STUDY ON WETLAND CHARACTERISTICS OF THE BILIN RIPARIAN AREA

Aung Swe[1], Khin San Yu[2], Saw Thandar[3]

Abstract

About fourty-six rivers and many streams run along the coast of Myanmar. Among them Sittaung and Bilin rivers have wetland character and enter into the Mottama Gulf. Bilin river has about 212.43 kilometers (132 miles) long. It originates from the mountainous region of the Kayin State and it flows from north to south. Since the last two decades, upstream of Bilin river has started gold mining economy (Aung Swe, 2017). Lower course of the Bilin river experiences the accelerate deposition from the headwater sources and effect of tidal action from the Mottama Gulf. Due to gradual increase of tidal range, surface saline water intrusion also gradually increased around the lower course of the Bilin river. This paper presents wetland characteristics of the Bilin riparian area by relation to the relief, climatic condition, soils and geology of the Bilin catchment area, morphological conditions of upper and lower Bilin river course, bathymetry condition of Mottama Gulf, tidal condition of Yangon river and Mawlamyine tidal gauge stations. In this research, Normalize Difference Water Index (NDWI) method used to classify deep water (active channel), shallow water and intertidal zone area. Gradually change to wetland characteristics of the lower course of the river has been identified using a time series satellite images (1990-2018) by using Geographic Information Systems (GIS) and Remote Sensing (RS) techniques. After analyzing based on the NDWI method, lower Bilin riparian area is more influenced ***mud flat character*** than the wetland character.

Keywords Bilin river, riparian area, bathymetry, tidal condition, wetland characteristics, Normalize Difference Water Index (NDWI)

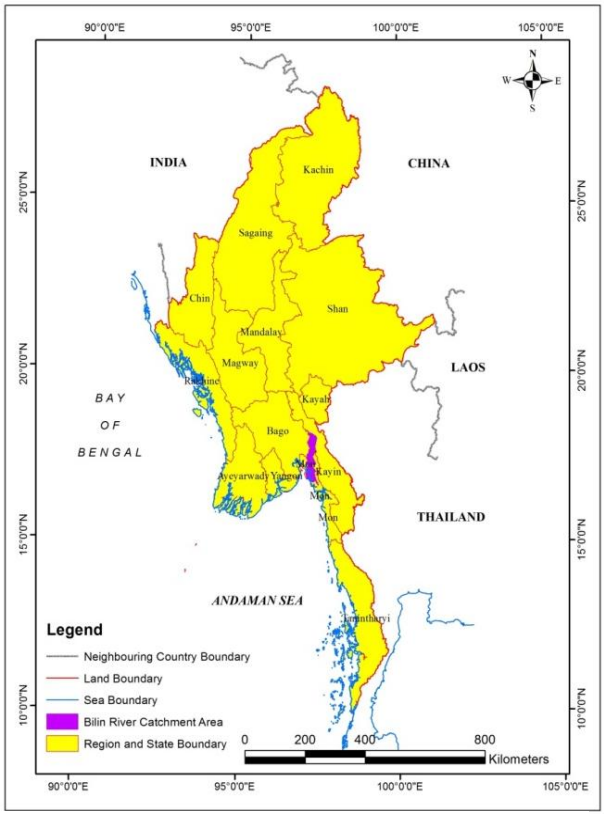
Introduction

Wetland: the aquatic, a natural or artificial landscape in which fresh or salt water play a key role, i.e. where the soil is waterlogged, the Water Table is at or near the surface, or the land is covered occasionally, periodically or permanently, by shallow or salt water. (Ashok Arora, 1999).Wetlands are defined as areas of marshes, swamp, mangrove forest, peat bogs or water whether natural or artificial, permanent or temporary or still, dead water and the place where there are flowing fresh or saltwater, including areas of marine water the depth of which at low tide does not exceed six meters. (Thein Aung, 2011). About fourty-six rivers and many streams are running along the coast of Myanmar. Among them Sittaung and Bilin rivers have wetland characteristics and enter into the Mottama Gulf. Bilin river originates from the mountainous region of the Kayin State. Bilin river flows from north to south and enters into the Gulf of Mottama and it has about 212.43 kilometers (132 miles) long. Bilin river catchment area has 4178.09 sq-km (1613.17 sq-miles). Hpapon Township in Kayin State, Shwegyin Township in Bago Region, Kyaikto, Bilin, Thaton and Paung Townships consists of Bilin catchment area. Figure 1(a) and (b).

[1] Dr, Associate Professor, Department of Geography, University of Yangon
[2] Lecturer, Department of Geography, University of Yangon
[3] Lecturer, Department of Geography, University of Yangon

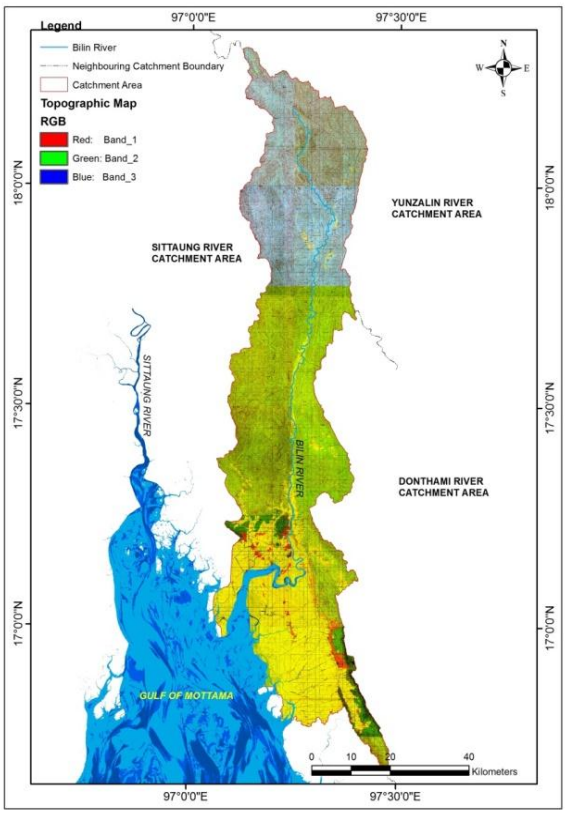
Aim and Objectives

The main aim of this research is to assess wetland characteristics of lower Bilin riparian area from the geomorphological point of view. The main objectives are to study the general character of the Bilin catchment area, to present morphology of the Bilin river, to describe bathymetry and tidal condition of Mottama Gulf (Martaban Gulf), and to examine relationship between tidal effect and wetland condition of lower Bilin riperian area.



Source : Myanmar Survey Department, Yangon

Figure 1 (a) Location of Region and State of Myanmar and Bilin catchment area



Source: Myanmar Survey Department, Yangon

Figure 1 (b) Location of Bilin catchment area and Bilin river

Materials and Methods

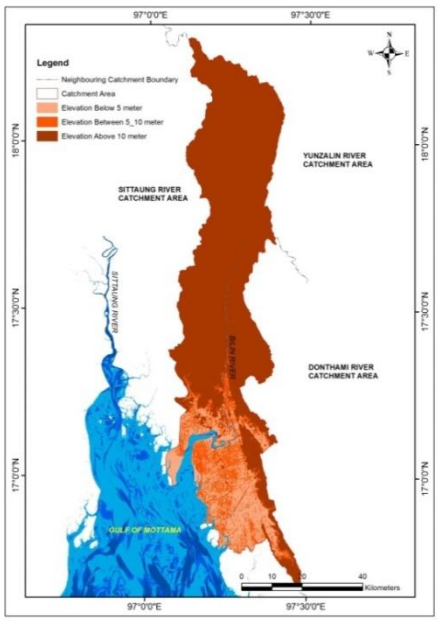
UTM topographic maps (1:50000 scale, 2002, Myanmar Survey Department, Yangon) are used to obtain length measurement of Bilin river. Minimum temperature, maximum temperature, rainfall, soils type and geology type data are derived from the Union of Myanmar Agriculture Atlas, 2002. Bilin catchment area and elevation classes are extracted from the 30 meter resolution DEM (Digital Elevation Model). High tide and low tide data of Yangon River and Mawlamyine gauge stations are derived from Myanmar Port Authority, Yangon. Landsat 5, Landsat 7ETM+ and Landsat 8 satellite images are used to extract the area of deep water, shallow water and intertidal zone area. In this research, Normalize Difference Water Index (NDWI) method is used to classify deep water, shallow water and intertidal zone area.

Results and Discussion

General Characteristics of Bilin Catchment Area

Relief

Elevation condition of Bilin catchment area can be classified into three groups such as elevation below 5 meter, elevation between 5-10 meter and elevation above 10 meter above sea level based on the 30 meters resolution DEM (Digital Elevation Model). From the classification result, about 16 percent of the total catchment area lies below 5 meter above sea level as shown in figure 2.



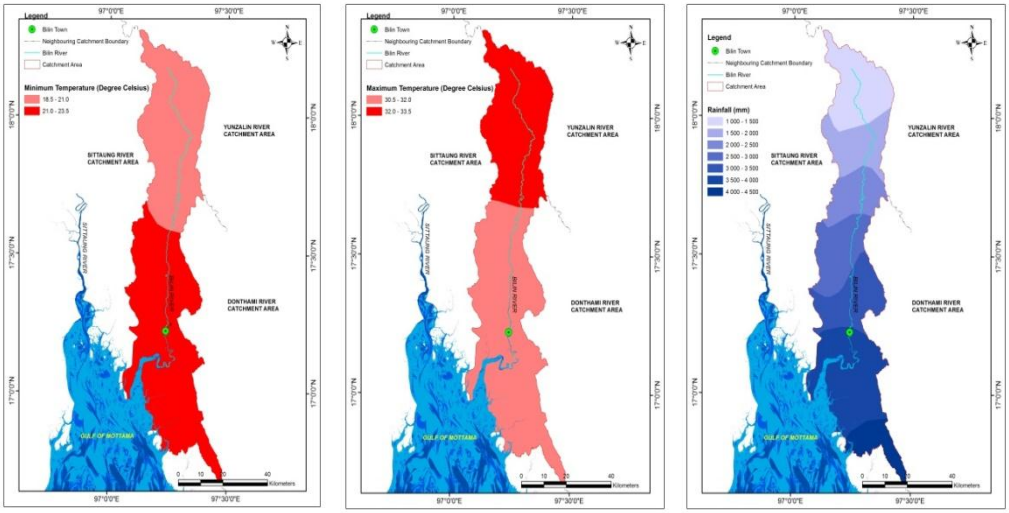
Source: 30 meter resolution DEM

Figure 2 Relief of Bilin catchment area

Climate

Temperature and Rainfall

The study area experiences Tropical Monsoon (Am) type of climate. Average minimum temperature is between 18.5 ºC and 23.5 ºC and average maximum temperature is between 30.5 ºC and 33.5 ºC respectively. According to the rainfall data, Bilin catchment area receives between 1000 mm-1500 mm in the northern part of the study area and gradually increased southward. Southernmost part of the Bilin catchment area receives between 3500 mm-4500 mm as shown in figure 3.



Source: The Union of Myanmar Agriculture Atlas, 2002

Figure 3 Climate of Bilin catchment area

Soils

There are three types of soils dominant in Bilin catchment area namely Gley and Gley Swampy Soil, Lateritic Soil and Red Brown Forest Soils. In the lower Bilin riverine area, dominant soil is Gley and Gley Swampy Soil and it has an area of 1127.72 sq-km (26.99 percent) of the total as shown in table 1 and figure 4 .

Table 1 Soil types and occupy area of Bilin catchment area

Soil Type	Area (sq-km)	Area (%)
Lateritic Soil	416.667965	9.97
Gley & Gley Swampy Soil	1127.725838	26.99
Red Brown Forest Soil	2633.732329	63.04

Source: The Union of Myanmar Agriculture Atlas, 2002
Area calculated by author

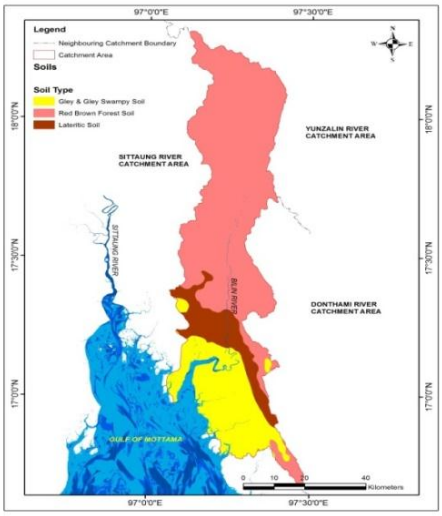
Geology

Bilin catchment area composes seven geologic types, there are Recent Alluviun; Older alluvium and gravels; Taungnyo Series, Lebyin Group, and equivalents; Granites and other non-basic intrusives; Shan Dolomite Group (Permian, Devonian), Moulmein Limestone (permian) and equivalents; Mergui Series, Mawchi Series, and equivalents; Metamorphics Rxs. Mainly Schists and Gneisses, equivalent to Mogok Series. Recent Alluviun and Older alluvium and gravels occupy lower Bilin riverine area and have an area of 1103.38 sq-km (26.4 percent) of the total. Table 2 and figure 5 show geology condition of the study area.

Table 2 Occupy area of each rock type in Bilin catchment area

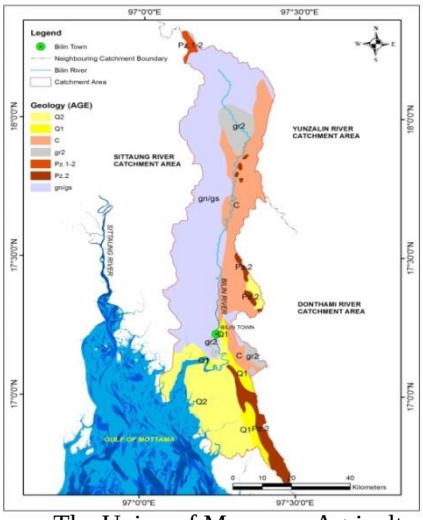
Symbols	Age	Rock type	Area (sq-km)	Area (%)
Q2	Holocene	Recent alluvium	946.338874	22.65
Q1	Pleistocene	Older alluvium and gravels	157.055149	3.76
C	Carboniferous	Taungnyo Series, Lebyin Group, and equivalents	783.238546	18.75
gr2	Mesozoic & Cenozoic	Granites and other non-basic intrusives	218.276341	5.22
Pz.2	Upper Paleozoic	Shan Dolomite Group (Permian, Devonian), Moulmein Limestone (permian) and equivalents	212.558851	5.09
Pz.1-2	Paleozoic, Mainly Up. Pz & Partly Lr.	Mergui Series, Mawchi Series, and equivalents	28.675897	0.68
gn/gs	Unknown age	Metamorphics Rxs. Mainly Schists and Gneisses, equivalent to Mogok Series(?)	1831.949085	43.85

Source: The Union of Myanmar Agriculture Atlas, 2002
Area calculated by author



Source: The Union of Myanmar Agriculture Atlas, 2002

Figure 4 Soils type of Bilin catchment area



Source: The Union of Myanmar Agriculture Atlas, 2002

Figure 5 Geology of Bilin catchment area

Morphology of the Bilin River

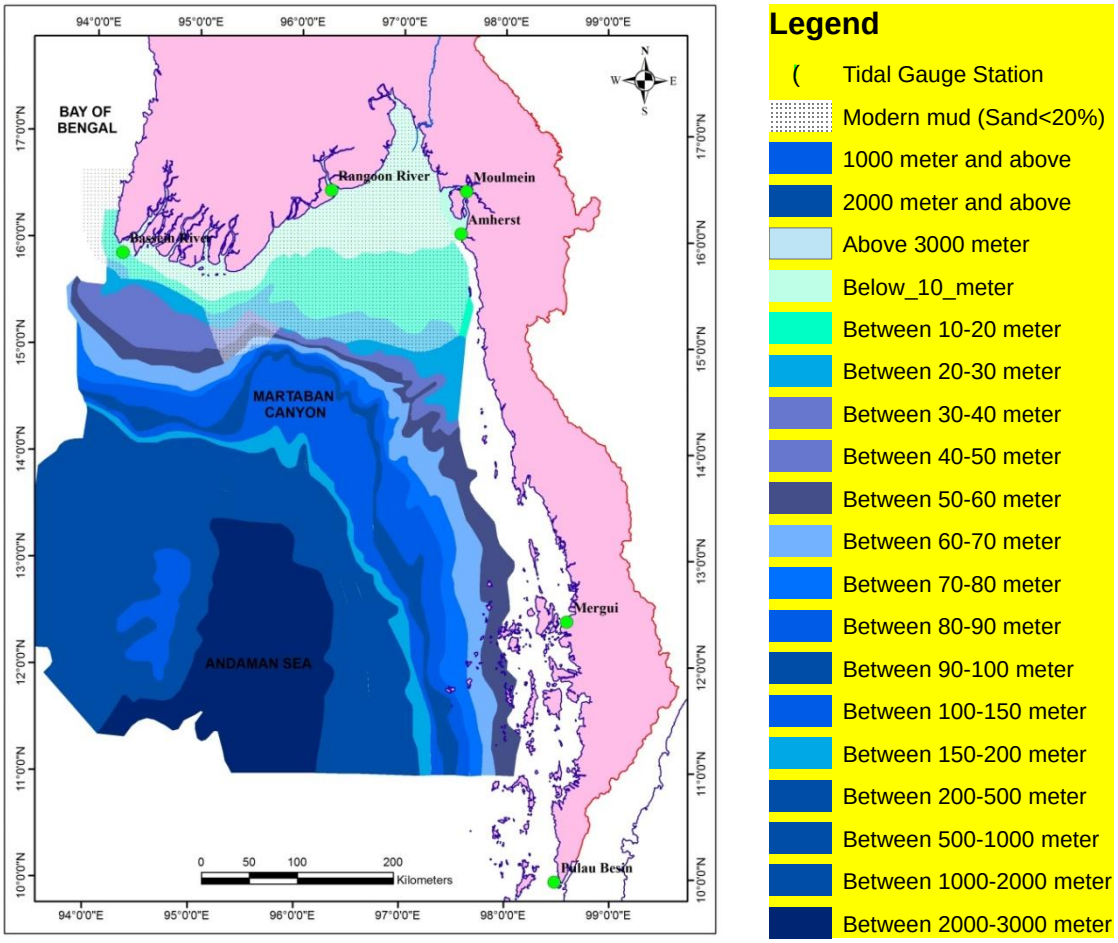
Northern portion of the Bilin river flows in the mountainous region of Kayin state and run north to south direction as a narrow channel until Bilin town. Southern part of the Bilin town, Bilin river freely flows in the recent alluvial area. So, the river channel which flows from northern tip of the catchment area to Bilin town identified the upper Bilin river and the river channel which flows from Bilin town to river mouth identified lower Bilin river.

The ratio between the measured length of a stream channel and that of the thalweg of its valley is measure of the sinuosity. Sinuosity ratio is 1.0 for straight channel, 1.2 transitional between straight and regular, 1.5 for regular channel, 1.7 for irregular channel and 2.1 for

tortuous (Chorley, R.J., 1984). Channel length of upper Bilin river is 105.58 km, thalweg line length is 140.80 km, sinuosity ration is 1.33. Channel length of lower Bilin river is 43.34 km, thalweg line length is 71.96 km, sinuosity ratio is 1.66. Therefore, channel pattern of upper Bilin river is nearly regular and lower Bilin river is nearly irregular. Between Hninpale village and Leikkon village, Bilin river flows as a meandering channel pattern and southern part of the Zokkali village, Bilin river flows as a braided channel pattern as shown in Figure 6.

Bathymetry and Tidal Condition of Mottama Gulf (Martaban Gulf)

Studies on bathymetry by Ramasamy and Rao of the National Institute of Oceanography supplemented with satellite data and images indicate that the sea floor in the Gulf of Mottama, the surrounding coastal areas and estuaries are covered with silty clays and subject to constant settling and resuspension due to tidal forces (Dr. Panwad Wongthong and Dr. James True, 2015). According to the bathymetry map, the area below 30m depth has about 50000 sq-km. This area composes the modern mud (sand < 20%). The shallow depth zone of the Mottama Gulf encourage to the more height of high tide water level. (Figure 7)



Source: Community-Led Coastal Management in the Gulf of Mottama Project (CLCMGoMP), 2015

Figure 7 Bathymetry of Mottama Gulf

There are six tidal gauging stations along the Delta coast and Mon-Tanintharyi coast: Pathein (Bassein) River, Yangon (Rangoon) River, Mawlamyine (Moulmein), Amherst, Mergui and Pulau Basin. Yangon and Mawlamyine gauge stations within the Mottama Gulf are taken as nearest tidal gauge stations of the Bilin river mouth. So, tidal statistics of Yangon and Mawlamyine gauge stations were used to assess the wetland conditions of lower Bilin riparian area.

In Yangon River, lowest water level of high tide for the year 1990, 2000, 2006, 2010, 2015 and 2018 are 4.12m, 4.07m, 4.02m, 3.94m, 3.96m, 4.22m and 4.04m. Highest water level of high tide for the year 1990, 2000, 2006, 2010,2015 and 2018 are 6.94m, 6.93m, 6.87m, 7.04m, 7m, 7.05m and 6.8m. Highest tide is 7.05m high and lowest tide is -0.04m, the tidal range is 7.09m (23.26 ft). (Table 3 and 4)

Table 3 Highest and lowest water level (meter) of high tide in Yangon River for the selected years

Year	January		February		March		April		May		June	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1990	6.44	4.3	6.47	4.12	6.5	4.14	6.6	4.34	6.55	4.66	6.52	4.78
1996	6.49	4.2	6.39	4.07	6.36	4.15	6.37	4.41	6.56	4.67	6.74	4.84
2000	6.37	4.2	6.27	4.02	6.19	4.05	6.43	4.28	6.7	4.65	6.83	4.94
2006	6.35	4.1	6.34	3.99	6.63	3.94	6.65	4.05	6.48	4.36	6.35	4.7
2010	6.39	4.14	6.45	4.01	6.49	3.96	6.52	4.14	6.35	4.56	6.5	4.68
2015	6.45	4.23	6.5	4.22	6.61	4.3	6.68	4.52	6.62	4.71	6.48	4.76
2018	6.53	4.39	6.41	4.14	6.31	4.04	6.46	4.15	6.68	4.43	6.68	4.75

Year	July		August		September		October		November		December	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1990	6.68	4.77	6.92	4.72	6.94	4.65	6.87	4.54	6.54	4.49	6.23	4.47
1996	6.93	4.92	6.93	4.77	6.85	4.63	6.66	4.54	6.53	4.54	6.47	4.44
2000	6.85	4.94	6.87	4.74	6.68	4.55	6.64	4.41	6.66	4.51	6.58	4.44
2006	6.55	4.67	6.8	4.54	6.97	4.4	7.04	4.39	6.82	4.46	6.39	4.39
2010	6.73	4.66	6.89	4.63	7	4.6	6.99	4.48	6.71	4.58	6.26	4.34
2015	6.61	4.71	6.94	4.67	7.05	4.65	6.93	4.71	6.65	4.66	6.27	4.5
2018	6.89	4.91	6.9	4.7	6.8	4.53	6.73	4.43	6.57	4.44	6.49	4.42

Source: Myanmar Port Authority, Yangon

Table 4 Highest tide and lowest tide water level (meter) of Yangon River for the selected years

Year	January		February		March		April		May		June	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1990	6.44	0.09	6.47	-0.01	6.5	0.15	6.6	0.42	6.55	0.76	6.52	0.89
1996	6.49	0.02	6.39	0.07	6.36	0.35	6.37	0.59	6.56	0.59	6.74	0.6
2000	6.37	0.17	6.27	0.23	6.19	0.47	6.43	0.49	6.7	0.47	6.83	0.57
2006	6.35	0.1	6.34	0.13	6.63	0.03	6.65	0.49	6.48	0.93	6.35	1.1
2010	6.39	0.06	6.45	0	6.49	0.06	6.52	0.49	6.35	0.9	6.5	0.87
2015	6.45	0.06	6.5	-0.04	6.61	0.11	6.68	0.29	6.62	0.62	6.48	0.94
2018	6.53	0.15	6.41	0.09	6.31	0.19	6.46	0.51	6.68	0.57	6.68	0.63

Year	July		August		September		October		November		December		Tidal
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	Range
1990	6.68	0.82	6.92	0.55	6.94	0.53	6.87	0.46	6.54	0.53	6.23	0.67	6.95
1996	6.93	0.57	6.93	0.58	6.85	0.68	6.66	0.68	6.53	0.67	6.47	0.4	6.91
2000	6.85	0.65	6.87	0.66	6.68	0.78	6.64	0.82	6.66	0.56	6.58	0.34	6.7
2006	6.55	0.9	6.8	0.68	6.97	0.59	7.04	0.5	6.82	0.49	6.39	0.66	6.94
2010	6.73	0.71	6.89	0.58	7	0.64	6.99	0.52	6.71	0.58	6.26	0.56	7
2015	6.61	0.84	6.94	0.55	7.05	0.49	6.93	0.38	6.65	0.4	6.27	0.49	7.09
2018	6.89	0.63	6.9	0.61	6.8	0.63	6.73	0.73	6.57	0.54	6.49	0.31	6.81

Source: Myanmar Port Authority, Yangon

Table 5 Highest and Lowest water level (meter) of high Tide of Mawlamyine gauge station for the selected Years

Year	January		February		March		April		May		June	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1990	3.47	1.57	3.53	1.35	3.88	1.5	4.2	1.91	4.45	2.32	4.63	2.73
1996	3.78	1.74	3.53	1.58	3.6	1.64	3.79	2.04	4.19	2.56	4.65	3.02
2000	3.7	1.7	3.47	1.52	3.44	1.57	3.81	2.06	4.26	2.57	4.65	3.02
2006	3.74	1.68	3.54	1.59	3.83	1.49	4.07	1.65	4.22	2.08	4.35	2.59
2010	3.84	1.75	3.36	1.6	3.82	1.5	3.99	1.69	4.14	2.18	4.5	2.63
2015	3.78	1.82	3.7	1.73	3.83	1.82	4.08	2.13	4.29	2.53	4.45	2.84
2018	3.96	1.99	3.65	1.64	3.51	1.55	3.93	1.69	4.37	2.19	4.75	2.77

Year	July		August		September		October		November		December	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1990	4.74	2.92	4.74	2.82	4.96	2.7	4.96	2.57	4.7	2.53	4.25	2.25
1996	5.12	3.23	5.09	3.24	4.94	3.06	4.63	2.79	4.41	2.56	4.11	2.25
2000	5.02	3.21	5.05	3.17	4.82	3	4.7	2.87	4.49	2.44	4.17	2.25
2006	4.72	2.89	4.97	3.02	5.08	2.95	4.99	2.69	4.61	2.4	4.02	2.09
2010	4.86	3.09	5.06	3.1	5.13	2.93	4.98	2.7	4.53	2.46	3.92	2.03
2015	4.86	3.06	5.14	3.16	5.14	3.11	5.01	2.98	4.34	2.65	3.81	2.3
2018	5.02	3.2	5.11	3.18	4.97	2.93	4.76	2.6	4.35	2.36	4.02	2.15

Source: Myanmar Port Authority, Yangon

Table 6 Highest tide and lowest tide water level (meter) of Mawlamyine gauge station for the selected years

Year	January		February		March		April		May		June	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
1990	3.47	-0.82	3.53	-0.94	3.88	-0.83	4.2	-0.54	4.45	6.03	4.63	0.23
1996	3.78	-1.1	3.53	-1.15	3.6	-0.9	3.79	-0.59	4.19	-0.34	4.65	-0.02
2000	3.7	-1.01	3.47	-1.06	3.44	-0.84	3.81	-0.64	4.26	-0.39	4.65	-0.06
2006	3.74	-1.07	3.54	-1.06	3.83	-1.13	4.07	-0.78	4.22	-0.16	4.35	0.35
2010	3.84	-1.11	3.36	-1.14	3.82	-1.11	3.99	-0.81	4.14	-0.25	4.5	0.19
2015	3.78	-0.97	3.7	-1.2	3.83	-0.97	4.08	-0.73	4.29	-0.24	4.45	0.16
2018	3.96	-0.94	3.65	-1.11	3.51	-1.07	3.93	-0.73	4.37	-0.23	4.75	0.06

Year	July		August		September		October		November		December		Tidal Range
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	
1990	4.74	0.46	4.74	0.6	4.96	0.63	4.96	0.36	4.7	0.02	4.25	-0.5	5.9
1996	5.12	0.15	5.09	0.31	4.94	0.3	4.63	0.11	4.41	-0.1	4.11	0.49	6.24
2000	5.02	0.2	5.05	0.35	4.82	0.41	4.7	0.2	4.49	-0.04	4.17	-0.51	6.11
2006	4.72	0.43	4.97	0.44	5.08	0.4	4.99	0.19	4.61	-0.03	4.02	-0.34	6.15
2010	4.86	0.31	5.06	0.41	5.13	0.38	4.98	0.2	4.53	0	3.92	-0.45	6.27
2015	4.86	0.33	5.14	0.39	5.14	0.21	5.01	-0.06	4.34	-0.35	3.81	-0.61	6.34
2018	5.02	0.26	5.11	0.35	4.97	0.36	4.76	0.26	4.35	-0.18	4.02	-0.66	6.13

Source: Myanmar Port Authority, Yangon

In Moulmein station, lowest water level of high tide for the year 1990, 2000, 2006, 2010, 2015 and 2018 are 1.35m, 1.58m, 1.52m, 1.49m, 1.5m, 1.82m and 1.55m. Highest water level of high tide for the same selected years are 4.96m, 5.09m, 5.05m, 5.08m, 5.13m, 5.14m and 4.97m. Highest tide water level of Mawlamyine gauge station is 5.14m. Lowest tide water level is –1.2m. Therefore, tidal range is 6.34m (20.8 ft). (Table 5 and 6)

Relationship between Tidal Effect and Wetland Condition of Lower Bilin Riparian Area

This paper presents wetland condition of the lower Bilin riparian area based on the delineation intertidal zone. Intertidal zone is the area that above water level at low tide and underwater at high tide (Ashok Arora, 1999). According to the study of Yangon River and Mawlamyine stations tidal statistics, height of the high tide water level is no more than 5m above sea level at the Bilin river mouth.

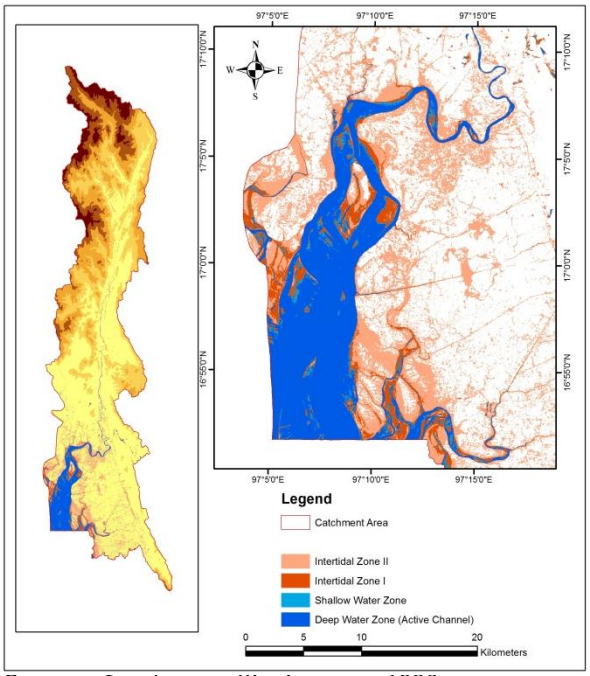
Normalized Difference Water Index (NDWI) method used to find deep water area (active channel), shallow water area and intertidal zone area (I) and (II). Based on the NDWI results, the Bilin riparian area is divided into five classes: NDWI value between (-1 to 0) mature land area, NDWI value between (0 to 0.4) intertidal zone II, NDWI value between (0.4 to 0.6) intertidal zone I, NDWI value between (0.6-0.7) shallow water area, and NDWI value between (0.7 to 1) deep water area (active channel).

According to table 7 intertidal zone I area is gradually increased from the year 1990 to 2018. Intertidal zone II area gradually increased from the year 1990 to 2015 and it abruptly decreased for the year 2018. Shallow water zone is also gradually increased and deep water zone (active channel) is gradually decreased until 2015 and abruptly increased for the year 2018 as shown in figure 8,9,10,11,12,13,14.

Table 7 Wetland condition of Bilin riparian area for the selected years

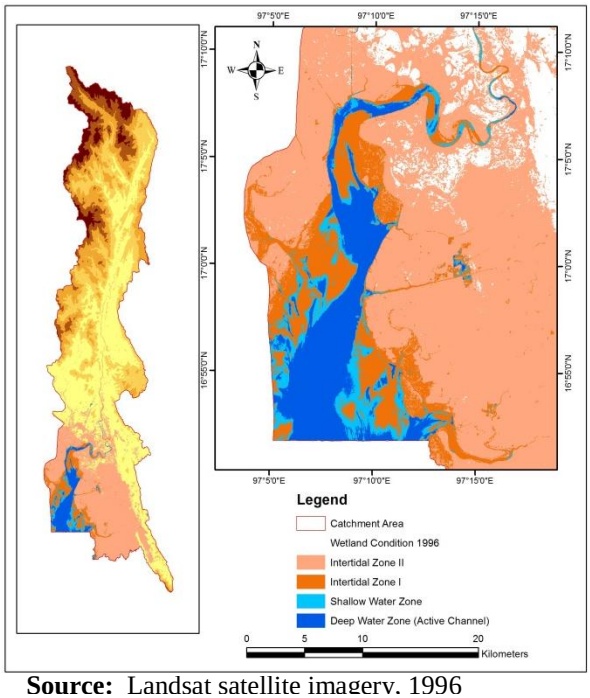
Year	Inter Tidal Zone II (sq-km)	Inter Tidal Zone I (sq-km)	Shallow Water Zone (sq-km)	Deep Water Zone (sq-km)
1990	281.50	48.00	16.79	165.90
1996	805.79	136.19	51.01	89.36
2000	519.21	134.64	93.50	81.39
2006	871.54	167.98	49.22	24.64
2010	787.51	129.88	95.88	57.01
2015	728.254	197.773	42.83	43.41
2018	794.95	96.04	94.55	142.36

Source: Landsat satellite imagery
Area calculated by author



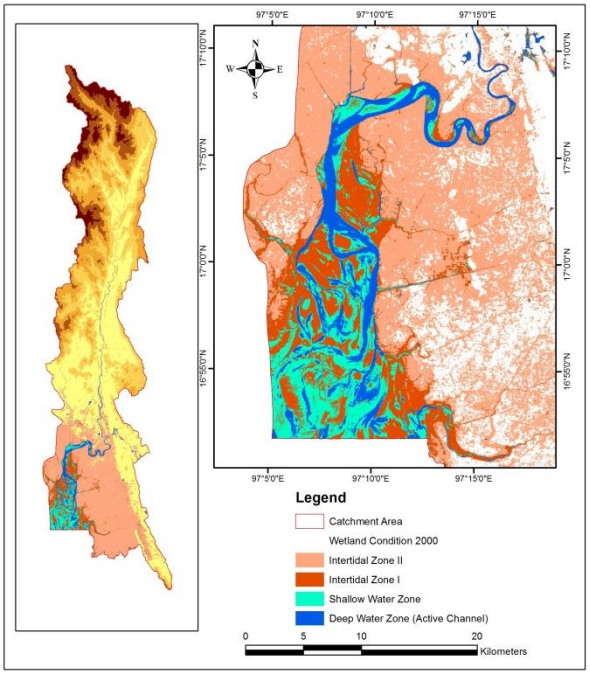
Source: Landsat satellite imagery, 1990

Figure 8 Intertidal zone I, intertidal zone II, shallow water zone and deep water zone of lower course of Bilin riparian area (1990)



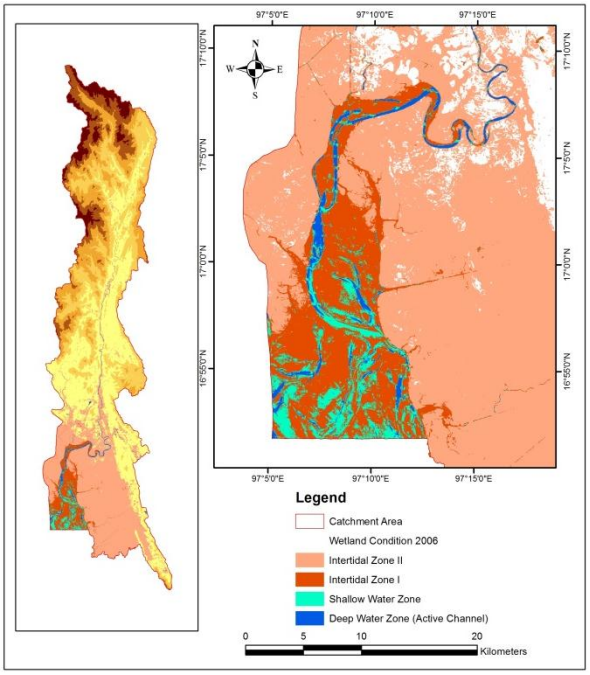
Source: Landsat satellite imagery, 1996

Figure 9 Intertidal zone I, intertidal zone II, shallow water zone and deep water zone of lower course of Bilin riparian area (1996)



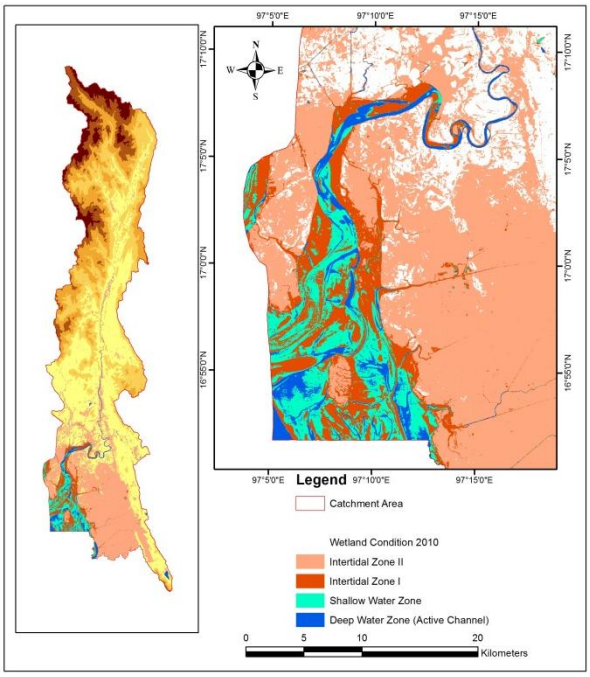
Source: Landsat satellite imagery, 2000

Figure 10 Intertidal zone I, intertidal zone II, shallow water zone and deep water zone of lower course of Bilin riparian area (2000)



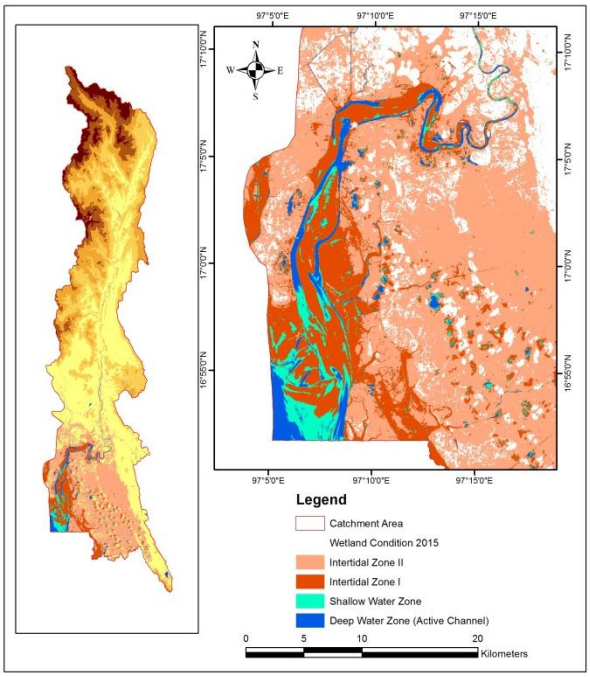
Source: Landsat satellite imagery, 2006

Figure 11 Intertidal zone I, intertidal zone II, shallow water zone and deep water zone of lower course of Bilin riparian area (2006)



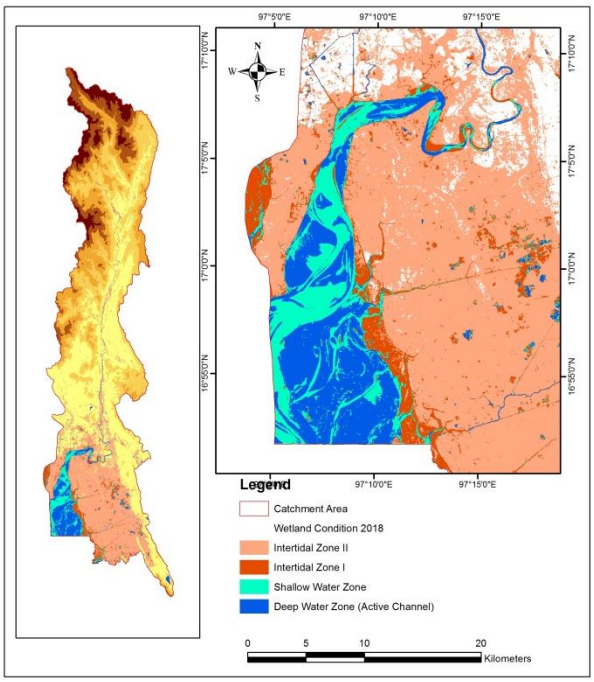
Source: Landsat satellite imagery, 2010

Figure 12 Intertidal zone I, intertidal zone II, shallow water zone and deep water zone of lower course of Bilin riparian area (2010)



Source: Landsat satellite imagery, 2015

Figure 13 Intertidal zone I, intertidal zone II, shallow water zone and deep water zone of lower course of Bilin riparian area (2015)



Source: Landsat satellite imagery,

Figure 14 Intertidal zone I, intertidal zone II, shallow water zone and deep water zone of lower course of Bilin riparian area (2018)

Conclusion

Wetlands are classified into five main groups: Marine, Estuarine, Riverine, Lacustrine, and Paludal. Each group has unique character. Topography, climate, soils and geological condition of lower Bilin riverine area are favourable to the wetland situation. Morphology of lower Bilin riparian area is also favourable to wetland character such as meandering and braided channel patterns. Additionally bathymetry and tidal condition encourage salt water intrusion toward the inland area. After analyzing based on the NDWI method, lower Bilin riparian area is more influenced ***mud flat character*** than the wetland character.

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