RESEARCH ARTICLE

Remote sensing application in monitoring change of river and coastlines of Morong, Bataan, Philippines

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Abstract: Remote sensing offers fast, cheap and reliable method in detecting river and coastal changes. In this study, satellite imageries of Morong river and coastlines from 2006 to 2016 were collected and analyzed to monitor changes. Field measurements were also done using South Total Station (NTS-362R6L) in 2016 for comparison and validation of data. Results showed that the river outlet and the riverbank increased in width size due to erosion brought about by torrential rains and urban run-offs. Coastlines near the river narrowed in size or shifted landward due to coastal erosion and sea level rise. An interview was conducted to locals residing nearby the river and coast where strong typhoons were reported which cause geophysical changes in the area. The residents also observed sea level rise, coastal and river erosion which caused narrowing of the coastlines and widening of the river, respectively. Records of high tides and low tides collected were projected in annual average levels per month. The average level of low tides increased per year which can be a result of sea level rise. The computed RMSE between field and remote sensing measurements ranged from 0.1m to 0.67m which indicated positional accuracy of Google Earth in the area.

Keywords: Remote Sensing; River Outlets; Riverbank; Coastlines; Urban Runoff

1. Introduction

Remote sensing applications in monitoring rivers and coastlines offer fast, cheap and reliable data acquisition. River and coastlines are regions of high accessibility, numerous physical and biological processes, and they also act as recreational, leisure, and tourism centers. Geophysical changes occurred in the past and happening at present times project how the area were utilized or affected by natural occurrences. In this study, Morong River and its coastlines were analyzed and monitored for geophysical changes both via remote sensing and field survey. Morong River has the greatest potential of being a suitable source of surface water. The river is estimated to have a flow of round 15 m^3/s. The downstream stretch is presently used by nearby communities for domestic purposes such as bathing and for washing clothes. Morong has a rugged mountainous terrain. The relatively flat areas are found along the coasts facing West Philippine Sea. All of the town's built up areas is located on the Philippine Sea. Much of the lowlands in the municipality are intensively cultivated. With the vast community residing in the area together with the high accessibility in terms of tourism and land use, Morong River and coastlines experienced geophysical changes overtime.

2. Objectives of the study

The study generally aimed to monitor the changes in Morong river and the coastlines nearby, Specifically, the objectives of this study were:

a. Determine the change in width of the river outlet, riverbank and coastlines;

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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 area

3. Materials and methods

3.1 Google Earth historical imagery platform and its uses

Google Earth has been widely used for researches regarding remote sensing applications. Generally it was used by most users for finding places, travel guides, geo-tagging, and many more everyday used. Tagged as free and user-friendly, Google Earth's features include historical imagery which enabled users to track back in time and monitor changes occurring in an area. Built-in tools were included for measurement and horizontal and vertical positional assessment. High resolution satellite imageries were used by Google Earth which enabled accurate measurement with its up-to-date application software.

3.2 Imaging satellite specifications of Google Earth

High resolution satellite imageries of Morong river and coastal areas were gathered from Google Earth satellites starting from 2006 to 2016. The coordinates from the satellite imagery in 2016 were used to measure the actual data from field survey using South Total Station (NTS-362R6L). Below are the satellites and their specifications used in the study:

Satellite	Panchromatic Resolution	Multispectral Resolution	Altitude	Date Acquired
QuickBird	55cm	2.16m	400	2006
GeoEye-1	46cm	1.64m	681	2009
SkySat-1	90cm	2.0m	450	2013
WorldView-4	31cm	1.24	617	2016

3.3 River outlet and riverbank width measurement

The widths of the river outlet and the riverbank were measured from 2005 to 2016. Points and measurement were placed every 500m as baseline of measurement on each side of the riverbank starting from the river outlet to upstream. Plot lines and points for measurements were adjusted per year using the historical imageries. The latest coordinates of the points gathered in 2016 were recorded and used for field validation and measurement.

3.4 Coastline measurement

The coastlines were measured from 2005 to 2016. A path was drawn in the coastline in 2005 which served as the baseline of measurement. Points of measurement were assigned every 500m from both side of the river outlet extending up to the nearby river or whether clear satellite imagery of the area is available. 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 will be 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 2016 were recorded and used for field validation and measurement.

3.5 Community survey in the City of Morong

Residents nearby the river and the coastlines of Morong River were interviewed to collect past and present events which may cause geophysical changes in the area.

3.6 Root mean square error (RMSE) computation

Measurements form remote sensing data (predicted value) and field measurements (observed value) gathered in 2016 from Morong River and coastlines were compared and computed. The mean squared difference between the predicted and observed values was square-rooted to have the Root Mean Square Error. Below is the formula used for RMSE (1):

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

where X_p = predicted value

X_o = observed value

N = number of sample

3.7 Measuring sea level rise

The historical record from tide gauges of Manila Bay, Philippines Tide Chart at online tides and currents predictions[6](TideGeo) 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

4. Results and discussion

4.1 River outlet of Morong

The images captured through different years projected a quick variability and complexity of river outlet in Morong. The river outlet constantly increased in size from 2006 (37.5m), 2009 (17.3m), 2013 (180m) until it widened in 2016 (231.1).The river outl*et al*so changed in different direction throughout the years (**Figure 1**).

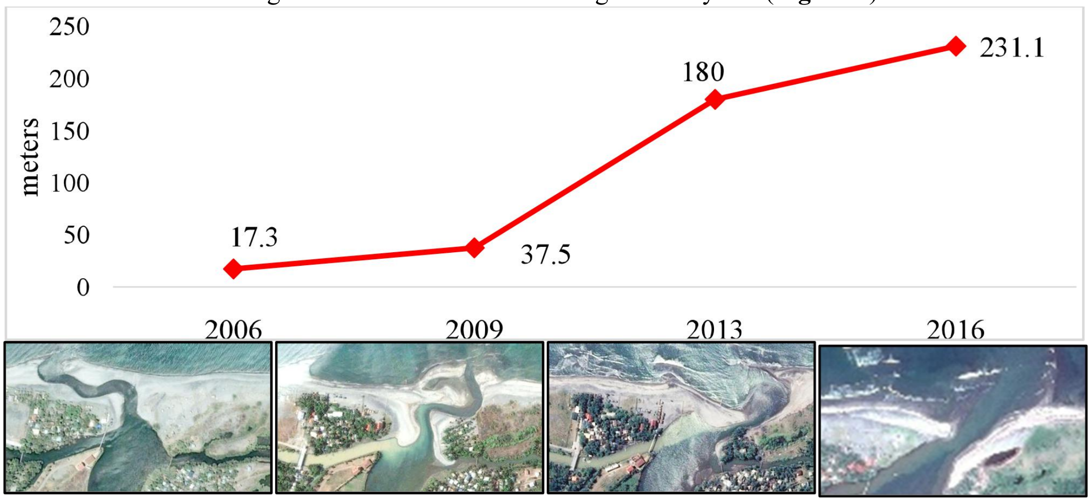

Figure 1. Morong River outlet

Residents observed the change in direction and position of the river outlet throughout the years. The river outl*et al*ong the coastlines was mostly utilized for tourist spots like Beach-side resorts, hotels and restaurants. Some buildings in the river outlet were abandoned due to sudden change in sea level and sensitive soil which can easily be eroded.

4.2 Riverbank of Morong

The average change shows that Morong River slowly widened from 2006 to 2016 (**Figure 2**). Riverbank shifting was also observed (**Figure 3**). Data points vary per year due to the complexity and disturbance of land area from persistent erosion which frequently triggers human response to mitigate erosion in the form of hard (building of dikes or infrastructures near water bodies) and soft (such as sand re-nourishment) engineering projects.

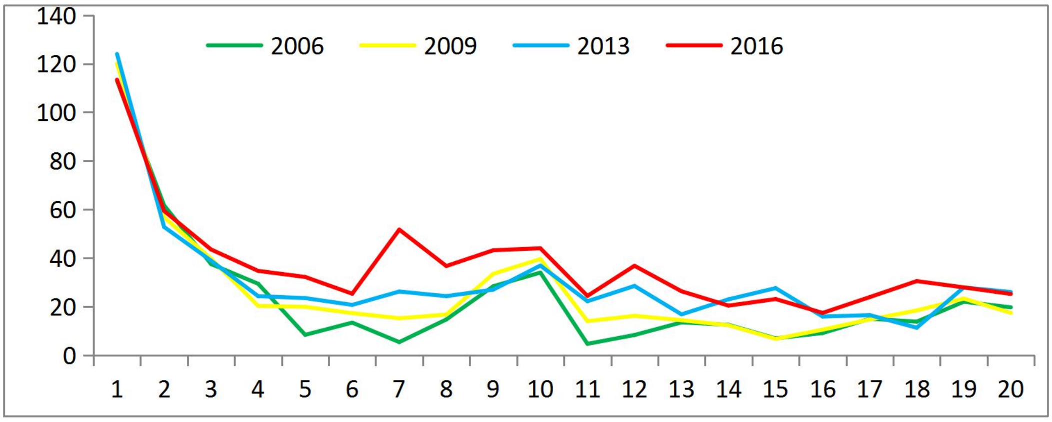

Figure 2. Morong riverbank

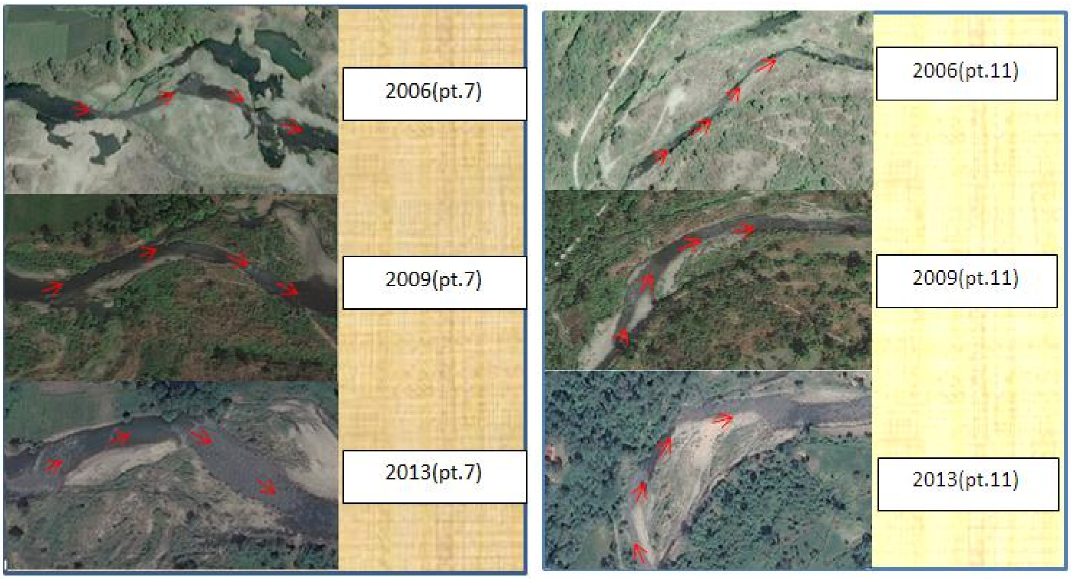

Figure 3. Riverflow shifting

Once sensitive soil is disturbed, they may lower strengths when they are altered. This loss of strength increases the variability of structural change[1](Diagne, 2007).

Table 1 shows the rapid increase in residential areas near Morong River[5](NSO, Bataan QUICKSTAT 2006 – 2015). Urban runoff or surface runoff caused by heavy rainfall may deposit sediments of land or property in a built-up environment especially when observed in near bodies of water such as Morong River affecting both upstream and the outlet region.Urbanization and human activity within an urban system produces many destructive and irreversible effects on natural environments such as climate change, air pollution, sediment and soil erosion, increased flooding magnitude, and loss of habitat[3](Fernandes, 2007). The building construction in the province of Bataan increased its infrastructures more than four times from 2006 to 2015 indicating a fast pace in urban development (Table 1).

Infrastructure	2006	2009	2013	2015
Buildings	162	584	699	772
Residential	126	485	547	615
Non-Residential	23	67	95	96

Table 1. Infrastructure in the province of Bataan.

4.3 Coastal area of Morong

The baseline for measurement started from the image captured by Google Earth for year 2006 (March 23, 2006). Coastline data shows varying increase and varying decrease in land area (**Figure 4**) ranging from 1m to 41.6m. Factors such as typhoons, erosion and sedimentation augmented the coastal evolution.

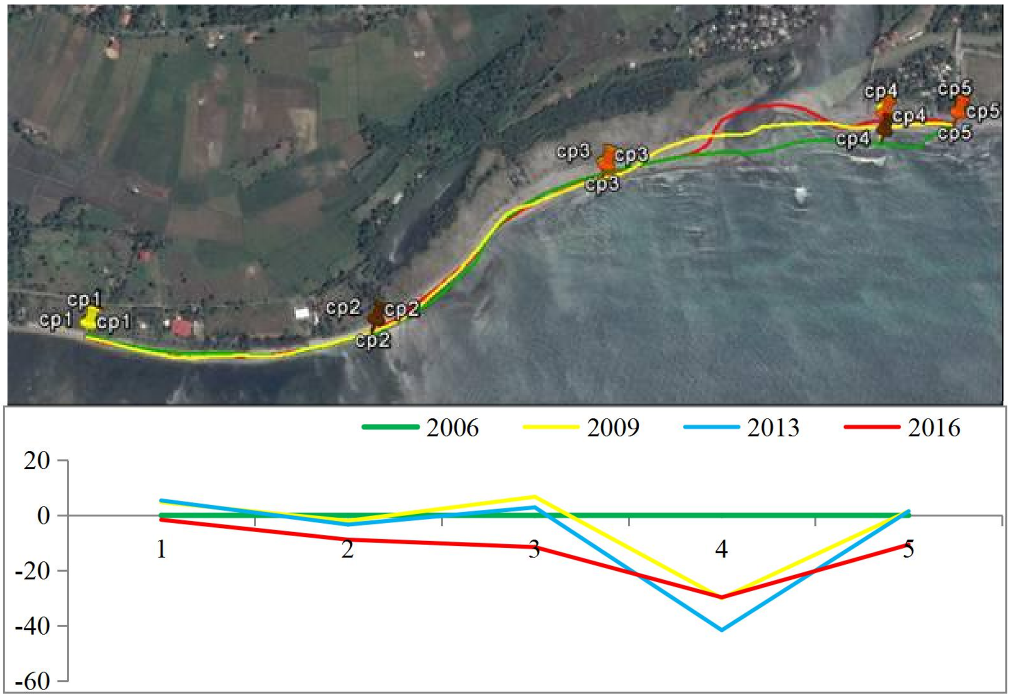

Figure 4. Coastal changes from year 2006 to 2009 and 2013

Beach, shoreline and river evolution occur due to seasonal changes in summer/winter wave environments, earthquake, extreme storm events, changes in natural sand supply and transport, alongshore variations in coastal geomorphology and elevated by long water levels caused -term sea-level rise[4](Long and Plant, 2012). Coastal change is driven by processes that vary significantly in both space and time. Understanding how the coast has changed in the past and what factors have influenced those changes guides our understanding of what may happen in the future. Historical data also shows typhoons that hit Central Luzon specifically in the year 2008 (FRANK**), 2009 (ONDOY***) and 2013 (Yolanda*) were classified as super typhoons which may have a great impact in coastal areas[2](JTWC, JMA and PAGASA).

*	Storm surge, rains spawned floods
**	Abrupt change in tides and cause strong waves
***	Mudslides and flooding
JTWC	Joint Typhoon Warning Center
JMA	Japan Meteorological Agency
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration

4.4 Root mean square error

Measurements between Google Earth Tools and Field Survey were compared and showed minimal differences. Google Earth provides horizontal positional accuracy with less than 1 meter error but may vary in different areas[9](Potere, 2008). The RMSE ranged from 0.1m to 0.67m which indicated horizontal and positional accuracy of Google Earth in the area (Table 2).

Areas	**RMSE**
Riverbank	0.668581 meter
Coastlines	0.469042 meter
River outlet	0.1 meter

Table 2. RMSE between Google Earth Measurements and Field Measurements

4.5 Social aspect

The ocular inspection and one on one interview with the residents of Morong was done with the consent of concerned authorities particularly the Local Government of the Municipality of Morong, Bataan. The interview was done in the three barangays of Morong namely: Binaritan, Poblacion and Sabang. This was done to have additional information regarding the past and present situation of the coastal and river of the Morong River. Results of the interview such as major features of coastal, upstream, river mouth and natural disasters in Morong River were summarized as follows:

4.5.1 Morong River major features

The soil characteristic observed in the riverbanks of Morong River was a mixture of sand, rocks and clay. During the interview, the respondents described the river water as clear and flowing. It corresponds to the observation of the research team during the field validation. The respondents also claimed that the river was awarded as the cleanest river in Bataan. During wet season, as similar with other tropical rivers, the mud in the riverbanks were being disturbed which results to the obscure appearance of the water. Acacia, bamboo, banana, coconut and mango trees are also observed in the riverbanks. Other crops include papaya, sweet potato and some vegetables. The main source of drinking water of people residing at the riverbanks is water pumps. The means of transportation in the river were dominated by boats which are also used by fishermen for their livelihood. The most common activity in the river is fishing. Some respondents also claimed that quarrying is an on-going activity in the river though the purpose of the said activity is not clearly identified.

4.5.2 Morong River (Coastal area and River outlet) major features

The type of soil in the coastal part of Morong River is sandy. The land area of the coast was generally described by the respondents as wide and flat. On the other hand, some respondents added in the interview that the land area changes during rainy season in which it becomes very narrow due to high water level. It corresponds to the images of the river mouth taken by Google Earth through a satellite which indicates the intense changes over the years in its coast and river mouth.

The wave height during fair weathers is around 0-2 meters but it reaches roughly up to 4 meters when there is typhoon or when it is rainy season which could be the reason for the changes in the unstable sandy coastal areas. The wind intensity is mostly calm but still subject to changes depending on the season.

The human activities in the coast include fishing while some residents are working in many resorts and restaurants along the coastal areas of Morong as a source of living. There is no sand quarrying in the area aside from some residents acquiring sands for household uses.

4.5.3 Natural disaters in Morong River

Morong, Bataan is blessed with mostly fair weather; that is according to the respondents and even attested by the Municipal Mayor. Although they are not exempted from typhoons and floods, the municipality is rarely hit by too much typhoon compared to other towns or provinces. Moreover, the typhoons that are passing through their municipality do not distress them in the way other places in country are affected.

4.6 Annual average level of tides per month in Manila Bay

Average level of tides per month showed the high tide levels decreased per year (2004-2015) while low tide levels increased overtime. This projection can be observed in the area wherein the base height of the sea was higher than before, although we experienced lower height of high tides than before, we can observed that during low tides the change of depth of the tide were lower. This was also observed by the residents in Balanga Bataan, wherein the sea slowly covers and moves landward (**Figure 5**).

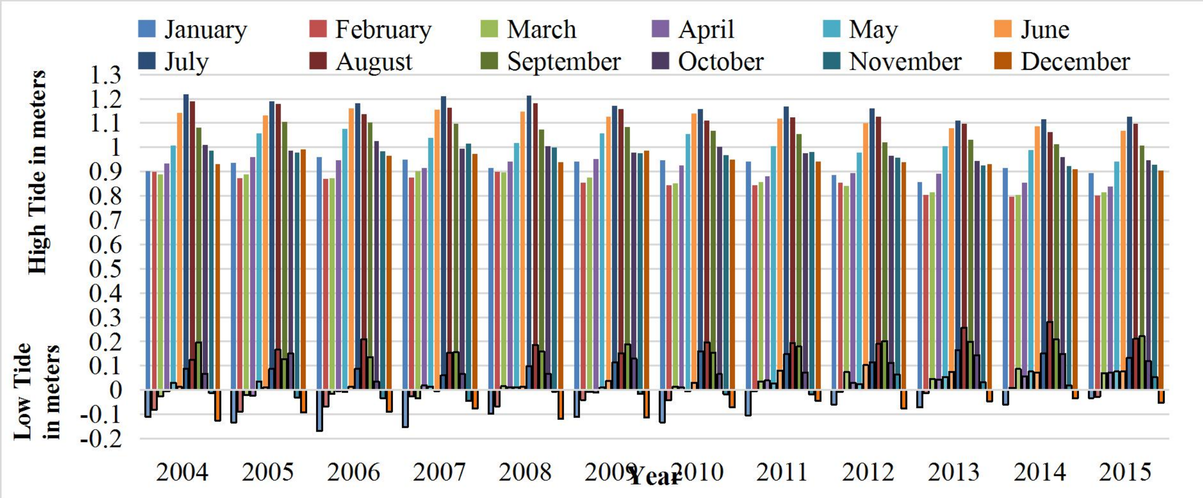

Figure 5. Annual average level of tides per month in Manila Bay

5. Conclusion

5.1 Morong River

Morong river outlet and the riverbank increased in width size due to erosion brought about by torrential rains and urban run-offs. Urban built-up was also observed which increased the number of residential buildings 4 times.

5.2 Coastlines near Morong river

Coastlines near the river narrowed in size or shifted landward due to coastal erosion and sea level rise. The residents also observed sea level rise, coastal and river erosion which caused narrowing of the coastlines and widening of the river, respectively.

5.3 Google Earth measurement and positional accuracy

The computed RMSE between field measurements and remote sensing measurements ranged from 0.1m to 0.67m which indicated horizontal and positional accuracy of Google Earth in the area.

5.4 Sea level rise

Records of high tides and low tides were compiled and projected in annual average levels per month. The average level of low tides increased per year which can be a result of sea level rise.

6. Recommendation

Google Earth availability of high resolution imageries, and its measurement and positional accuracy can differ in specific areas. Further study can also be done to conduct more complex measurement, evaluation and further examine different areas for geophysical changes through remote sensing.

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Author Contributions

Authors:	**Responsibility**
Dr. Annie Melinda Paz-Alberto	The main author of this study; Supervised and implemented protocols and workflow of the study; Responsible of editing and finalized the paper
Mr. Edmark P.Bulaong	Co-author; Assisted in writing and finalizing the paper; Obtained primary

	and secondary data
Engr. Jose T. Gavino	Co-author; Conducted validation study, field measurements and data analysis;
Mr. Christopher R. Genaro	
Mr. Ranilo B. Lao	Co-author; Responsible for data gathering and writing the socio-economic part of the study

Conflict of Interest

No conflict of interest was reported by the authors.

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