USE OF REMOTE SENSING IN DETECTION OF GEOPHYSICAL CHANGES IN DAGUPAN RIVER, PANGASINAN, PHILIPPINES

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ABSTRACT

Remote sensing offers some key advantages in monitoring and mapping geophysical changes taking place in the river outlets, riverbanks and coastlines of Dagupan River in Pangasinan which include indirect access to certain places that are usually hard to obtain specific spatial data. Geophysical changes were determined using quantitative measurement and analysis using Google Earth high resolution satellite imageries. Clear aerial imageries were analyzed from years 2004 to 2013 determining the change in width of the river outlet, riverbank and coastlines. Remote sensing data were also compared to actual measurements in the field using South Total Station (NTS-362R6L) in September 2015. Root Mean Square Errors (RMSE) were computed to evaluate horizontal positioning and measurement accuracy between remote sensing data and field measurements. An interview was conducted to the residents of the area to perceive feature changes of the river and coastlines. Furthermore, the historical data (2004-2015) from tide gauges of Bolinao, Philippines Tide Chart at online tides and currents predictions were also analyzed. Results showed that Dagupan river outlet and riverbank increased in width size due to human interventions such as quarrying and construction of fish pens. The North and South coastlines shifted landward decreasing its size overtime due to land use and natural factors. A possible correlation were observed between the predicted heights of tides and the geophysical changes wherein sea level rise was a probable cause. Residents reported frequent flooding in the area due to typhoons, heavy rains and the emergency release of water from the dam. RMSE between Google Earth measurements and actual field data was low which indicates minimal difference between the two datasets.

INTRODUCTION

Remote sensing has been used to detect the river and coastlines change both from natural and man-made causes 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 geophysical and biophysical characteristics of terrain features, and monitoring effects of weather-related problems like flooding. Owing to the presence of large tract of grassland in highly elevated part of the watershed, Dagupan is considered degraded in nature. With its steep slopes, erodible soils as well as geological instability are critically triggered by the current climate change phenomenon manifested by high rainfall intensity. The present conditions and the occurrences of torrential rains have immensely contributed to the watershed vulnerability to landslide and flooding directly affecting communities along and nearby 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 devastating consequences and have 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 through remote sensing from the Google Earth was used.

OBJECTIVES OF THE STUDY

This study aimed to determine the geophysical changes of the river outlet, riverbank and coastlines of Dagupan river in Pangasinan Philippines. The study specifically aimed to:
a. Detect and analyze the geophysical changes in the river outlet, riverbank and coastlines through satellite imagery;
b. Determine the causes of geophysical changes in the river outlet, riverbank and coastlines, and;
c. Determine the positional accuracy and measurement of Google Earth in the study areas.

MATERIALS AND METHODS

Satellite imageries of the Google Earth from years 2004 to 2013 of Dagupan river in Pangasinan, were used in the analysis to identify changes. Clear images of the river outlet, riverbank and coastlines were selected and analyzed quantitatively. Moreover, the actual measurements were gathered in September 2015. The methodology used in gathering data in different study sites such as river outlet, riverbank and coastlines of the watershed are as follows:

River Outlet

The distance of the width of the river outlet for years 2004 to 2013 were measured. Only clear images of historical data of the Google Earth were analyzed. Gathered data from Dagupan river outlet was compared from 2004 to 2013.

Riverbank

The width of the riverbank was measured every 500m from the outlet of the river to upstream. Data were gathered using historical views of the Google Earth for years 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 of the rivers. The coastline in 2004 was the basis of the measurement. Coastlines images were measured every 500 meters from the coastline near the outlet of the river up to the coastline of the nearby river.

Field Validation

Coordinates of every sampling points of the latest Google Earth Satellite images were recorded for field validation. The actual distance of the river outlet 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 validated measurement. RMSE was computed by getting the difference for each Google Earth Measurements (predicted value) and Field Validated Measurements (observed value) and the results were squared to have positive value. Then the sum of all values was divided by the number of observations, which were then square-rooted to have the Root Mean Square Error. Below is the formula used for RMSE:

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

where xp = predicted value
xo = observed value
N = number of sample

Measuring Sea Level Rise

The historical record from tide gauges of Bolinao, Philippines Tide Chart at online tides and currents predictions (http://tides.mobilegeographics.com/locations/655.html) 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 determined. Gathered data 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 2004 (573m) to 2006 (507m) by 66 meters but eventually increased again in size in 2013 from 582 to 610 meters during the field validation in 2015, respectively (Figure 1). Erosion and accretion were 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.

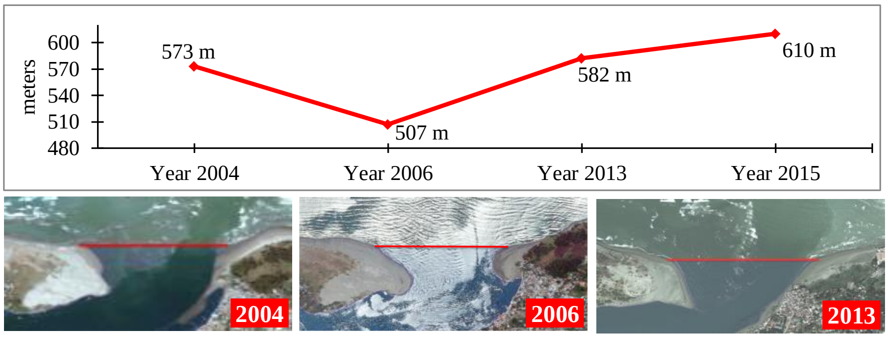

Figure 1. Width of Dagupan River outlet measured in different years

The human activities conducted by the residents in the river are 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 flowing of water during heavy rains and holds the soil to prevent riverbank erosion. With the steep slopes of the riverbank and erodible soils due to fish wastes and sediments which accumulated 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

Generally, Dagupan River slightly increased its width size from 2004 to 2015 (Figure 2). Frequent flooding due to heavy rains in conjunction with the release of water in San Roque dam directly affects the soil in the river. However, the presence of fish pens/cages alongside the riverbank artificially holds the soil and the riverbank from further erosion. Based on the data from National Disaster Risk Reduction and Management Council (NDRRMC Preparedness Measures, 2015), fish cages can help hold the soil and decreased the river flow but can easily be destroyed during typhoons that can cause millions of milkfishes 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 has 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 in Dagupan City.

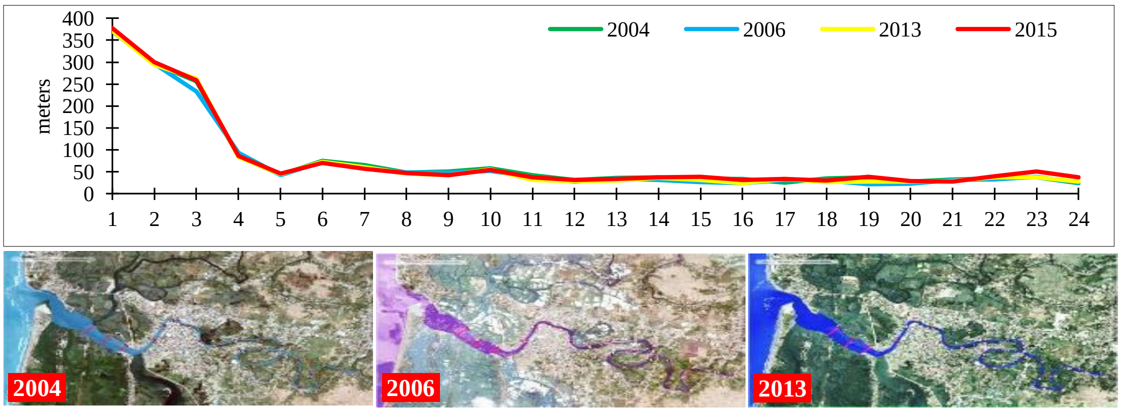

Figure 2. Dagupan Riverbank

Residents nearby observed land formation or siltation as big as a baseball field which was caused by numerous illegal fish pen wastes and organic debris. Mitigation activities were done by the government like the installation of three dredging machines which were all simultaneously working on a big mass of land in Sitio Guebang, Barangay Pantal. On 17 May 2007, Typhoon Halong (local name Cosme) hit Dagupan City which resulted to 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 at USD 0.69 million. There was no rain 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 PhP 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 Coast of Dagupan River

Figure 3 shows the measurement of the North Coast of Dagupan River from 2004 to 2015. Erosion and accretion were observed in the area; Points 1 to 5 of the coast were detected to be eroded in the years 2006, 2013 and 2015 while points 6 to 8 accreted in year 2013.

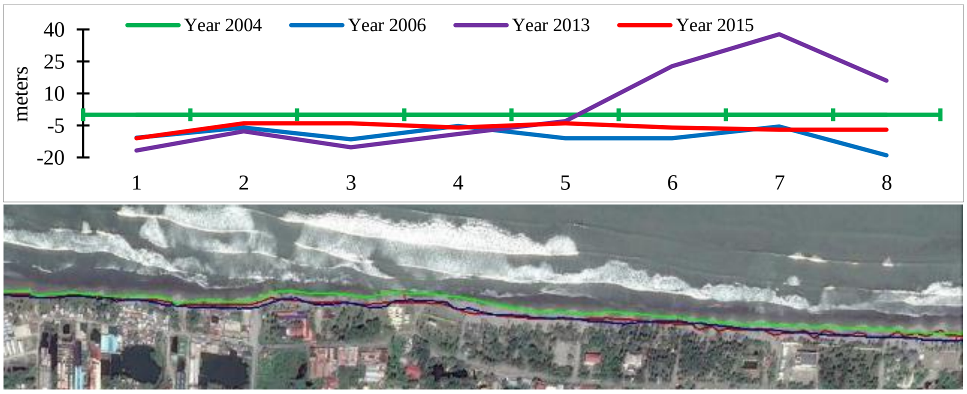

Figure 3. North Coastline of Dagupan River

The coastal area was varied from wide to narrow coastal land. The narrow coastal land was observed near the outlet of the river showing that coastal erosion usually occur 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 were heavy rains resulted to severe flooding and also sand storm which can limit visibility in the area and can cause dry eyes. It was observed that severe flooding became a serious burden to the residents in the area which are getting worse when stored water from the dam was released downstream. However, during high tides, the waves which rise up to 4 meters constantly carried the sand from the sea. The beach level lowered drastically which enabled 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 northeasterly wind is more prominently influenced by the sediment transport and coastal drifting as evidenced 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).

South Coastline of Dagupan River

Figure 4 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.

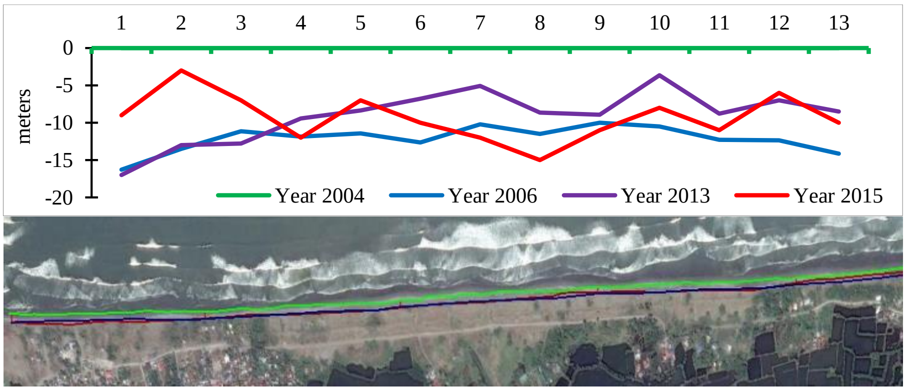

Figure 4. South Coastline of Dagupan River

Large areas of aquaculture and fish ponds were found near the study area. The city is devoted to 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 accounts prominently in the economy. The conversion of land into fish ponds/ fish cages had a great contribution 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 of the demolition order are the fish pens located in prohibited zones or outside the designated navigational lanes which resulted to obstruction of the natural flow of water and other aquatic resources (http://www.mb.com.ph/dagupan-fish-pen-demolition-begins/). This policy could bring a huge impact to 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 intensifies the coastal erosion (Prasetya, 2007).

Analysis of Sea Level Rise in Pangasinan

The graph shown in Figure 5 is a decade collective data from Bolinao Philippines tide chart at http://tides.mobilegeographics.com/locations/. 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 depicted 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 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 are lower than in the years 2004 to 2009. As the level of low tides increases, the level of high tides decreases.

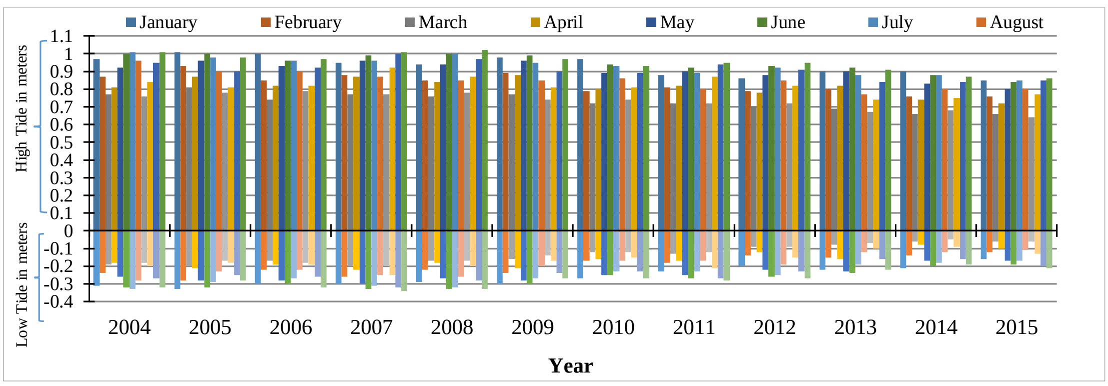

Figure 5. Tide table-peak measurement per year at Bolinao, Pangasinan

The trend, linked to global warming, puts thousands of coastal cities, even whole islands at risk of being claimed by the ocean (http://ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise/). 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 (http://ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise/).

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. These findings indicate that the positional accuracy and measurement of Google Earth in Dagupan Watershed 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.

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 sized brought about by frequent flooding caused by heavy rains, typhoons and the emergency released 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 in Dagupan river and coastlines.

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REFERENCES

References from Journals:

Beveridge, M.C.M., 1984 Cage and pen fish farming. Carrying capacity models and environmental impact. FAO Fish.Tech.Pap., (255) : 131 p.

Dehouck, A. (2014). Coastline changes and satellite images, Storms over La Salie Beach, French Atlantic Coast. Airbus Defence and Space - Geo-Intelligence.

De las Alas, J.G., 1986. Prediction of levels and trends of non-oil pollutants in Lingayen Gulf and Manila Bay. University of the Philippines-Science Research Foundation, Manila.

Prasetya G. 2007. Thematic paper: The role of coastal forests and trees in protecting against coastal erosion. Regional Office for Asia and the Pacific.

References from websites:

DENR-MGB Region 1 (2013). Coastal Geohazard Survey and Mapping in Dagupan City, Pangasinan.

Impacts of open pen freshwater aquaculture production on wild fisheries. Retrieved on May 20, 2015 from http://www.mb.com.ph/dagupan-fish-pen-demolition-begins/

Preparedness Measures and Effects of Typhoon “LANDO” (I.N. KOPPU). Retrieved on October 29, 2015 from http://ndrrmc.gov.ph/attachments/article/2607/SitRep_No_07_re_Preparedness_Measures_ana_Effects_of_Typhoon_LANDO_19OCT2015_12AM2.pdf

Philippine Development Plan 2011–2016. Conservation, Protection and Rehabilitation of the Environment and Natural Resources. Pp 304-337. Retrieved on June 2, 2015 from http://www.neda.gov.ph/wp-content/uploads/2013/09/CHAPTER-10.pdf
Philippine Institute for Development Studies 2014. Community Governance for Disaster Recovery and Resilience. Retrieved on May 27, 2015 from http://dirp3.pids.gov.ph/webportal/CDN/PUBLICATIONS/pidsdps1438.pdf
Tanhueco, R. (2008). Assessment of Disaster Risk Management in Dagupan City. Retrieved on May 27, 2015 from http://info.worldbank.org/etools/docs/library/239525/SC_ECP_RenanTanhueco%203-16.pdf