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Dagupan River, Pangasinan, Philippines: Morphology and Channel Changes

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Abstract

Indirect access to regions where it is often difficult to get particular spatial data is one of the primary benefits of remote sensing for monitoring and mapping morphological and channel changes occurring in the Dagupan river and neighboring beaches. Quantitative measurements and analyses of Google Earth's high-resolution satellite pictures revealed morphological and channel alterations. The breadth of the river's mouth, banks, and neighboring beaches were measured using satellite pictures taken between 2004 and 2013. In addition, in September 2015, the South Total Station (NTS-362R6L) was used to compare remotely sensed photos to in-field measurements. The RMSE was calculated to compare the horizontal positioning and measurement accuracy of the field measurements with the remote sensing data. Bolinao, Philippines Tide Chart at online tides and currents projections and examined historical data from tide gauges (2004-2015). Human actions, such as quarrying and the building of fish cages, were found to have widened the Dagupan River's discharge and banks. As a result of land usage and natural processes, the river's surrounding coasts have migrated inland, reducing its size over time. Predicted tidal heights and morphological and channel alterations, for which sea level rise is a likely cause, were shown to have a positive association. Locals said they had to evacuate their homes many times due to floods caused by typhoons, strong rains, and the sudden releasing of water from the dam. The root-mean-squared error (RMSE) between the Google Earth measurements and the actual field data was small, indicating that there was little variation between the two.

Keywords: *Google Earth, River Outlets, Riverbank, Coastlines, Human Activities & Flood.*

Introduction

Remote sensing has been used to detect the river and coastlines change both from natural and man-made factors in various parts which include indirect access to certain places of Dagupan river in Pangasinan. Remote sensing can be used extensively for mapping change in land cover, estimating morphological characteristics of terrain features, and monitoring effects of flooding as well. Dagupan river upstream originates from Benguet and passes through San Manuel, Binalonan and Urdaneta City and finally feeding Lingayen Gulf (Figure 1). Owing to the presence of large tract of grassland in highly elevated part of the watershed of Dagupan river is considered degraded in nature. With its steep slopes, erodible soils as well as geological instability can be attributed to the current climate change phenomenon manifested by high rainfall intensity.

Figure 1: Dagupan River, Pangasinan, Philippines.

The present conditions and the occurrences of torrential rains have immensely contributed to the vulnerability of this watershed to landslide and flooding that directly affects the communities along and nearby the river systems. The high stream flow during heavy and erratic rainfall pattern exacerbate the situation. Low lying areas in Pangasinan especially in Dagupan are always prone to flooding during typhoons due to its geographic location. Local topography, including lengthy river and ocean coastlines, dense urban development patterns, the capacity of our aging sewer system and increasingly extreme weather are some of the biggest causes of flooding. Floods can have adverse effects on the economy, people and natural resources. In this study, the detection of changes in coastlines, river outlet and river banks of Dagupan river in Pangasinan was done using remote sensing data from Google Earth.

Objectives of the Study

This study is aimed at determining the geophysical changes of the river outlet, riverbank and nearby coastlines of Dagupan river in Pangasinan Philippines. The objectives of this study are:

a. To detect and analyze the morphological and channel changes in the river outlet, riverbank coastlines through satellite imagery;
b. To determine the causes of morphological and channel changes in the river outlet, riverbank and coastlines, and;
c. To determine the positional accuracy and measurement of Google Earth data for the study area.

Methodology

Satellite images of the Google Earth from years 2004 to 2013 of Dagupan river in Pangasinan, were used for the analysis to identify changes. Satellite images of the river outlet, riverbank and coastlines were selected and analyzed quantitatively (Figure 2). Moreover, the actual measurements were done in September 2015. The methodology used in collecting data in different sites such as river outlet, riverbank and coastlines are as follows:

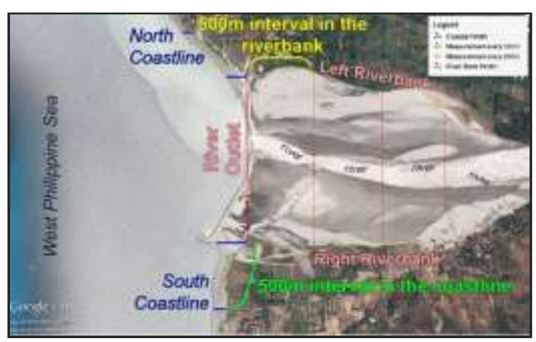

Figure 2: Image analysis of Google Earth Satellite Imageries.

River Outlet

The distance of the width of the river outlet for the period of 2004 to 2013 were measured through analysis of Google Earth images. Only clear imageries were analyzed which included the year 2004, 2006, 2013 and 2105. Plot lines and points for measurements were adjusted per year using the historical imageries.

Riverbank

The width of the riverbank was measured at every 500m from the outlet of the river upto the upstream. Data were gathered using satellite scenes downloaded from the Google Earth for the period of 2004 to 2013. Sampling points of the latest Google Earth images were also recorded for field validation.

Coastline

Data were gathered from North and South coastlines near the river outlet. The coastline in 2004 was the baseline of measurement. The width of the coastlines was measured every 500 meters starting from the outlet of the river up to the coastline of the nearby river. In a perspective wherein the sea is on the top side and the coast on the bottom, negative values will be assigned if the points were placed lower than the baseline indicating landward movement or narrowing of the coast, while positive values were assigned if the points were placed above the baseline indicating seaward movement of or widening of the coastline. The coastlines were assigned as North Coastline (located on top of the river) and South Coastline (located below the river). The latest coordinates of the points gathered in 2013 were recorded and used for field validation and measurement.

Field Validation

Coordinates of every sampling point of the latest Google Earth Satellite images were recorded for field validation. The actual distance was measured in September 2015 by the LiDAR1 researchers using South Total Station (NTS-362R6L).

Root Mean Square Error (RMSE) Computation

RMSE measures how much error there is between two datasets, usually compares a predicted value and an observed value. In this study, coordinates gathered during the field validation were plotted in Google Earth and measured to compare with the actual measurement. Google Earth Measurements were assigned as the predicted value (x_p) while the Actual field measurements were assigned as the observed (x_o).

$$RMSE = \sqrt{\frac{1}{N}\sum_{p=1}^{N}(x_p - x_o)^2}$$

Where,

xp = predicted value (Google Earth measurements)

xo = observed value (Actual measurements in the field)

N = total number of points measured

Measuring Sea Level Rise

The historical record from tide gauges of Bolinao, Philippines Tide Chart at online tides and currents predictions (Online Tides World View, 2016) for the years 2004 to 2015 were gathered to perceive the changes of the sea level. Records of the low tide and high tides per day were collected. The datasets were compared and analyzed.

Results and Discussion

Dagupan River Outlet

Dagupan river outlet increased in width size in a span of 9 years. It decreased in size in year 2006 from 573 meters to 507 meters but eventually increased again in size in 2013 from 507 to 582 meters. During the field measurement in 2015, the river outlet increased in size from 582 meters to 610 meters (Figure3). Erosion and accretion were both observed in the area and these processes maybe the reasons for the river outlet changes and these also may be due to huge number of fish cages installed in the area because fishing is the primary source of livelihood of the local communities near the study area.

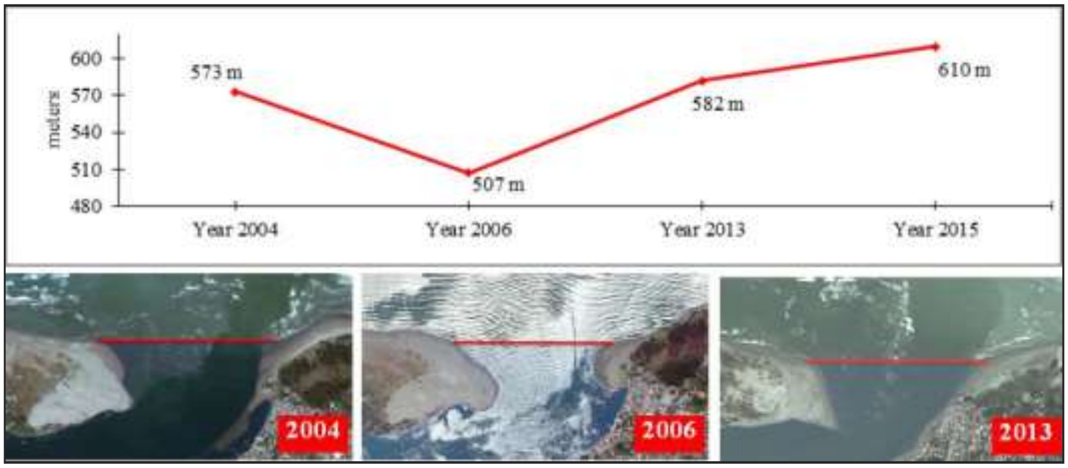

Figure 3: Width of Dagupan River outlet measured in different years.

The human activities by the residents in the river are mainly quarrying and construction of fish pens. The introduction of cages and pens to a water body can transform its appearance (Beveridge, M.C.M., 1984). Moreover the impacts of cage and pen culture could change the water flow, currents and sediment transport, and on soil terrain.

Mangroves, Makahiya and Pine trees were found planted in the river outlet which obstruct the rapid flow of water during heavy rains and holds the soil to prevent riverbank erosion. The steep slopes of the riverbank and erodible soils due to fish wastes and accumulated sediments in the area contribute to the vulnerability of the river outlet and the riverbank to landslide and flooding which can directly affect the local communities along and nearby the river. The high stream flow during heavy and erratic rainfall pattern and the emergency release of water from the dam exacerbate the flooding in the area.

Dagupan Riverbank

Dagupan River slightly increased its width during the period of 2004 to 2015 (Figure 4). Frequent flooding due to heavy rains in conjunction with the release of water in San Roque dam directly affects the river morphology the river. However, the presence of fish pens/cages alongside the riverbank artificially holds the soil and the riverbank from further erosion. The data from National Disaster Risk Reduction and Management Council (NDRRMC Preparedness Measures, 2015), indicates that the fish cages can help hold the soil and decrease the river flow but can easily be destroyed during typhoons that in turn may cause millions of milk fishes to escape in the open waters just like in Dagupan.

Dagupan river carries mainly erosion and agricultural runoffs (De las Alas, 1986). Certain area of the study site witnessed a major change because of manmade structure. Dagupan City is prone to heavy flooding. In 2007, typhoons with monsoon rains hit Northern and Central Luzon in August and November causing swelling of the river system. Residents nearby observed land formation or siltation in an area of the size of a baseball field which was caused by numerous illegal fish pen wastes and organic debris. Mitigation activities undertaken by the government include the installation of three dredging machines which were all simultaneously working on a big mass of land in SitioGuebang, Barangay Pantal.

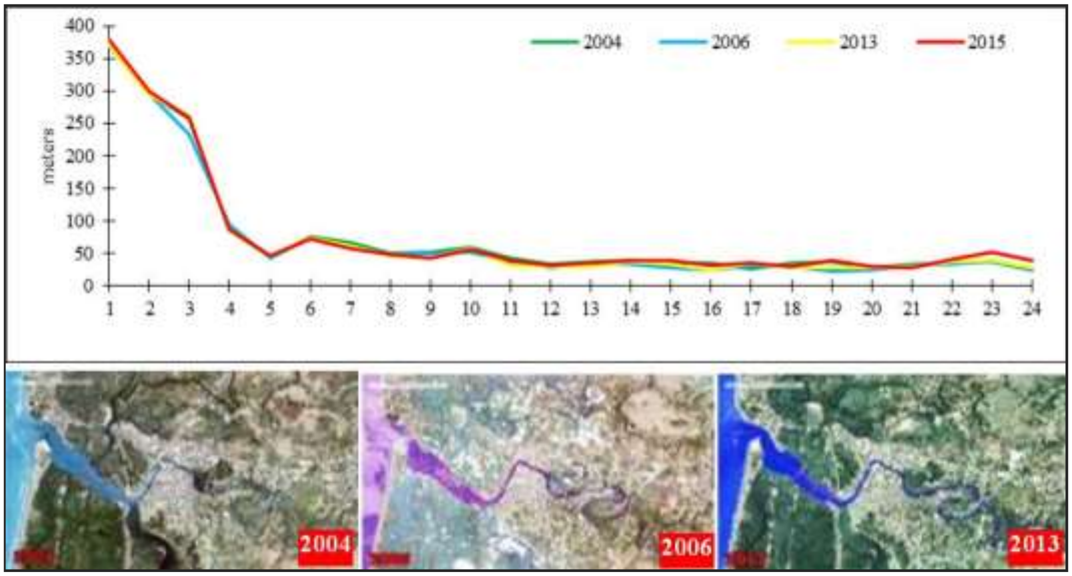

Figure 4: Width of Dagupan Riverbank measured in different years.

On 17 May 2007, Typhoon Halong (local name Cosme) hit Dagupan City which caused 4 deaths, severe damage to 3,349 houses and partial damage to 15,034 houses and affected 24,973 families. Damage to public infrastructure was of the order of USD 0.69 million. There were no rains in Dagupan, but the city experienced flooding due to water release from the dam and from high tide (Philippine Institute for Development Studies, 2014).

Residents also noted that during Typhoon Parma in 2009, the city was submerged by the worst flooding in Northern Luzon history and at least 7 billion-worth of damage to properties. Other cities and municipalities were also badly affected by floods that came from a combination of rain from Typhoon Parma and emergency dam water release. Calamities were experienced by the residents near the river. The respondents said that they were usually hit by strong typhoons every year since the Philippines sit astride the typhoon belt, and the country suffers an annual onslaught of dangerous storms from July through October. Some typhoons were found to be very destructive which resulted to floods, overflowing of river, erosion and hurricane. The calamities passed through the area often changed the effect the natural features of the river including erosion that caused the enlargement of the river width.

North Coastline nearby Dagupan River

The measurement of the North Coastline nearby Dagupan River from 2004 to 2015 is demonstrated in the Figure 5. Erosion and accretion were observed in the area; Points 1 to 5 on the coast were detected to be eroded in the years 2006, 2013 and 2015 while points 6 to 8 accreted in the year 2013.

Outlet of the river shows that coastal erosion usually occurs near the outlet. The area was reportedly hit by several typhoons every year which cause damages and natural changes in the area. The residents described how strong typhoons affected their everyday living when heavy rains cause severe flooding and also sand storm which sometimes limits visibility in the area thereby

causing the dry eyes. It was observed that severe flooding became a serious problem for the residents in the area and are getting worse when stored water from the dam is released downstream. However, during high tides, the waves which rise up to 4 meters constantly carry the sand from the sea. The beach level lowers drastically which enables larger waves to reach as far as the sandbank. Erosion in the coastal area of Dagupan could be the result of the consistent calamities and disasters experienced by the area every year.
The Department of Environment and Natural Resources - Region 1 reported that the north easterly wind is more prominently influenced by the sediment transport and coastal drifting as is evident by the fifty (50) hectares accreted land and convex shape shoreline near the Dagupan river (Coastal Geo-hazard Survey, 2013). These findings perhaps maybe due to the effects of accretion of sand which was observed in the coast near the Dagupan river outlet apparently in the last points of the North coast of the Dagupan river. From point 6 up to the last point of the coast, the beach was very wide due to the accumulation of sand and sediments coming from San Fabian river which is in parallel to the Dagupan river located up north. This limits the energy of waves which are weaker when they reach the back shore (Dehouck, 2014).

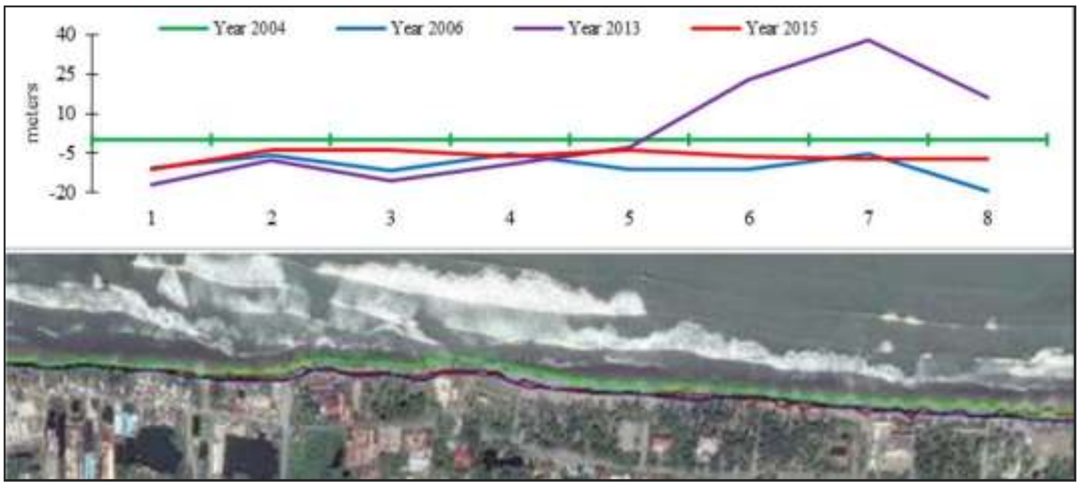

Figure 5: North coastline changes from 2004 to 2015.

South Coastline nearby Dagupan River
Figure 6 shows the coastline variation from the years 2004 to 2015. Only negative values were observed which indicates erosion. The highest rates of erosion occurred in year 2006. Large areas of aquaculture and fish ponds were found near the study area. The city is a hub for fisheries since about thirty eight percent (38%) of the area consists of ponds and rivers (Tanhueco, 2008). It is no wonder that aquaculture and fishing significantly contribute to the economy. The conversion of landuse for creation of fish ponds/ fish cages has contributed to coastal erosion. The remaining beaches are almost vanished because large areas of coastal land have been converted into fish and shrimp ponds.
Due to the escalating construction of fish ponds within the river, the natural flow of water and the supply of sediment from the river to a coast have been affected. However, the city government started implementing the city's fishery ordinance against construction and operation of fish pens in prohibited zones and designated navigational lanes. The subject to the demolition order are the fish pens located in

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prohibited zones or outside the designated navigational lanes which resulted in the obstruction of the natural flow of water and other aquatic resources (http://www.mb.com.ph/dagupan-fish-pen-demolition-begins/). This policy can reduce the coastal and riverbank erosion of the area hence, implementation is very imperative. Apart from the impact of human activity, strong onshore winds and high waves that typically erode the beach are simply natural evolutionary phenomena. However, extreme events and human activities along the coast and within river catchments of the study area often intensify the coastal erosion (Prasetya, 2007).

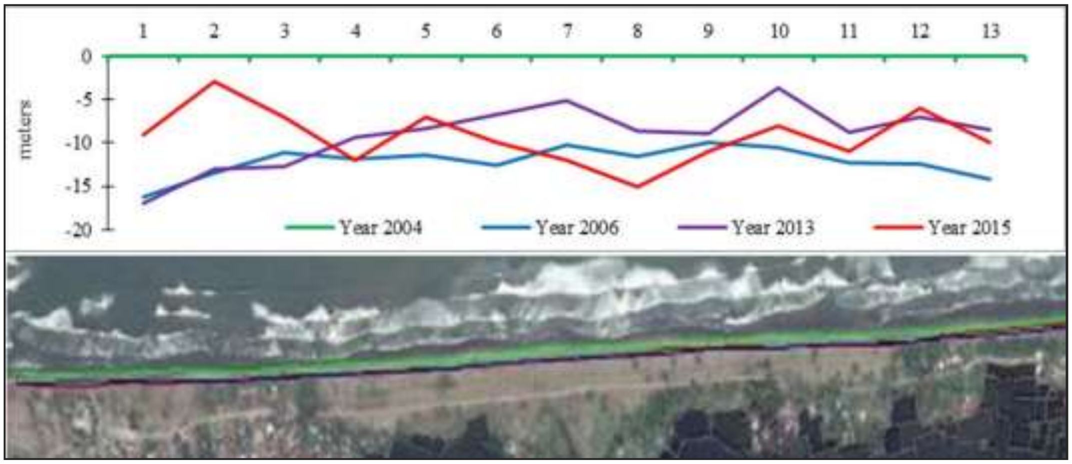

Figure 6: South coastline changes from 2004 to 2015.

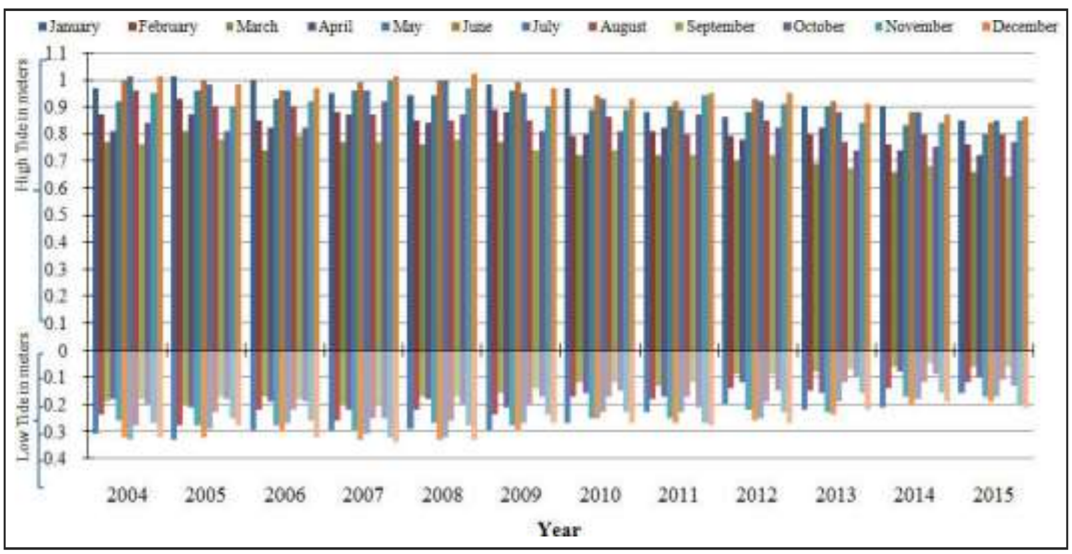

Figure 7: Tide table-peak measurement per year at Bolinao, Pangasinan.

Analaysis of Sea Level Rise in Pangasinan

The graph shown in Figure 7 is a decadal scale data from Bolinao Philippines tide chart (Online Tides World View, 2016). It provides tide predictions for over 7000 places around the world. Bolinao tide table-peak measurement predictions per year which represent the tide level measurements in the coastal areas of Pangasinan indicate that, average level of low tides in Pangasinan Gulf is increasing overtime. The average low tide in 2004 (-0.098 m) and the average low tide in 2015 (-0.045) had an average difference of 0.053 meter in terms of water level. The

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water level in the recent years (2013, 2014 & 2015) is nearer to land area than in the year 2004. However, the level of high tides in the year 2010 to 2015 is lower as compared to that in the years 2004 to 2009. As the level of low tides increases, the level of high tides decreases. The trend, linked to global warming, puts thousands of coastal cities, even whole islands at risk of being claimed by the ocean (Folger, 2013).Over the past century, the burning of fossil fuels and other human and natural activities has released enormous amounts of heat-trapping gases into the atmosphere. These emissions have caused the Earth's surface temperature to rise, and the oceans absorb about 80 percent of this additional heat. The rise in sea levels is linked to three primary factors, all induced by this ongoing global climate change such as thermal expansion, melting of glaciers and polar ice caps, and ice loss from Greenland and West Antarctica (Folger, 2013).

Root Mean Square Error

Root Mean Square Error (RMSE) computed between the observed and predicted measurements in Dagupan riverbank, river outlet, north coastline and south coastline were 0.543m, 0.2m, 0.564m and 0.611 respectively (Table 1.). These findings indicate that the positional accuracy and measurement of Google Earth data in Dagupan river and nearby coastlines showed minimal differences and errors which can be used for small scale data sets and for research purposes. Remote sensing data together with the observed/validated data from the field provide horizontal positional accuracy testing and evaluation of Google Earth positioning and measurement. As stated by Mohammed (2013), Google Earth positional accuracy may vary in locations and the time the image was captured thus can be checked by field validation.

Table 1: Root Mean Square Error Computation

Riverbank			
FM	GE	Diff	Diff^2
387	378.8	-0.8	0.64
300	300.3	-0.3	0.09
259	258.12	0.88	0.7744
86	86.2	-0.2	0.04
46	46.07	-0.07	0.0049
71	70.27	0.73	0.5329
57	57.29	-0.29	0.0841
47	46.49	0.51	0.2601
42	42.85	-0.85	0.7225
55	55.87	-0.87	0.7569
38	38.59	-0.59	0.3481
31	30.24	0.76	0.5776
34	34.72	-0.72	0.5184
38	38.32	-0.32	0.1024
39	39.29	-0.29	0.0841
31	30.25	0.75	0.5625
34	34.22	-0.22	0.0484
30	30.33	-0.33	0.1089
39	39.27	-0.27	0.0729
29	28.68	0.32	0.1024
28	27.75	0.25	0.0625
40	39.96	0.04	0.0016
51	51.07	-0.07	0.0049
38	38.76	-0.76	0.5776
Sum			7.078
RMSE			**0.543**

River outlet			
FM	GE	Diff	**RMSE**
510.4	510	0.4	**0.4**

North Coastline			
FM	GE	Diff	Diff^2
-11	-10.48	-0.52	0.2704
-4	-3.29	-0.71	0.5041
-4	-3.84	-0.16	0.0256
-6	-5.38	-0.62	0.3844
-4	-3.46	-0.54	0.2916

-6	-5.68	-0.32	0.1024
-7	-6.46	-0.54	0.2916
-7	-6.18	-0.82	0.6724
Sum			2.543
RMSE			**0.564**

South Coastline			
FM	GE	Diff	Diff^2
-9	-9.68	0.68	0.4624
-3	-2.1	-0.9	0.81
-7	-7.52	0.52	0.2704
-12	-12.4	0.4	0.16
-7	-7.69	0.69	0.4761
-10	-9.86	-0.14	0.0196
-12	-12.93	0.93	0.8649
-15	-15.93	0.93	0.8649
-11	-11.37	0.37	0.1369
-8	-7.32	-0.68	0.4624
-11	-10.64	-0.36	0.1296
-6	-6.43	0.43	0.185
-10	-10.1	0.1	0.01
Sum			4.852
RMSE			**0.611**

FM= Field Measurements, GE=Google Earth Measurements

Conclusions

Dagupan river outlet increased in width size in a span of 9 years. The river outlet changes were brought by the erosion and accretion phenomenon due to human interventions such as quarrying and construction of fish pens. On the other hand, the riverbank slightly increased in size and has changes morphology due to the frequent flooding caused by heavy rains, typhoons and the emergency release of the stored water from San Roque dam. Generally, Erosion was observed in the North and South coast of Dagupan River. Coastal erosion occurred mostly near the river outlet caused by frequent flooding during typhoons. High tides and big waves which carried the sand out to sea were also a big contributory factor in the erosion. Moreover, the erosion observed in the South coast was due to the conversion of the coastal area into aquaculture facility such as fish ponds and fish cages. Rise in sea level was also a probable cause wherein according to prediction, heights of low tides in Pangasinan Gulf is increasing overtime. The computed RMSE is low which shows positional accuracy and measurement of Google Earth data in Dagupan river and nearby coastlines.

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