REMOTE SENSING APPLICATION OF THE GEOPHYSICAL CHANGES IN THE COASTLINES AND RIVERS OF PANGASINAN, PHILIPPINES

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ABSTRACT

The study aimed to determine the geophysical changes of the river outlets, riverbanks and coastlines in Bued-Angalacan and Alaminos, Pangasinan. Quantitative measurement and analysis were used in the detection of changes. Image analysis using remote sensing from the Satellite imageries of the Google Earth from years 2004 to 2014 were used. The actual measurements of the width and length of river outlets, riverbanks and coastlines of the said rivers were gathered by the use of South Total Station (NTS-362R6L) in September 2015. The insight of the residents regarding the feature changes of the river was obtained through one on one interview. Root Mean Square Errors (RMSE) were also computed for horizontal positioning and measurement to determine the accuracy of Google Earth Satellite Imageries. Results revealed that Bued-Angalacan and Alaminos river outlets decreased in width size due to natural factors and human activities. There was increased in size of the Bued-Angalacan and Alaminos riverbanks which could be possibly due to natural calamities and weak bank resistance brought about by the frequent flooding caused by heavy rains and the emergency released of water from San Roque Dam. The coastline of the Bued-Angalacan river decreased in size due to directly and indirectly modification of land caused by natural occurrences. Generally the north and south coasts of Alaminos River increased and expanded. The computed RMSE for positional accuracy and measurement in the study is low which indicate only minimal differences and errors between field validation and Google Earth measurements.

INTRODUCTION

Remote sensing is a technology for acquisition of information and events at remote places with the use of remote sensing satellites equipped with sensors observing the earth. Hence, it has been used extensively to detect geophysical changes of rivers and coastlines. Land-use change can easily be monitored through the use of remote sensing and it can provide valuable information especially for areas that are now vanished or inaccessible to humans. Pangasinan is located on the western area of the island of Luzon along the Lingayen Gulf and South China Sea. A crescent-shaped province that occupies 5,368.82 square kilometers of verdant farmlands, hills, forest and rivers. To the east, it is bounded by the mighty Cordillera Mountains, the Zambales ranges to the west, the rice plains of Tarlac to the south and Lingayen Gulf and the West Philippine Sea to the north (http://pangasinan.gov.ph/the-province/about-pangasinan/). It encloses the Lingayen gulf, a semicircular embayment with an area of about 2,100 km^2 (McManus, 1990). The terrain of the province is typically flat, with a few being mountainous. Several rivers traverse the province and some of those are the Bued-Angalacan River, and the Alaminos River. Pangasinan coast is highly utilized for livelihood and coastal tourism. The gulf contains one of the oldest national parks in the country, the Hundred Islands located in the municipality of Alaminos. In this study, the detection of changes in river outlets, riverbanks and coastlines of Bued-Angalacan and Alaminos rivers in Pangasinan through image analysis using remote sensing from the Google Earth was used.

OBJECTIVES OF THE STUDY

This study aimed to determine the geophysical changes of the river outlets, riverbanks and coastlines in Bued-Angalacan and Alaminos, Pangasinan
The study specifically aimed to:

a. Detect and analyze the geophysical changes in the river outlets, riverbanks and coastlines through satellite imageries;
b. Determine the causes of geophysical changes in the river outlets, riverbanks 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 2014 in Bued-Angalacan and Alaminos rivers in Pangasinan, were used in the analysis to identify changes. Clear images of the river outlets, riverbanks and coastlines of the different rivers of the selected watersheds were analyzed quantitatively. Moreover, the actual data were gathered in September 2015. The methodology used in gathering data in different study sites such as river outlets, riverbanks and coastlines of the watersheds are as follows:

River Outlet

The distance of the width of the river outlet for years 2004 to 2014 were measured. Gathered data from Bued-Angalacan rivers were compared from 2004 to 2013 while Alaminos river was compared from 2009 to 2014.

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 2014. 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 for the Bued-Angalacan river, while 2009 was the basis of the measurement for the Alaminos river. 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 point of the latest Google Earth images were recorded for field validation. The actual distances of the river outlets, riverbanks and coastlines were 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 this 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 x_p = predicted value
x_o = observed value
N = number of sample

Community Survey on Coastline and River Changes of the Bued-Angalacan and Alaminos River

A questionnaire regarding river and coastal changes were made specifically to determine the natural occurrences and the natural features of the area. Focused groups were formed by selecting residents residing at least a decade in the area in order for them to describe the historical changes and natural occurrences in the area. The community survey was conducted on September 14-15, 2015 in Bued-Angalacan river and on November 26-27, 2015 in Alaminos River in Pangasinan.

RESULTS AND DISCUSSION

Bued-Angalacan River Outlet

Result of the study showed that there was a decreased and increased of width size of the Bued-Angalacan river outlet. Figure 1 shows that in 2004, the width of the river outlet is 648m but the width decreased in size in 2006 (305m). However, the width increased again in size in the years 2010 (585m) and 2013 (641m), respectively. These changes in size overtime are due to numerous factors such as natural and human interventions. In Bued-Angalacan river, the changes of its size are perhaps due to sedimentation/accretion and erosion. Moreover, during the actual ground validation in November, 2015 the width size decreased again to 475m that maybe due to sedimentation which occurred in the area.

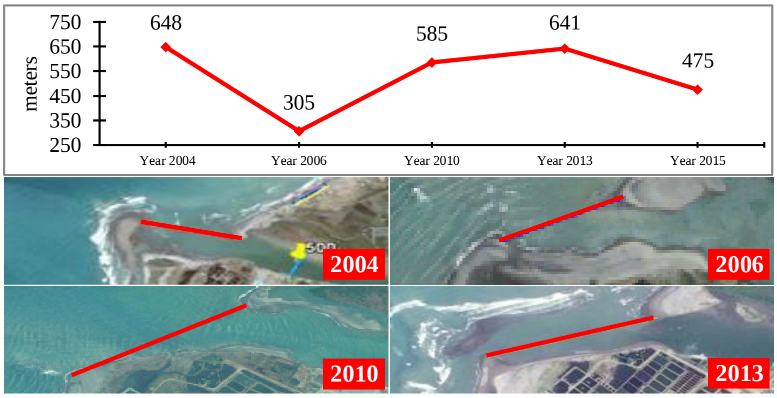

Figure 1. Satellite imageries of the Bued-Angalacan river outlet showing its width size in different years

These occurrences maybe due to erosion of the left side of the river outlet because of high velocity of the river flow during typhoons and heavy rains and sedimentation/accretion from transport of soil materials. These erosion and sedimentation/accretion processes played active roles in the changes of the Bued-Angalacan river outlet from 2004 to 2015. MGB (2004) reported that the upper portion of the river is silted and is occasionally dredged. During rainy season, mine tailing discharge affected the farmlands along the floodplains of Bued river (McManus, 1990).

Bued-Angalacan Riverbank

Generally, riverbank of the Bued-Angalacan river increased in width size (Figure 2). It shows that the riverbank widened overtime due to river embankment erosion. This bank erosion was possibly brought about by natural calamities and or weak bank resistance. According to Wanquan et al. (2013) low flows and flood flows caused high lateral channel erosion rates in sand-bank rivers which contribute to increased suspended sediment loadings. Soil condition is also a contributory factor in severe erosion. It was also stated by Lopez et al. (2011) that the Bued-Angalacan river watershed contributes high volume of flood waters to low lying areas during heavy rainfall/adverse weather conditions.

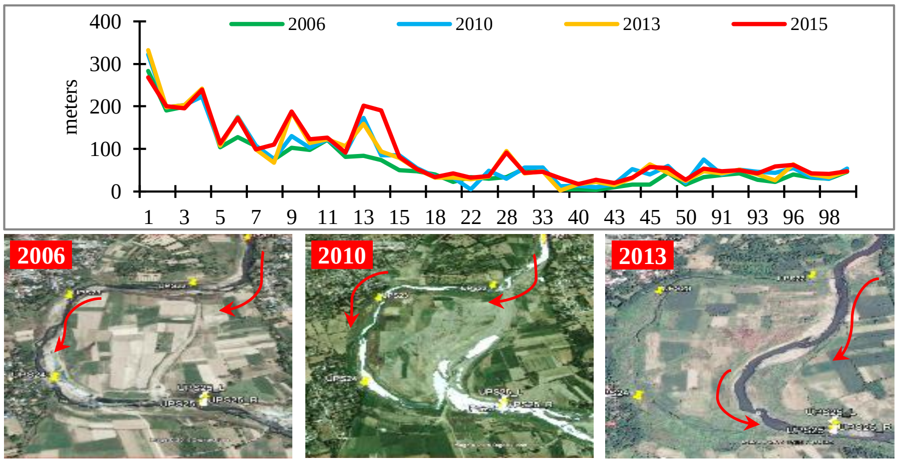

Figure 2. Bued-Angalacan riverbank for the years 2006, 2010 and 2013

Moreover, mobility or the shifting in the position of the riverbank (Figure 2) was also observed in the upper upstream of the river. The shifting was observed by the residents after flooding of the area which cause the re-routing of the river nearby agricultural farm lands and communities.

North Coast of Bued-Angalacan River

The northern coastline of the Bued-Angalacan river shows big changes through time, specifically near the river outlet which are data points 1 and 2 where there is a decrease in width size (Figure 3). The extent of changes in the coastline indicates that the coastline changed physically. It moves from seaward to landward from 2004 to 2015. The type of sand in the coastal area was coarse. The coast was described by the residents as flat and wide. Most of the time, the presence of strong winds was observed by the residents in the coastal area. A destructive wind was also observed during typhoons which contribute to the erosion in the coastal area.

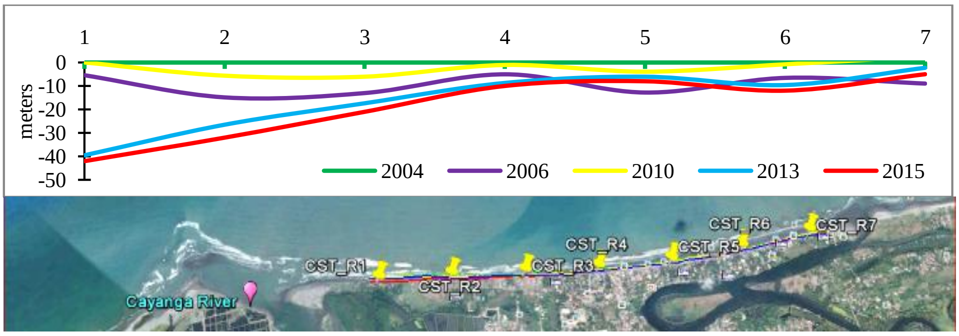

Figure 3. North coastline of the Bued-Angalacan River

Human and natural phenomena are the causes of coastal changes by modifying and disturbing, both directly and indirectly, the coastal environments. It was stated in the Philippine Development Plan of the municipality of San Fabian (2011-2016) that sedimentation occurred in coastal areas due to unsustainable land use in upland areas which continue to threaten the coastal ecosystems in Pangasinan.

South Coast of Bued-Angalacan River

The south coastline of Bued-Angalacan river decreased in size through the years. From 2004, the coastline eroded up to 19 meters in width size. Heavy rains brought by the southwest monsoon, or "habagat" on August 2013, caused severe flooding in the city that caused some soil particles and debris to accumulate near the coastlines which can be observed in Figure 4 wherein point 1 to 3 of the coastline accreted.

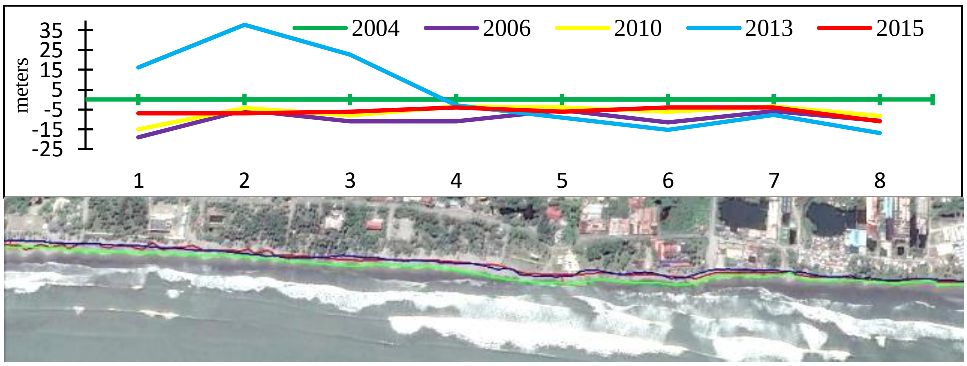

Figure 4. South coastline of the Bued-Angalacan River

The area according to the residents was hit by several typhoons every year which brought high waves with a height of up to 3 meters constantly weathering the coastlines. Frequent rains were also observed in the area which also cause the frequent release of water from San Roque Dam that caused flooding especially to low-lying areas. Moreover, some parts of the city had been declared under state of calamity due to severe flooding caused by continuous rains.

Alaminos River Outlet

The Alaminos River has two main outlets labeled as “Outlet A” and “Outlet B”. Outlet A had minimal changes, from 193m in 2009 it narrowed down to 189m in 2014 and then widens to 191m in 2015 as revealed from the data gathered in the field validation. Outlet B remained unchanged at 299m in 2009 to 2014 but changed a little in 2015 with a width of 300m. These minimal changes and maintenance of the land area near the river mouths might be the result of manmade infrastructures like salt beds and fish pens made of solid rocks and soil which further hardened with vegetation (Figure 5).

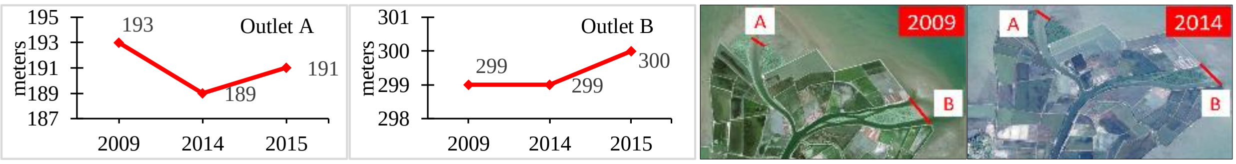

Figure 5. Alaminos River Outlets A and B and their changes over the years

Alaminos Riverbank

Alaminos riverbank increased in width size over time (Figure 6). According to the residents, the Alaminos River widens over the years, and is becoming muddy due to torrential rains especially if the rain was brought by a typhoon. The residents also observed that the water in the river mouth and salt beds gradually becomes more obscured because of aquatic waste deposits. Dams were also constructed at the upstream to control the water level that is being used for agricultural crop production purposes.

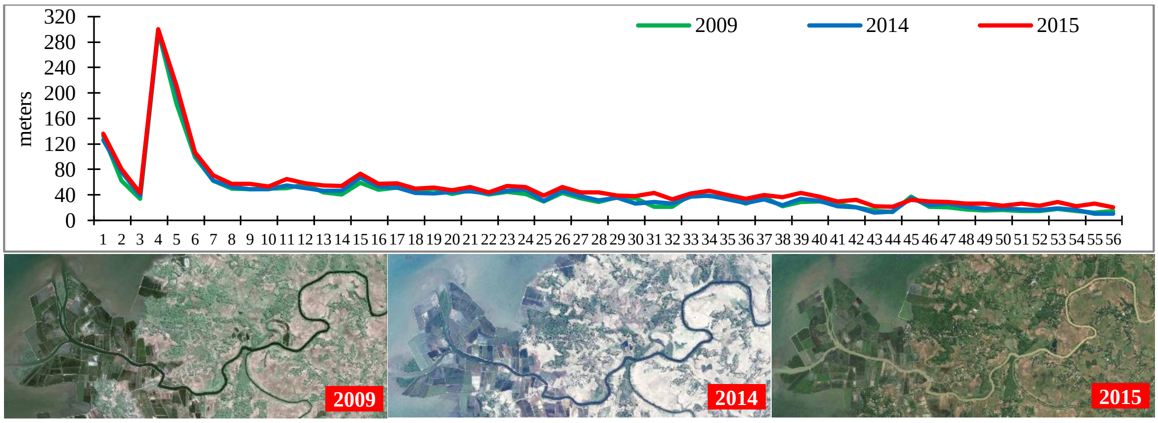

Figure 6. Alaminos Riverbank

Coastlines near Alaminos River

Figure 7 shows an increased or seaward movement of the north and south coastlines of Alaminos. Accretion was observed in the north coastlines near Alaminos river from 2009 to 2015 wherein salt beds were occasionally constructed in the area. Vegetation and manmade development for livelihood purposes have caused the land expansion in the area.

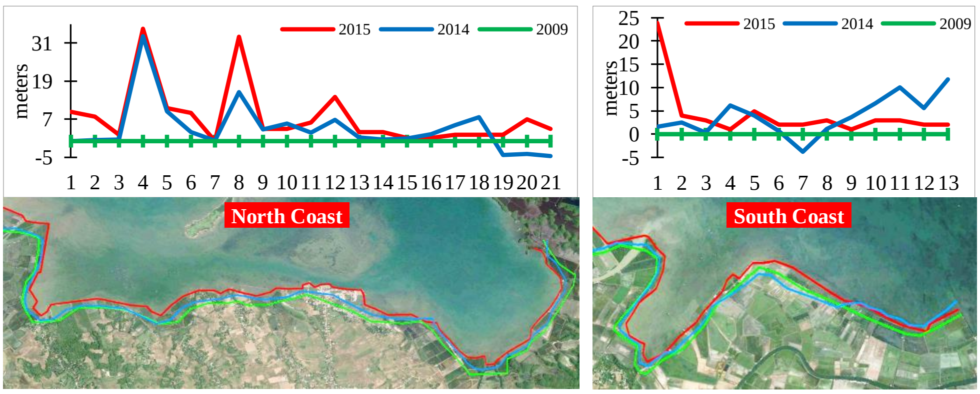

Figure 7. Alaminos Coastal Areas

The coastlines of Alaminos is highly utilized for tourism. Although salt beds can be found throughout this area, tourism is the main source of living in this part of the coast specifically in Lucap in which the famous “Hundred Islands” is located (Figure 8).

Figure 8. Alaminos Salt beds and the Hundred Islands.

The south coastlines also showed an increased movement of land which indicates that the land expanded from 2009 to 2015 (Figure 7).The coastlines consist mainly of salt beds, fish pens, agricultural lands and with a few local communities residing in the area (Figure 8). Salt is one of the primary sources of livelihood in the province of Pangasinan. Etymologically, the term Pangasinan means the \"place where salt is made\", owing to the rich and fine salt beds which are the prime source of livelihood of the province's coastal towns.

Community Survey regarding Coastline and River Changes of the Bued-Angalacan and Alaminos River

Majority of the residents near the Bued-Angalacan and Alaminos river experienced the effect of several typhoons. The typhoons also brought flooding in the area especially in the river mouth. Other natural disasters like earthquakes were felt in some areas in the past years. Strong winds usually tore apart their houses which were situated in open areas like in the salt bed areas. Also, according to the residents, incident of fish kill occurred in the river especially during summer time and or during the event of El Niño.

Root Mean Square Error

The computed RMSE in Bued-Angalacan and Alaminos river outlets, riverbank and coastlines show negligible differences between the measured data during the on-site validation and the measured data plotted in the Google Earth. The RMSE computed ranged from 0.31 to 1.1 meter which indicates that the data are accurate. According to Tewksbury, (2015) reconnaissance using Google Earth provides a virtually cost-free strategy for collecting enough data. This enables target critical areas for field data and sample collection to test structural interpretations and to acquire ground truth for more accurate mapping in inaccessible areas.

CONCLUSIONS

Bued-Angalacan and Alaminos river outlets experienced changes in time. A decreased in width size was due to erosion caused by high velocity of the river flow during typhoons and heavy rains. On the other hand the increased in width size was due to sedimentation/accretion caused by transport of materials during heavy rainfall. The establishment of salt beds also affected the size of the river outlets.
The riverbank of both Bued-Angalacan and Alaminos rivers increased in size overtime due to river embankment erosion caused by torrential rains and flooding.
The coastlines near Alaminos river increased and expanded in time because of the occurrence of salt beds, beach front resorts and man-made structures. However, the Bued-Angalacan river coastlines decreased in width size due to erosion in the area caused by strong typhoons and torrential rains.
The computed Root Mean Square Error in Bued-Angalacan and Alaminos river and coastlines were low which indicated positional accuracy and measurements of Google Earth and field validated points.

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