (DEM) using the slope tool.

The Stream Power Index (SPI) is a measure of the erosive power of flowing water. SPI is calculated based upon slope and contributing area.

SPI=Ln ((“flw_acc” +.001)*((“Slope_%”/100)+.001))

It shows negative values for areas with topographic potential for deposition and positive values for potential erosive areas. Highest values related to a strong slope gradient. This terrain morphology contributes significantly to the erosion’s aggressiveness and land dergradation risk process. The lowest values represent relatively flat areas influencing the susceptibily to flooding and sediment deposition and accumulation.

Data Analysis

According to index map, vector profile and reference points were prepared, next important step was calculation of river channel pattern, changes in river channel width due to erosion and deposition and identification of erosion and deposition areas. In order to calculate river channel migration, the distance from the reference point to the river banks on both sides was digitized as line features. Then, the lengths of these lines were calculated in attribute table by using the calculate geometry options. As a result, distance of right and left bank of river channel are about 196 km 206 km. Extracted River channel and channel migration in the selected years is shown in Figure 2 and 3. The river channel location in 2022 was entirely at opposite location as compared with the channel location in 1990 along the entire river reach. This typically indicates the meandering river pattern in this reach. Whereas, in the middle reach length, the river shows the braided pattern due to the presence of islands and sand bars. In order to identify areas of erosion and accretion, overlay analysis techniques were used in Arc Map for flood plains extracted from images. As a result of using erase and merge tools in Arc map, from flood plain shape files polygons of areas showing deposition and erosion between given time period were retrieved as shown in Figure 2.

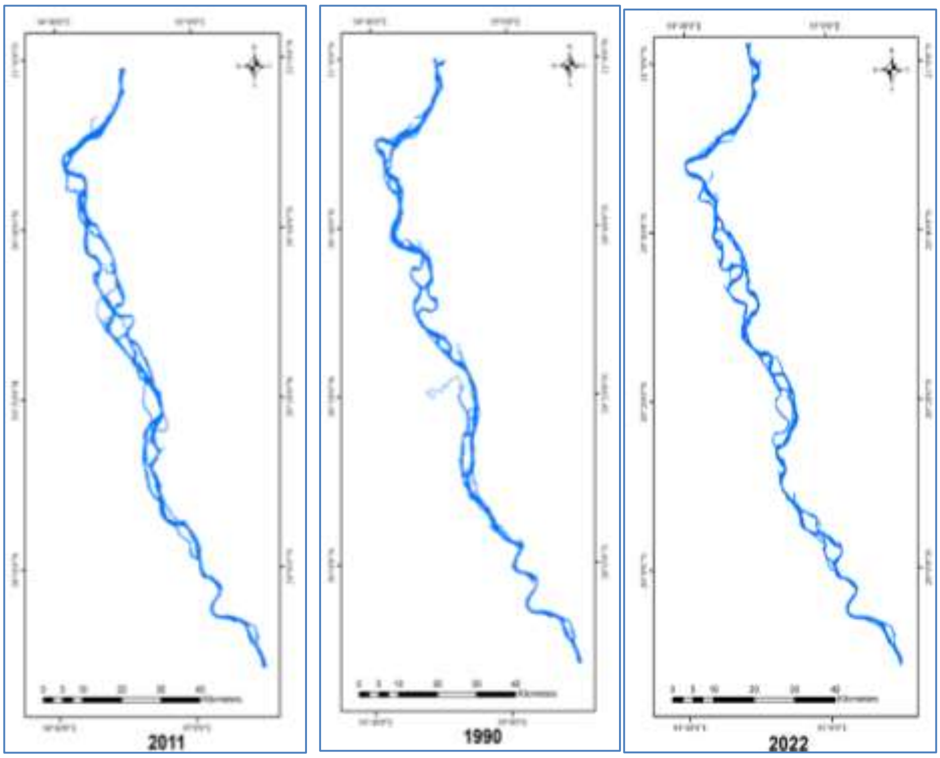

Figure 2. Channel Pattern of the Study Area (1990,2011 and 2022)

Sources: Extract from Landsat Images

Results and Discussion

Bank Line and River Channel Migration

Erosion and deposition variation at different reaches along the Ayeyarwady River are shown by analyzing data set in a form of overlay maps as shown in Figure 3. In 1990 and 2011, the erosion occurred right bank of the upstream and deposition occurred the middle stream parts of the reach along the left and right banks, respectively. In the middle reach, the upper braided portion experienced erosion along both banks. The lower braided portion of the Similarly, the middle portion also experienced at some of the cross sections along the both banks. During 1990-2022, almost the same pattern of erosion and deposition was found along both the river banks downstream part of the reach. Mostly, accretion is found at the left bank line and the lower portion of the reach showed the contrasting pattern where the erosion was observed along the both banks regardless of accretion. The shift of river channel is shown in the selected time periods (Figure 3).

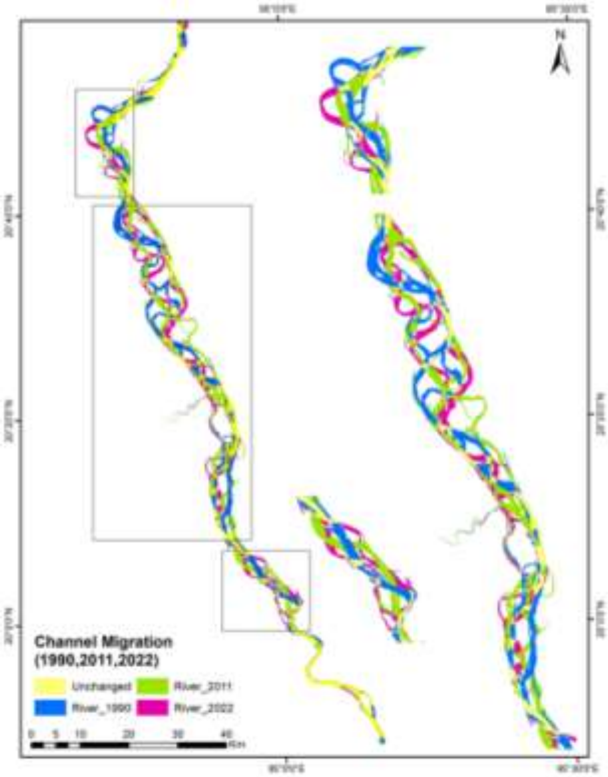

Figure 3 Channel Migration of the Study Area

Source: Extracted from Landsat 5 and 8 (30 m)

Table 1 Erosion and Deposition in the Study Area

Years	Previous 11 Years	Next 11 Years	Unchanged	Erosion	Deposition
1990-2011	20027.13	20240.77	8996.77	11030.37	11244.00
2011-2022	20240.77	19318.14	9701.91	10538.86	9616.23
1990-2022	20027.13	19318.14	8553.33	11473.80	10764.81

Source: Calculated by overlay Analysis

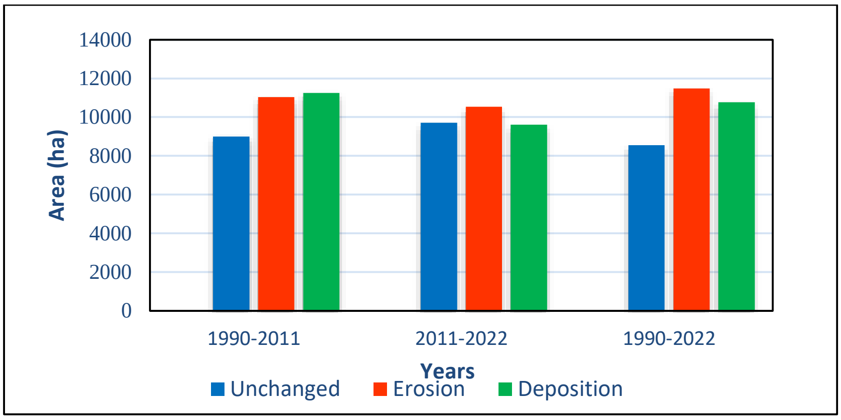

Figure 4 Changes in Erosion and Deposition in the Study area

Source: Table 1

River Banks Erosion and Deposition

The contrasting trends were observed along the right and left banks regarding deposition and erosion as shown in Figure 4 and Table 1. According to the Table 1, the deposition area is more than erosion in 1990-2011 because the left bank is primarily a trend of deposition in both 1990-2011 and 1990-2022 time periods, but the rate of deposition is very high as compared to rate of erosion along right bank. In 1990 and 2011, the channel migrates to east at the upstream near the Chauk area. Moreover, the geological formation is mainly composed of young alluvium. Mainly, deposition is caused immediately upperstream of the Ayeyarwady River due to the presence of stable islands and sand bars. The middle portion of reach river banks was also eroded on both sides due to the meandering pattern. Similarly, erosion along a bank results in deposition along the opposite bank that is attributed to the meandering of river channel. Areas for each polygon of erosion and deposition derived in Figure 4 were calculated and is given in Table 1 for the entire study periods. During 1990-2022, the channel migrate to the west near the Yenanchaung area and deposition occurred. Channel migration is not prominent at downstream area near Magway area. Analyses showed that the right bank was under erosion in both time spans, however, high rate of deposition is exhibited in middle reaches because of the underlying young alluvium and The eastern part of the study area is higher than the western part.

Data Validation

Accuracy assessment plays an important role in remote sensing image classification. It is important to know the quality of the classified maps (Jiang & Liu 2011). The accuracy of spatial data has been defined by the United States Geological Survey USGS, ‘Accuracy assessment or validation is an important step in the processing of remote sensing data. It determines the information value of the resulting data to a user’ (AbubakerHaroun et al. 2013). Most common techniques used for accuracy assessment of classified satellite images are error matrix generation by using ground sample data or any reliable published source data. However, in present study, sample data collection from field was not possible due to time of study area and location of cross sections. Ground truthing was not also an appropriate option for data validation. River channel delineated through Landsat image classification for 1990, 2011 and 2022 was validated through cross section generated according to similar vector profile of SRTM. And also, Sediment Transport Index and Stream Power Index methods are used for data validation. Because of the these are very useful for erosion and deposition. The Stream Power Index (SPI) is a measure of the erosive power of flowing water and Sediment Transport Index is also measure how much of sediment are transport by river.

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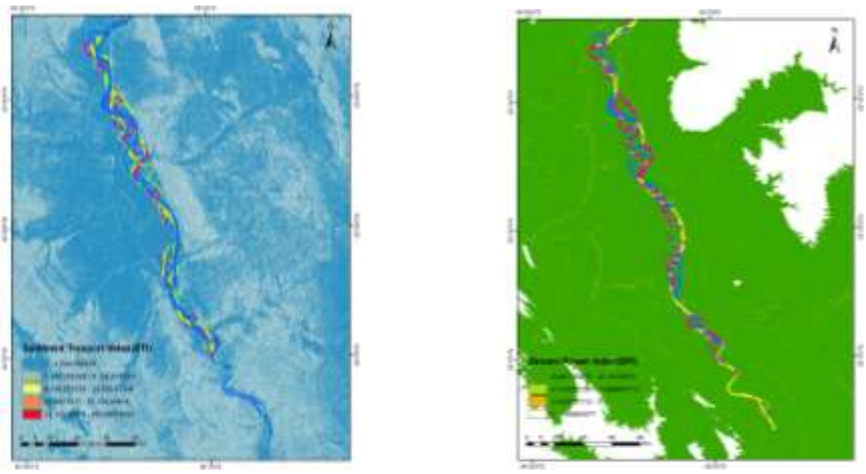

Figure 5 Sediment Transport Index and Stream Power Index

Source: calculated by formula

Conclusion

Alluvial flood plains are most important areas for agriculture, industry and human settlements. Nowadays supervising and forecasting changes in riverbanks are important and necessary for managing and detecting environment in marine infrastructure (Nguyen et al. 2010).

In the present study remote sensing and GIS techniques are used to identify changes in bank line of the Ayeyarwaddy River is about 206 km reach from Chauk to Magway. Cloud free Landsat satellite images of 1990, 2011 and 2022 are processed to identify changes in river morphology and location of eroded and deposited parts along river channel has been identified. The following conclusions are inferred after analyzing images. The middle reach exhibits a braided channel value because of its time and cost as no such investigations through field surveying techniques are regularly being carried in study area. The findings about river bank and flood plain dynamics will be valuable for erosion management plans and bank protection measures in study area whereas the rest of the channel exhibits meandering pattern. As left bank of the Ayeyarwady River is more subjected to deposition as compared to right bank which is more subjected to erosion. The present study is mainly based on image interpretation without incorporating other data like flow rate and volume, contributing to river channel migration erosion and deposition. Moreover, the processes of erosion and deposition are mainly affected on the socio-economic condition of local people.

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