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# STUDY ON MORPHOLOGICAL CHANGE OF AYEYARWADY RIVER FROM PYAY TO HINTHADA

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## Abstract

River morphology has been a subject of great challenge to scientists. It is based on a proper understanding of the morphological features and changes. In this paper, an overview of river morphology is presented from the geomorphic viewpoint. The main aim is to describe river channels shape and how they change overtime. This study examines the morphological change of Ayeyarwady River from Pyay to Hinthada segment by using Geographic Information Systems (GIS) technique. Channel pattern and channel movement, channel bar formation and morphology of point-bar have been identified using a time series images from Google Earth Engine (2015, 2011, 2006, 2001, 1996 and 1991). Settlement areas are also extracted from topographic maps of 1945 and 2002. ArcGIS is used for visual screen digitizing and to obtain accurate information about river channel movement.

**Key words**: Ayeyarwady River, channel pattern, channel movement, channel bar formation

## Introduction

The Ayeyarwady River is the major drainage basin and course life artery of the Union of Myanmar, running generally north-south reflecting the trend of the mountain ranges of the country. According to F. Bender (1983), the Ayeyarwady has a length of 2010 kilometers (1246.2 miles) and a catchment area covering 415700 sq.km (162123 sq-ml).In this paper, study area defines from Pyay to Hinthada along the Ayeyarwady River course. It is about over 205 km long.

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## Aim and Objectives

The main aim of this paper is to describe river channels shape and how they change over time. Major objectives are to identify channel pattern and channel movement, to examine the formation of channel-bar within the river course and to assess channel bank erosion within the study area.

## Materials and Methods

Based on satellite image quality and availability the primary data were used TM and ETM+ sensor of Landsat satellite for four and five different years. Settlement areas are extracted from topographic maps of 1945 and 2002.

| Satellite | Sensor | Month/Year |
|---|---|---|
| Landsat 5 | TM | March, 1991<br>March, 1996<br>March, 2001 |
| Landsat 7 | ETM+ | March, 2006<br>March, 2011 |
| Landsat 8 | OLI | March, 2015 |
| Topographic Map | | 1945 and 2002 |

Main channel, channel-bar and channel bank erosion data is derived from Google Earth Engine (GEE) by using the Normalized Differenced Water Index (NDWI).The NDWI maximizes reflectance of water by using green band wavelengths and minimizes low reflectance of NIR by absorbing maximum of wavelength. As a result, water features are enhanced owing to having positive values and vegetation and soil are suppressed due to having zero or negative values. ArcGIS is used for visual screen digitizing and to obtain accurate information about river channel movement. Our Space eye product uses the near-infrared and green spectral bands from **various satellites** (Landsat 8 OLI, Landsat 7 ETM+ and Landsat 5 TM) to calculate the NDWI with the following formulas:

$$NDWI_{L8} = \frac{Band_3 - Band_5}{Band_3 + Band_5} \quad \text{Landsat 8 OLI}$$

$$NDWI_{L5} = \frac{Band_2 - Band_4}{Band_2 + Band_4} \quad \text{Landsat 5 TM}$$

## Results and Discussion

### 1. Classification of Channel Pattern along the Course

Channel morphology is three-dimensional, cross-section; plan-form and long-profile properties constituting the complete morphology are closely interrelated: to emphasize one dimension alone is to achieve only a particular understanding. Wide, shallow cross-sections are associated with braided patterns, and meandering streams have lower gradient than straight channels between the same two end points.

Theoretically, morphological variables of alluvial channel are: Cross-section (width, mean depth, maximum depth, channel capacity, wetted parameter and hydraulic radius, form ratio, selection asymmetry, and selection roughness), Plan –form (axial wavelength, arc wavelength, bend amplitude, arc height, radius of curvature, radius: width ratio, sinuosity, index, index and braided intensity), long-profile: (profile gradient, Taylor-Schwartz slope, profile concavity, bed slope, water surface slope, floodplain wavelength, and bed-form amplitude) (Richard, K., 1982).

In this paper the emphasis is on the plan-form especially on sinuosity along the Pyay to Hinthada segment of Ayeyarwady River course. These parameter exhibits shape and lateral development of band of alluvial channel.

The ratio between the measured length of a stream channel and that of the thalweg of its valley is measure of its sinuosity. Sinuosity ratio P is 1.0 for straight channel, 1.2 for transitional between straight and regular, 1.5 for regular channel, 1.7 for irregular channel and 2.1 for tortuous (Chorley, R.J., 1984).

From Pyay to Hinthada segment of Ayeyarwady River's straight line length of main channel is 165.44 km and thalweg line length is 205.97 km for the year 1991. Therefore sinuosity ratio is 1.24. In 1996, thalweg line length becomes 209.29 km and sinuosity ratio is 1.26. In 2001, 2006, 2011 and 2015 thalweg line length is 205.61 km, 214.69 km, 213.66 km and 220.82 km respectively. So, sinuosity ratio is 1.24, 1.29, 1.29 and 1.33. Generally, channel pattern between Pyay to Hinthada segment is transitional between straight and regular as shown in Table 1.

**Table 1.** Sinuosity ratio and channel pattern along Pyay to Hinthada segment

| Year | Straight channel length (km) | Thalweg line length (km) | Sinuosity ratio | Channel pattern |
|---|---|---|---|---|
| 1991 | 165.44 | 205.97 | 1.24 | transitional |
| 1996 | 165.44 | 209.29 | 1.26 | transitional |
| 2001 | 165.44 | 205.61 | 1.24 | transitional |
| 2006 | 165.44 | 214.69 | 1.29 | transitional |
| 2011 | 165.44 | 213.66 | 1.29 | transitional |
| 2015 | 165.44 | 220.92 | 1.33 | transitional |

**Source:** Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

For more detail study, Pyay to Hinthada segment is subdivided into four segments from north to south, namely such as segment 1, 2, 3 and 4. Length of segment 1, 2 and 3 are 50km and segment 4 is 55.619 km respectively as shown in Figure 1.

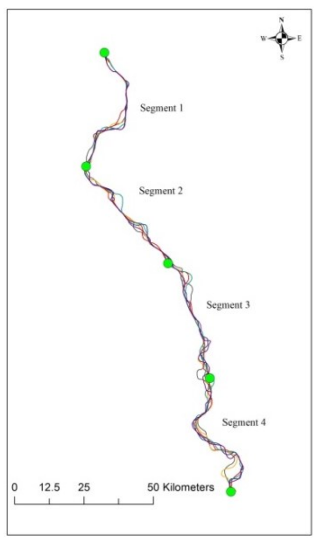


Figure1 Channel segment of study area
Source: Lansat 5, 7 and 8 satellite imagery

According to Table 2, channel pattern of segment 1 is transitional between straight and regular. Sinuosity ratio is gradually increased within 25 years as shown in Figure 2.

**Table 2.** Sinuosity ratio and channel pattern of segment 1

| Year | Straight channel length (km) | Thalweg line length (km) | Sinuosity ratio | Channel pattern |
|---|---|---|---|---|
| 1991 | 41.70 | 51.12 | 1.22 | transitional |
| 1996 | 41.70 | 51.98 | 1.24 | transitional |
| 2001 | 41.70 | 50.09 | 1.20 | transitional |
| 2006 | 41.70 | 52.34 | 1.25 | transitional |
| 2011 | 41.70 | 53.81 | 1.29 | transitional |
| 2015 | 41.70 | 55.63 | 1.33 | transitional |

**Source:** Based on Landsat 5,7 and 8 satellite imagery
**:** Calculated by author

According to Table 3, sinuosity ratio of segment 2 are 1.06 in 1991, 1.04 in 1996 and 1.06 in 2001. The channel pattern of the first three years is nearly straight. But, sinuosity ratios of second three years are 1.10, 1.13 and 1.08. The channel patterns of these years are nearly transitional. See Figure 3.

**Table 3.** Sinuosity ratio and channel pattern of segment 2

| Year | Straight channel length (km) | Thalweg line length (km) | Sinuosity ratio | Channel pattern |
|---|---|---|---|---|
| 1991 | 47.31 | 50.58 | 1.06 | nearly straight |
| 1996 | 47.31 | 49.48 | 1.04 | nearly straight |
| 2001 | 47.31 | 50.43 | 1.06 | nearly straight |
| 2006 | 47.31 | 52.25 | 1.10 | nearly transitional |
| 2011 | 47.31 | 53.72 | 1.13 | nearly transitional |
| 2015 | 47.31 | 51.47 | 1.08 | nearly transitional |

**Source:** Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

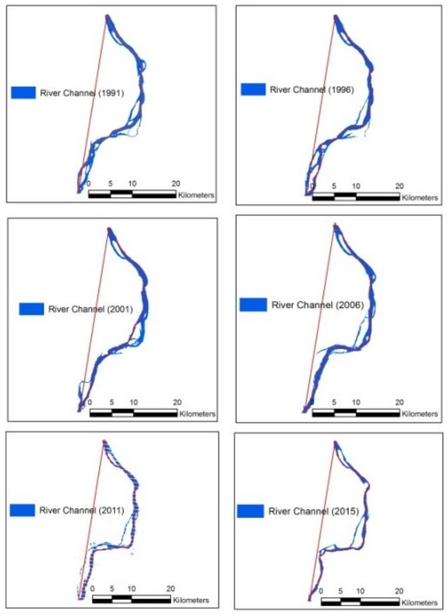


**Figure 2**. Channel plan-form of segment 1
**Source:** Lands at 5,7 and 8 satellite imagery

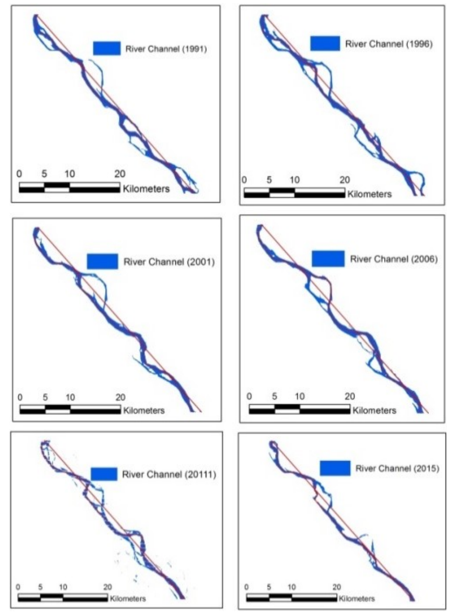


**Figure 3**. Channel plan-form of segment 2
**Source:** Lands at 5, 7 and 8 satellite imagery

In segment 3, sinuosity ratio for the years 1991, 1996, 2001, 2006, 2011 and 2015 are 1.15, 1.14, 1.17, 1.24, 1.11 and 1.24. Channel patterns of segment 3 are gradually changed from nearly transitional to transitional as shown in Table 4 and Figure 4.

The last segment's (segment 4) sinuosity ratio for the years 1991,1996,2001, 2006, 2011 and 2015 are 1.29, 1.39, 1.29, 1.35, 1.37 and 1.42. Channel patterns of that segment are progressively changed for transitional to nearly regular. See Table 5 and Figure 5.

**Table 4**. Sinuosity ratio and channel pattern of segment 3

| Year | Straight channel length (km) | Thalweg line length (km) | Sinuosity ratio | Channel pattern |
|---|---|---|---|---|
| 1991 | 42.23 | 48.86 | 1.15 | nearly transitional |
| 1996 | 42.23 | 48.24 | 1.14 | nearly transitional |
| 2001 | 42.23 | 49.60 | 1.17 | nearly transitional |
| 2006 | 42.23 | 52.38 | 1.24 | transitional |
| 2011 | 42.23 | 47.16 | 1.11 | nearly transitional |
| 2015 | 42.23 | 52.75 | 1.24 | transitional |

**Source:** Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

**Table 5**. Sinuosity ratio and channel pattern of segment 4

| Year | Straight channel length (km) | Thalweg line length (km) | Sinuosity ratio | Channel pattern |
|---|---|---|---|---|
| 1991 | 42.72 | 55.28 | 1.29 | transitional |
| 1996 | 42.72 | 59.42 | 1.39 | nearly regular |
| 2001 | 42.72 | 55.48 | 1.29 | transitional |
| 2006 | 42.72 | 57.71 | 1.35 | nearly regular |
| 2011 | 42.72 | 58.95 | 1.37 | nearly regular |
| 2015 | 42.72 | 60.95 | 1.42 | nearly regular |

Source: Based on Landsat 5,7 and 8 satellite imagery
: Calculated by author

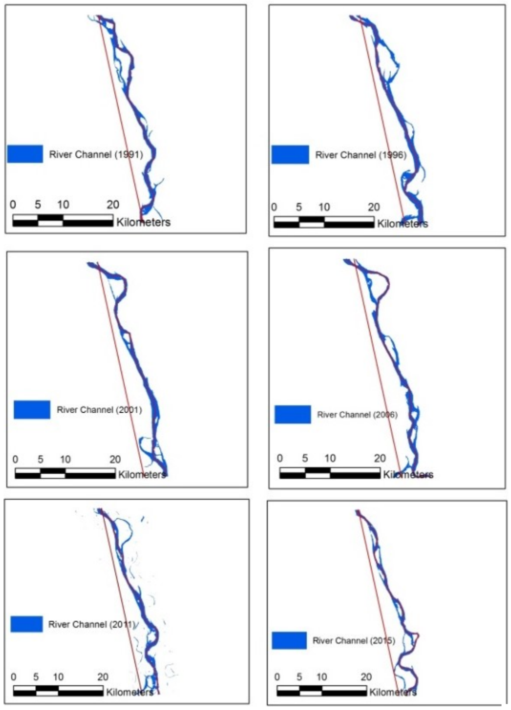


**Figure 4.** Channel plan-form of segment 3
**Source:** Landsat 5, 7 and 8 satellite imagery

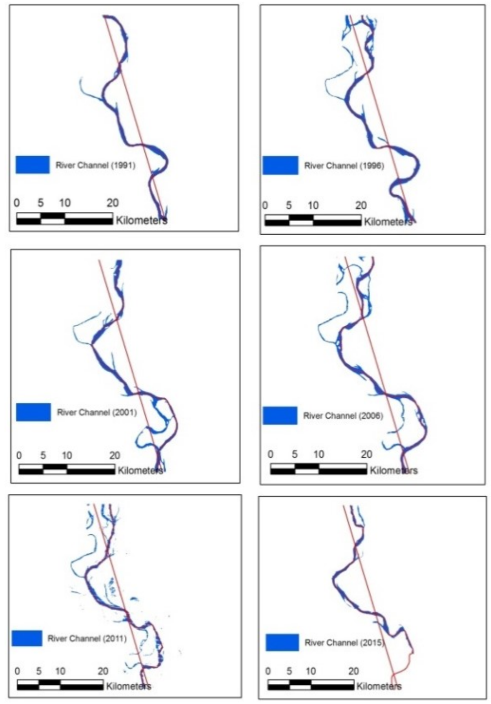


**Figure 5** Channel plan-form of segment 4
**Source:** Landsat 5, 7 and 8 satellite imagery

## 2. Channel Bar Formation along the Course

The nature and distribution of alluvial instream geomorphic units is fashioned by the interaction between unit stream power along a river reach and sediment calibre and availability.

The most common instream geomorphic units are accumulations of deposits referred to as bars. These areas of net sedimentation of comparable size to the channels in which they occur are key indicators of within-channel processes. Interpretation of bar type is often critical in elucidation of river character and behaviour. There are two main components in bar form. The basal feature, or platform, is made up of coarse material and is overlain by supraplatform deposits of varying forms which is subject to removal and replacement during floods. Bars are readily reworked as channels shift position over the valley floor. Bank attached features are much less likely to be reworked than mid-channel forms. The long-term preservation of bars is conditioned by factors such as the aggradational regime and the manner of channel movement.

Bars adopt many varied morphologies, ranging from simple unit bars (Smith 1970) to complex compound features (Briefly 1991, 1996). Bar character is controlled primarily by local-scale flow and grain size characteristics. Unit bars are simple features composed of one depositional style. The sediments of a unit bar (whether they be sand or gravel in composition) tend to be fine in a downstream direction. As unit bars are found at characteristic locations along long profiles under particular sets of flow energy (stream power) and bed material texture relationships, a 'typical' down-valley transition in forms can be discerned (Church and Jones1982). Bed material character, and the competence of flow to transport it, determines formation of longitudinal bars as flow divides around a tear-drop shaped feature. When flow is oriented obliquely to the long axis of the bar, a diagonal feature is produced. This is commonly associated with a dissected riffle. In highly sediment-charged sandy conditions, flow divergence results in transverse or linguoid bars, which extend across rather than down the channel (Collinson 1970; Cant and Walker 1978). Alternatively, the entire channel bed may comprise a homogenous sandsheet.

Instances in which patterns of sedimentation are dominated by within-channel bars reflect situations in which the material on the channel bed is either too coarse to be transported or the volume of material is too great to be transported. These scenarios are generally associated with gravel and sand bed systems respectively, such that competence and capacity limits are exceeded and flow divides around sediment stored in the channel zone.

In contrast to various mid-channel sedimentation features, rivers that are more readily able to accommodate their sediment load or have lower available energy are commonly characterized by bank-attached bars. Dependent on channel/flow alignment, lateral and point bars are found at channel margins under both sand and gravel conditions. These features record sediment accretion on the convex slopes of river bends. Lateral bars tend to occur along straighter river reaches, while point bars are formed on bends. Scroll bars on the inside of bends may form a distinct element in themselves, while former positions of the channel may be recorded by a series of accretionary ridges and intervening swales (Nanson 1980). A range of bar forms have also been characterized for laterally constrained sinuous channels, such as point dunes (Hickin1969), gravel counterpoint bars (Smith 1987) and convex bar deposits (Goodwin and Steidtmann 1981).

In this paper, emphasise is given to the area of channel bar, in channel bar and total area of bar in the channel along the river course from Pyay to Hinthada segment. According to Table 6, total channel bar area is 291.5963 sq-km, 257.2957 sq-km, 336.1158 sq-km, 307.3269 sq-km, 313.47.5 sq-km and 335.7910 sq-km respectively. Channel bar area in 1991 was 234.2458 sq-km (80.33% of the total bar area) and in channel bar area was 57.3505 sq-km (19.67% of the total channel bar area). In 1996 channel bar area was decreased to the 174.0022 sq-km (67.63% of the total bar area, while in channel bar area was increased to 89.2937sq-km (32.37% of the total bar area). Channel bar area was increased again in 2001 with the area of 285.61 sq-km (84.97% of the total), while the area of in channel bar was decreased again with the area of 50.5058 sq-km (15.03% of the total) in 2001.Channel bar area was decreased again in 2006 with the area of 244.0008 sq-km (79.39% of the total), while the area of in channel bar was increased again with the area of 63.3261 sq-km (20.61% of the total) in 2006. Between 2006 to 2011, within five years period, percentage area of channel bar and in channel bar are nearly the same, but channel bar area became 267.7123 sq-km (80.32% of the total) and in channel bar area became 66.0787 sq-km in 2015 respectively.

**Table 6.** Channel bar, in channel bar and total bar area along the river course

| Year | Channel Bar Area (sq-km) | Channel Bar Area (%) | In Channel Bar Area (sq-km) | In Channel Bar Area (%) | Total Bar Area (sq-km) | Total Bar Area (%) |
|---|---|---|---|---|---|---|
| 1991 | 234.2458 | 80.33 | 57.3505 | 19.67 | 291.5963 | 100 |
| 1996 | 174.0022 | 67.63 | 83.2937 | 32.37 | 257.2959 | 100 |
| 2001 | 285.61 | 84.97 | 50.5058 | 15.03 | 336.1158 | 100 |
| 2006 | 244.0008 | 79.39 | 63.3261 | 20.61 | 307.3269 | 100 |
| 2011 | 247.6315 | 79.00 | 65.84 | 21.00 | 313.4715 | 100 |
| 2015 | 269.7123 | 80.32 | 66.0787 | 19.68 | 335.7910 | 100 |

**Source:** Calculated by author

## 3. Channel Movement along the Course

River course changes can be quantified by superimposing early maps, aerial photographs and satellite imagery (e.g. Hooke and Redmond 1989; Lewin 1987), often using analytical photogrammetry and GIS (e.g. Lane *et al.* 1993). In this paper, channel movement and erosion data are derived from the topographic maps and satellite imagery by using screen digitizing and auto data extraction methods.

For channel movement and bank erosion studies, there are eight selected channel movement sites along the study river course as shown in Figure 6. Absolute location of selected channel movement sites are as follows:

**Absolute location**

Channel movement site 1: North Latitude 18˚ 29′ 40.98" and
East Longitude 95˚ 07′ 48.72"
(Thauk Kyar Du village tract, Kyangin township, west bank of the Ayeyarwady River)
Channel movement site 2: North Latitude 18˚ 23′ 39.56" and
East Longitude 95˚ 12′ 29.23"
(Sonle village tract, Kyangin township, west bank of Ayeyarwady River)
Channel movement site 3: North Latitude 18˚ 13′ 1.25" and
East Longitude 95˚ 22′ 3.12"
(Ka Zun Khon village tract, Myanaung township, east bank of Ayeyarwady River)
Channel movement site 4 :North Latitude 18˚ 00′ 6.40" and
East Longitude 95˚ 28′ 7.87"
(Nyaung Waing village tract, Monyo township, esat bank of Ayeyarwady River)
Channel movement site 5: North Latitude 17˚ 56′ 39.28" and
East Longitude 95˚ 27′ 4.33"
(Gway Tauk Chaung village tract, Ingapu township, west bank of Ayeyarwady River)
Channel movement site 6: North Latitude 17˚ 52′ 22.69" and
East Longitude 95˚ 28′ 0.50"
(Sitkone village tract, Ingapu township, east bank of Ayeyarwady River)

Channel movement site 7: North Latitude 17˚ 43′ 2.66" and
East Longitude 95˚ 26′ 34.51"
(Aing Ta Loke village tract, Letpadan township, west bank of Ayeyarwady River)
Channel movement site 8: North Latitude 17˚ 39′ 10.14" and
East Longitude 95˚ 28′ 37.17"
(Gaung Say Kyun village tract, Hinthada township, west bank of Ayeyarwady River)

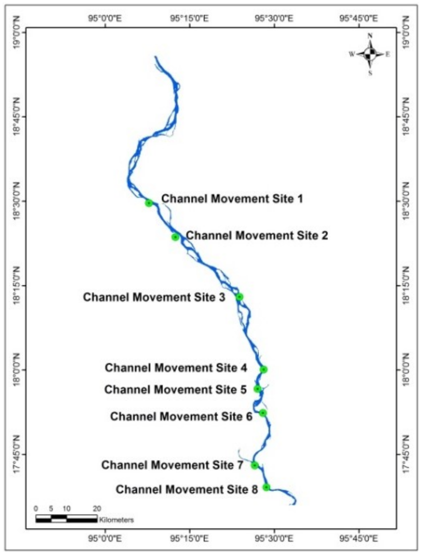


**Figure 6.** Channel movement sites along the course
**Source:** Landsat 5, 7 and 8 satellite imagery

Channel movement data for all selected channel movement sites for the year 1996, 2001, 2006, 2011, and 2015 are measured based on the 1991 active channel. Selected site number 1, which is Thauk Kyar Du village tract, Kyangin township, is located on the west bank of the Ayeyarwady River. No channel movement was seen in 1996, and channel shift to the eastward direction with the distance of 0.5567 km in 2001, 1.2117 km in 2006, 1.6624 km in 2011, and 2.4269 km in 2015 from the reference point. In this site, channel shifts to the eastward direction within 25 years as shown in Figure 7 and Table 7.

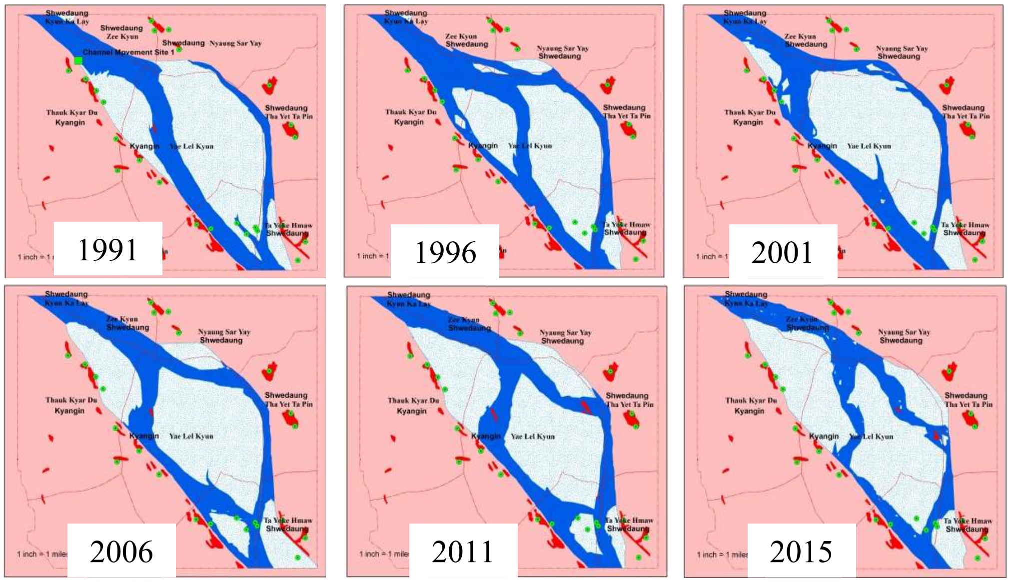


**Figure 7.** Channel movement of site 1
**Source:** Landsat 5, 7 and 8 satellite imagery

Site number 2,which is Gway Tauk Chaung village tract, Ingapu township, is located on the west bank of the Ayeyarwady River. Channel shifts in westward direction from the reference point with the distance of 0.635 km in 2001, 1.3106 km in 2006, 1.5539 km in 2011 and 1.548 kmin 2015 (figure 8).

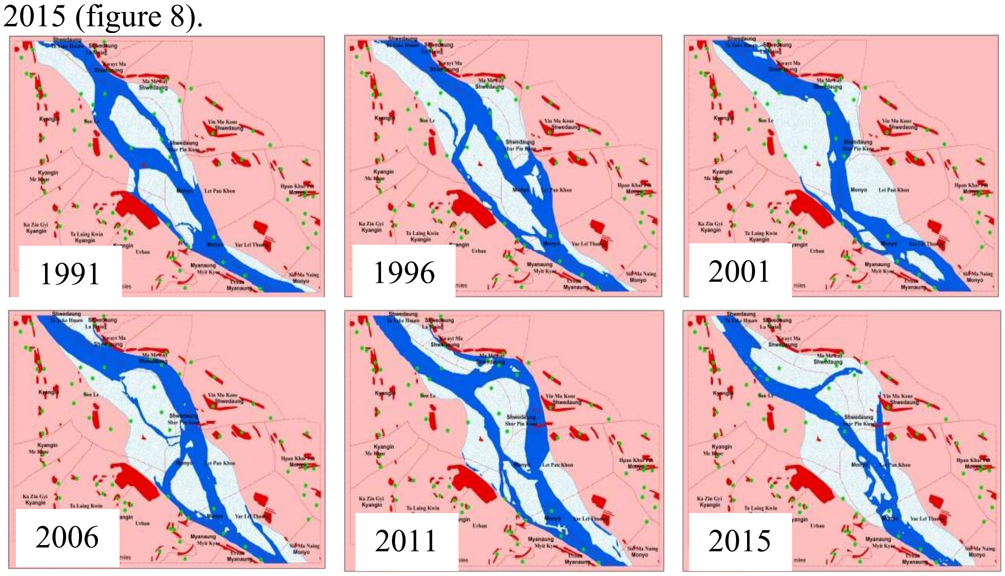


**Figure 8.** Channel movement of site 2
**Source:** Landsat 5, 7 and 8 satellite imagery

**Table 7.** Channel Movement of Ayeyarwady River from Pyay to Hinthada

| Channel Movement Site | Referenced Point Location | Year | Distance of Channel Movement from Referenced Point to West (km) | Referenced Point (km) | Distance of Channel Movement from Referenced Point to East (km) |
|---|---|---|---|---|---|
| 1 | 18° 13′ 1.25"N, 95° 07′ 48.72"E | 1991 | | 0 | |
| | | 1996 | | | 0 |
| | | 2001 | | | 0.5667 |
| | | 2006 | | | 1.2177 |
| | | 2011 | | | 1.6624 |
| | | 2015 | | | 2.4269 |
| 2 | 18° 23′ 39.56"N, 95° 12′ 29.23"E | 1991 | | 0 | |
| | | 1996 | 0 | | |
| | | 2001 | 0.635 | | |
| | | 2006 | 1.3106 | | |
| | | 2011 | 1.5539 | | |
| | | 2015 | 1.548 | | |
| 3 | 18° 13′ 1.25"N, 95° 22′ 3.12"E | 1991 | | 0 | |
| | | 1996 | | | 0.1061 |
| | | 2001 | | | 2.0232 |
| | | 2006 | | | 2.9015 |
| | | 2011 | | | 2.5911 |
| | | 2015 | 0.3108 | | |
| 4 | 18° 00′ 6.40"N, 95° 28′ 7.87"E | 1991 | | 0 | |
| | | 1996 | | | 0 |
| | | 2001 | | | 0.1793 |
| | | 2006 | | | 0.1754 |
| | | 2011 | | | 0.7632 |
| | | 2015 | | | 0.7451 |
| 5 | 17° 56′ 39.28"N, 95° 27′ 4.33"E | 1991 | | 0 | |
| | | 1996 | 1.4236 | | |
| | | 2001 | | | 1.0014 |
| | | 2006 | | | 0.4267 |
| | | 2011 | | | 0.3824 |
| | | 2015 | 1.2019 | | |

| Channel Movement Site | Referenced Point Location | Year | Distance of Channel Movement from Referenced Point to West (km) | Referenced Point (km) | Distance of Channel Movement from Referenced Point to East (km) |
|---|---|---|---|---|---|
| 6 | 17° 52′ 22.69"N, 95° 28′ 0.50"E | 1991 | | 0 | |
| | | 1996 | | | 1.3380 |
| | | 2001 | | | 2.1398 |
| | | 2006 | | | 3.2224 |
| | | 2011 | | | 1.0717 |
| | | 2015 | | | 1.0985 |
| 7 | 17° 43′ 2.66"N, 95° 26′ 34.51"E | 1991 | | 0 | |
| | | 1996 | 0.8273 | | |
| | | 2001 | 1.1851 | | |
| | | 2006 | 1.7039 | | |
| | | 2011 | 1.8592 | | |
| | | 2015 | 2.3740 | | |
| 8 | 17° 39′ 10.14"N, 95° 28′ 37.17"E | 1991 | | 0 | |
| | | 1996 | | | 0 |
| | | 2001 | | | 1.2250 |
| | | 2006 | | | 1.9592 |
| | | 2011 | | | 3.4468 |
| | | 2015 | | | 5.2292 |

**Source:** Calculated by author

Site number 3, which lies in Ka Zun Khon village tract, Myanaung township, is located on the east bank of the Ayeyarwady River. Channel shifts to the eastward direction from the reference point with the distance of 0.1061 km in 1996, 2.0232 km in 2001, 2.9019 km in 2006 and 2.5911 km in 2011. The channel shifts again to the westward direction with the distance of 0.3108 km in 2015 (figure 9).

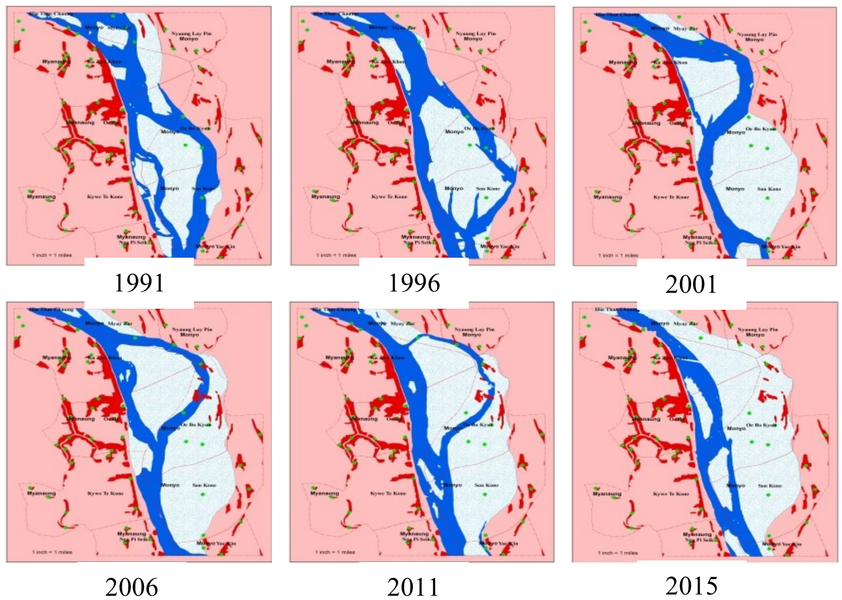


**Figure 9.** Channel movement of site 3
**Source:** Landsat 5, 7 and 8 satellite imagery

At selected site number 4, which is Nyaung Waing village tract, Monyo township, is located on the east bank of the Ayeyaewady River. Channel movement is absent in 1996, and channel shifts to the eastward direction with the distance of 0.1793 km in 2001, 0.1754 km in 2006, 0.7632 km in 2011, and 0.7451 km in 2015 from the reference point.

Site number 5, which is Gway Tauk Chaung village tract, Ingapu township, is located on the west bank of the Ayeyarwady River. Channel shift to the westward direction from the reference point with the distance of 1.4236 km in 1996, and then channel is moved eastward direction with the distance of 1.0014 km in 2001, 0.4267 km in 2006 and 0.3824 km in 2011. And then channel shifts again to the westward direction with the distance of 1.2019 km in 2015 as shown in figure 10.

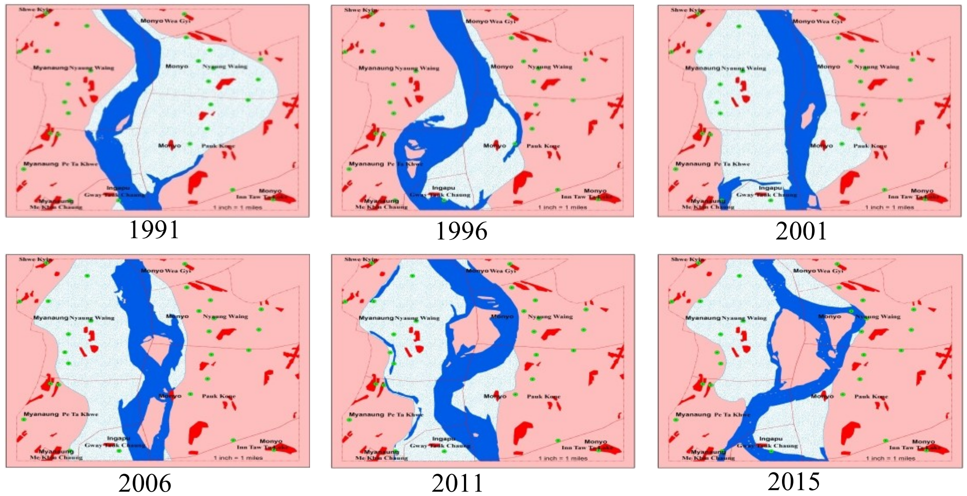


**Figure 10**. Channel movement of site 4 and 5

**Source:** Landsat 5, 7 and 8 satellite imagery

Site number 6, which is situated in Sitkone village tract, Ingapu township, is located on the east bank of Ayeyarwady River. Channel shifts to the eastward direction from the reference point with the distance of 1.3380 km in 1996, 2.1398 km in 2001, 3.2224 km in 2006, 1.0717 km in 2011, and 1.0985 km in 2015 (figure 11).

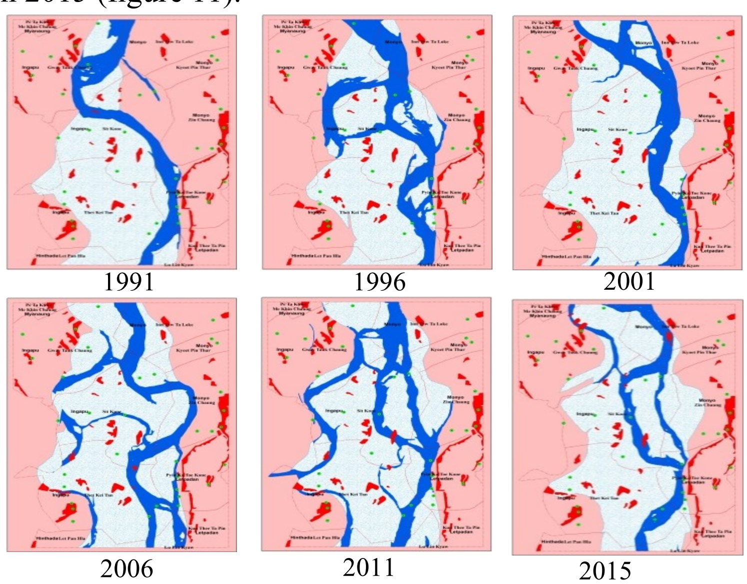


**Figure 11**. Channel movement of site 6

**Source:** Landsat 5, 7 and 8 satellite imagery

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Site number 7, which lies the Aing Ta Loke village tract, Letpadan township, is located on the west bank of Ayeyarwady River. Channel shifts to the westward direction from the reference point with the distance of 0.8237 km in 1996, 1.1851 km in 2001, 1.7039 km in 2006, 1.8592 km in 2011, and 2.3740 km in 2015 (figure 12).

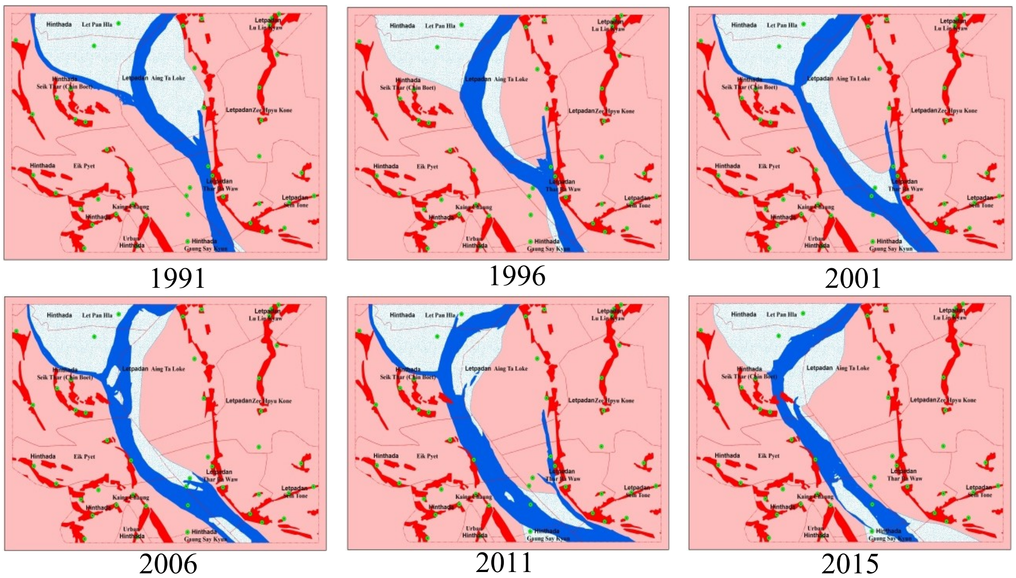
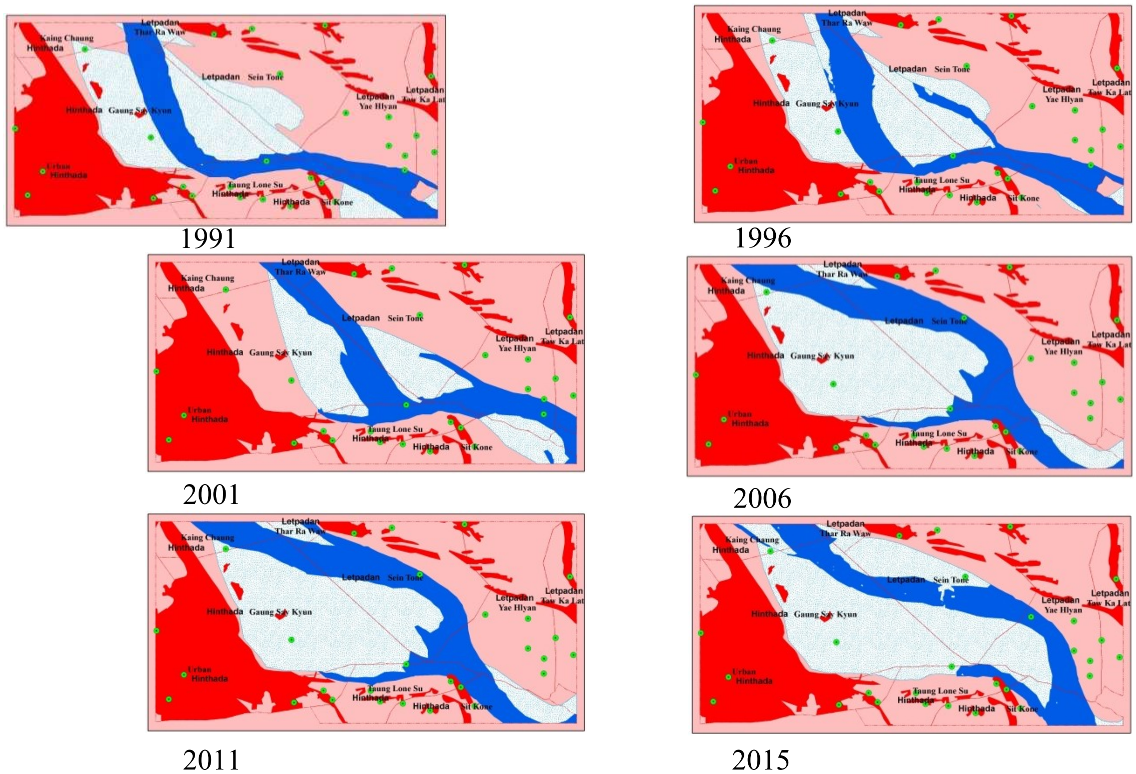



**Figure 12** .Channel movement of site 7
**Source:** Landsat 5, 7 and 8 satellite imagery

At selected site number 8, which lies the Gaung Say Kyun village tract, Hinthada township, is located on the west bank of Ayeyarwady River. No channel movement in 1996, and channel shift to the eastward direction with the distance of 1.2250 km in 2001, 1.9592 km in 2006, 3.4468 km in 2011, and 5.2292 km in 2015 from the reference point. In this site, channel shifts to the eastward direction within 25 years as shown in figure 13.




2011

**Figure 13**. Channel movement of site 8
**Source:** Landsat 5, 7 and 8 satellite imagery

## Conclusion

The study demonstrates efficient way to determine river channel pattern and understanding river erosion and siltation and how it has trended on settlement alongside the study area channel using GIS from medium resolution Landsat images and topographic maps. This type of study is appropriate for further planning of river and river adjacent to settlement management an effective manner as it could be incorporated in the long time changes of the river morphology. GIS analysis result shows in form 1991 to 2015 as a little bit change along the river course.

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