MAPPING SAND AND GRAVEL EXTRACTION ACTIVITIES AND EVALUATING THEIR IMPACTS ON RIVER GEOMETRIC CHARACTERISTICS IN CABADBARAN CITY USING REMOTE SENSING

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ABSTRACT: Remote Sensing and GIS Integration are commonly used methods showing systematic analysis of remotely sensed data providing a reliable, safe, and cost-effective way of mapping and mitigating environmental problems. The sand and gravel extraction often disturb the river's physical characteristics, which significantly impacts the river's geometric characteristics and morphology. Cabadbaran River is one of the area's primary sources of sand and gravel resources. There are a total of seventeen maps of sand and gravel extraction that shows information that validates the generated multi-temporal Land Use Land Cover (LULC) maps. The evaluation of changes along the Cabadbaran river's geometric characteristics was successfully done through change detection. It was analyzed through the generated multi-temporal LULC maps as the inputs. The result showed that the land cover changes on the exposed riverbed and water class significantly increased by 37.7% in 1995-2000 and 7.4% in 2015-2018, respectively. Change Detection maps revealed that in the interval of 5 years from 1995-2018, changes in the river channel and increase in river area happened due to sand and gravel extraction activities mainly in the years 2005 up to 2018.

1. INTRODUCTION

Sand and gravel, as part of the growing industry and developing economy, are used in the production of other forms of material like aggregates for building, road construction, asphalt mixing, construction fill, and the production of construction materials like concrete blocks, bricks, pipes, and culverts and many more applications (T. Madyise, 2013). These are underground geological resources formed from eroding rocks carried by streams and rivers. Sand and gravel are directly obtained through quarrying, defined as the activity where sand and gravel are excavated and extracted from the river channel, flood plain, and adjacent river terrace (M. A. Devi and L. Rongmei, 2015).

Extraction activities of sand and gravel often occur in many areas, like rivers. Rivers serve as the source of providing sand and gravel for developing economies. The extraction of these two critical raw materials for construction that the needs of humans have driven for specific purposes is bound to have a considerable negative effect on the place where they occur (K. Ayenagbo, J. N. Kimatu, J. Gondwe, and W. Rongcheng, 2011). Sand and gravel extraction affect the geometric characteristics of the river or the variation in terms of its cross-sectional area, length (downstream variation), width and depth, and channel (discharge variation). Primarily, this river extraction activity induces channel changes that extend significantly beyond the excavated area through the continuous operation.

Remote sensing and GIS were used to conduct different kinds of research and studies like sand and gravel characterization, mapping, land-cover change detection, and determining environmental tale impacts relating to human activities (E. Chaussard and S. Kerosky, 2016). They are used for different types of applications for a specific purpose. In classifying land cover types like sand and gravel and other land-cover classes, supervised classification algorithms were applied to generate outputs like land cover maps and different image analysis results (M. Prasad, M. R. ReddSunitha, 2016).

River Geometric Characteristics (hydraulic geometry) deal with channel characteristics variations in discharge actions. Two sets of activities occur at a particular cross-section (at-a-station) and variations along the length of the stream (downstream variations). Characteristics responsive to an analysis by hydraulic geometry include width (water-surface width), depth (mean water depth), velocity (mean velocity through the cross-section), sediment (usually concentration or transport, or both, of suspended sediment), downstream slope, and channel friction (Britania.com, 2018).

The researcher conducted this study to advocate environmental awareness to all the community to help mitigate ecological destruction for the city's sustainable development since making a profit and conserving/preserving the environment must go together.

2. MATERIALS AND METHODS

2.1. Data Acquisition and Processing

Data acquisition involves gathering information on the variables of interest, including readily available and downloadable datasets from other reliable sources. The ground validation within the study area through collecting accurate ground coordinates using a handheld GPS receiver. Satellite images were also used in the research, particularly Landsat images. A high-resolution image like 'Google Earth' was used as a primary reference during image classification, digitization, and in generating a base map where collected ground coordinates of the study area were projected.

2.1.1. Data Acquisition and Processing

Pre-processing is fundamental for any raw image dataset, such as Landsat Images. This process is applied to display or record the data more effectively for subsequent visual interpretation transforming raw data into usable information. It is highly required to extract specific information to extract certain details before others. This process is essential since captured satellite images compensate for errors due to radiometric and atmospheric influences. Thus, applying image pre-processing will turn raw image datasets into properly corrected and calibrated data which was used further to generate a more accurate and reliable result. Visualizing Images (ENVI) software was used to perform image pre-processing.

2.1.2. Image Classification

Image classification categorizes pixels into land cover classes, i.e., built-up, dense, and sparse vegetation, bare land, water bodies, etc. The output classified image was utilized to generate thematic maps per the objectives of any studies.

There are two types of Image Classifications in the ENVI Software: Supervised and Unsupervised Classifications. In this study, the researcher is performing a Supervised Classification which is the Maximum Likelihood Classification (MLC), in generating the Land Cover Maps of the following years; 1995, 2000, 2005, 2010, 2015, and 2018 having six land cover classes; built-up areas, forest, sparse vegetation, barren, water, and exposed riverbed. Identifying these classes follows an appropriate scheme that helps categorize the land cover classes to be classified in the conduct classification process.

Finally, the classified image was verified to its accuracy through different mechanisms. It was assumed that the result of classified classes corresponds to ground truth field samples obtained using a handheld GPS receiver, mainly the sand and gravel extraction sites, which are the study's primary concern.

2.1.3. Multi-temporal Land Cover Mapping

Land cover describes and represents the observed physical cover on the earth's surface. In this study, it is essential to use land cover maps; that's why one of its steps involves the generation of land cover maps derived from Landsat images. A multi-temporal land cover map of Cabadbaran City is one of the aims to be generated in this study from 1995-2018, having a 5-year interval. The projection used was WGS84 UTM Zone 51N.

2.1.4. Ground Validation of the Study Area

Ground validation was conducted to collect actual ground coordinates of sand and gravel extraction sites using a handheld GPS receiver to generate a base map/image. The researcher used the extracted points as bases for ground truth ROI upon performing image classification and assessing its accuracy, particularly in the 2015 and 2018 images. The researcher used Google Earth for validation, referencing purposes, and river width digitization.

2.1.5. Change Detection Analysis

Change Detection Analysis bound a broad range of methods used to identify, describe, and quantify differences between images of the same scene at different times or under other conditions. In addition, the Change Detection concept offers a straightforward approach to measuring changes between a pair of images representing an initial and final state. For classification images, Change Detection Statistics was used. For grayscale (single-band) images, the Change Detection Difference Map was used. Change detection statistics were used in the study to generate change detection maps and other statistical information based on the classified multi-temporal LULC maps. It was also used to evaluate the river's geometric characteristics' impacts. Indices differencing were used in the study to determine the changes in the LULC from 1995-2018.

2.1.6. River Geometric Characterization Mapping

One way to determine impacts on river geometric characteristics is to identify its changes. Changes in the river geometry may contribute to adverse effects on the environment. It may cause risks to the people near the river when unpredictable disasters occur since rivers are large natural streams of water in channels and emptying into larger bodies of water like seas. It is a big deal to consider its status concerning its geometric characteristics since sudden changes will occur in its attributes from time to time, mainly when there is continuous extraction of its resources, such as sand and gravel. The greater the impact, the greater danger to humans and property.

2.1.7. Evaluation of Impacts in the River Geometric Characteristics

Evaluation of impacts on the geometric characteristics thoroughly depends on the results of change detection analysis. Out of the 6 (six) land cover classes, the researcher focused more on the water and exposed riverbed classes to see and determine the changes in the river system, particularly with its connection to sand and gravel extraction activities, and to evaluate its impacts. Based on the base map generated earlier, certain portions of the river where sand and gravel extraction occur are essential things to focus on since these areas were considered critical in evaluating impacts on the river's geometric characteristics. A digitized river dimension for each 5-year interval 1995 was used to aid the evaluation of river geometric characteristics impact. The pre-processed Landsat images were used as the base image for the digitization of river dimensions in the following years; 1995, 2000, 2005, 2010, and 2015. The latest one is digitized from Google Earth. This digitized portion of the river was based on the generated sand and gravel extraction map, where sand and gravel were highly present from the river upstream to downstream.

2.2. Accuracy Assessment

Accuracy assessment is an important thing to be considered in every output that needs to be done. In the same way as the generation of the land cover maps, each is assessed with its corresponding accuracies. To determine the accuracy, still using ENVI software, there were samples of pixels that the user created in the classified image. These samples are to be compared with the reference data taken from validations on the ground. Two sets of pixel sampling are called ROI's (Region of Interest). For supplemented images with another year, its accuracy assessment was done using ArcMap and manually creating a confusion matrix using Microsoft Excel.

3. RESULTS AND DISCUSSION

3.1. Sand and Gravel Extraction Location Map

The gathered data from the study area through validation were processed, and the sand and gravel extraction location map were produced, as shown in Figure 1. Red triangles represent the sand and gravel extraction site locations. Digitized Cabadbaran River boundary from google earth was also shown on the map with a specific boundary. Extraction sites are present in the barangays of Cabadbaran City, namely, Barangay Mabini, Katugasan, and Bay-ang, which are situated along the river.

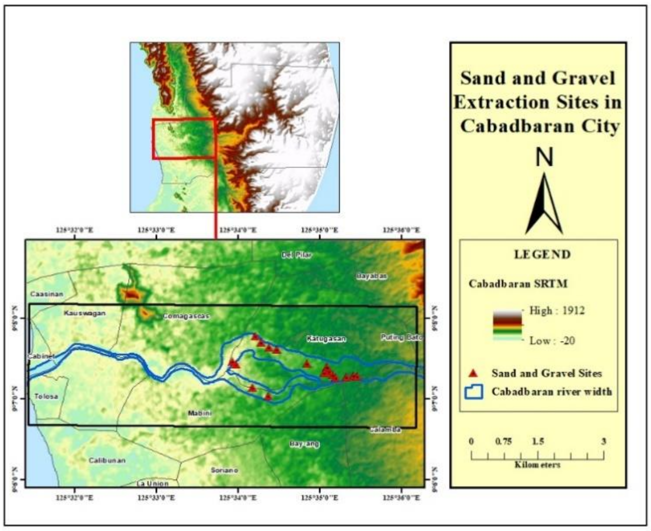

Figure 1. Sand and gravel extraction location map

3.2. Land Use/Land Cover Maps and Accuracy Assessment

The LULC maps of 1995, 2000, 2005, 2010, 2015, and 2018 using Supervised Maximum Likelihood Classification in ENVI Classic software were generated as shown in Figure 2. A base map has been developed through the collection points of sand and gravel extraction sites to validate the study area. Those points serve as reference ground truth data for image classification and accuracy assessments.

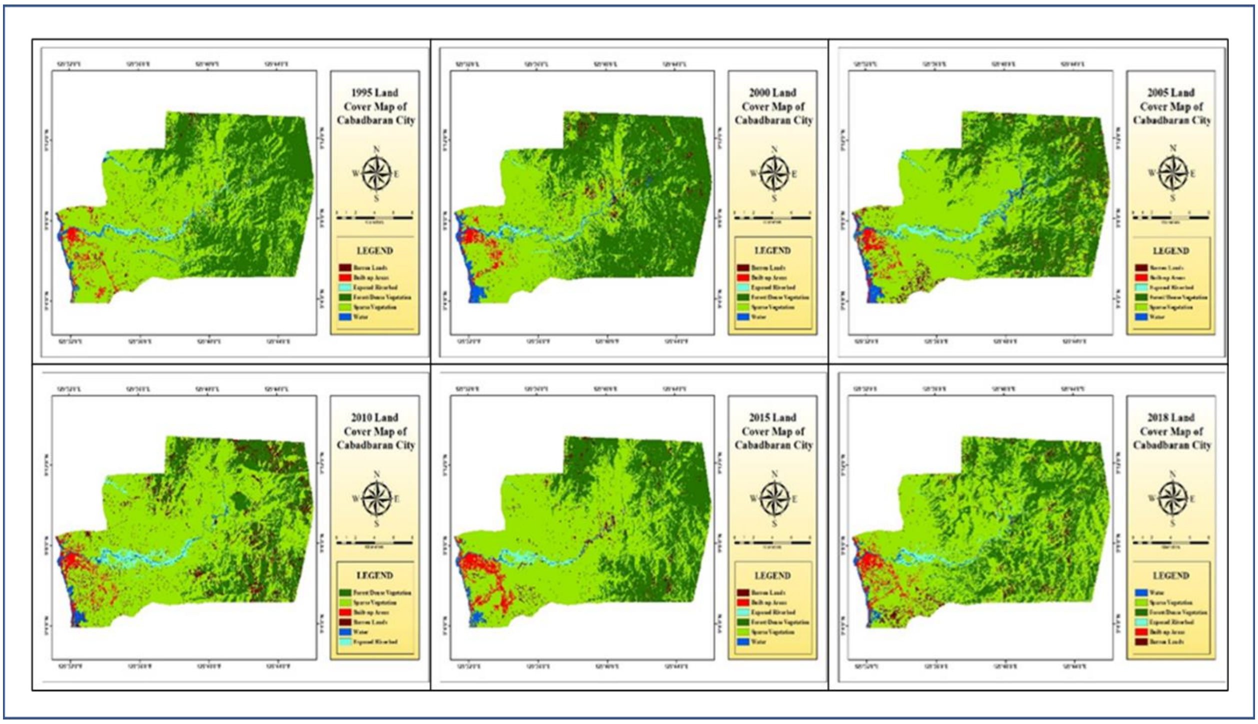

Figure 2. Land Cover Maps (1995, 2000, 2005, 2010, 2015 and 2018)

3.2. Change Detection on Multi-temporal Land Cover Maps

Numeric values in the rate of changes in every five year-interval in the land cover were shown in Table 1 and Figure 3. These classes were the most significant in the LULC maps in determining the changes in the river's geometric characteristics. It shows that the water area has a maximum change from the year 2015 to 2018 with a change rate of 7.4%, while the exposed riverbed area has a maximum change from the year 1995 to 2000 with a change rate of 37.7%, which implies that the changes in the water and exposed riverbed class has no uniform pattern. It has to decrease and increase changes concerning five (5) year intervals starting 1995-2018. In the water class, the year 1995 has the most significant area being classified, and the year 2015 has the smallest size being classified. In the Exposed Riverbed class, the year 2010 has the largest area being classified, and the year 1995 has the smallest area. Only in 2000 and 2010 the exposed riverbed has a greater extent than water. The rest follows that the water area along the river is greater than the exposed riverbed.

Table 1. Area of Water and Exposed Riverbed land cover classes/ change rate (1995, 2000, 2005, 2010, 2015 and 2018)

CLASSES	**AREA FROM THE YEAR 1995-2018 (HA)**						**CHANGE RATE (%)**				
	1995	**2200**	**2005**	**2010**	**2015**	**2018**	**1995-2000**	**2000-2005**	**2005-2010**	**2010-2015**	**2015-2018**
Water	580.2	536.1	548.1	534.8	448.6	481.7	***-7.6***	**2.2**	**-2.4**	**-16.1**	***7.4***
Exposed Riverbed	389.7	536.4	524.8	611.0	422.9	450.3	***37.7***	**-2.2**	**16.4**	***-30.8***	**6.5**
Total	969.9	1072.5	1072.8	1145.8	871.6	932					

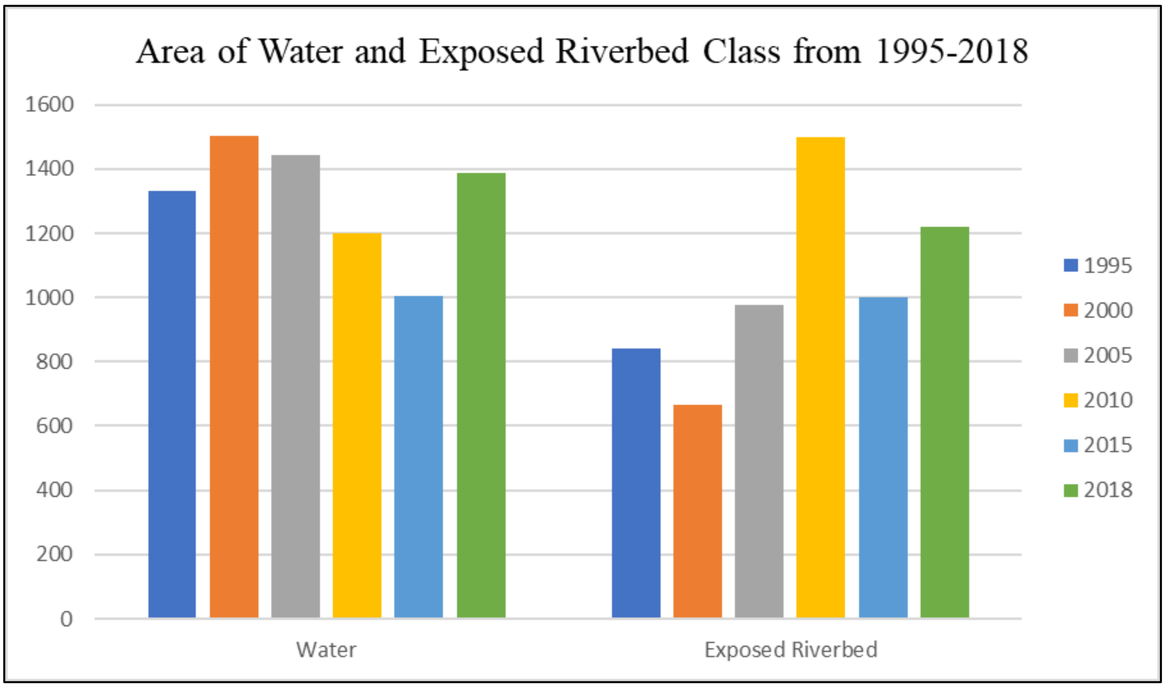

Figure 3. Class Area of Water and Exposed Riverbed
(1995, 2000, 2005, 2010, 2015 and 2018)

3.3. Change Detection Maps on Water and Exposed Riverbed

From the derive map below through Change detection and analysis, seeing the differences in land-cover type changes, especially water and exposed riverbed classes, could help establish the relationship in evaluating impacts in river geometric characteristics due to sand and gravel extraction. The Change Detection maps indicate that change was detected from the input land cover maps (i.e., exposed riverbed classes from the initial state are no longer exposed but changed into other land cover classes in the final state).

Based on the derived base map and with the help of digitized river dimensions from pre-processed Landsat images for each 5-year interval, most detected changes take place in the areas where there is the extraction of sand and gravel present. The impact on River Geometric Characteristic Maps was generated. Figures 4 and 5 will show the change detection maps on Exposed Riverbed and Water, respectively.

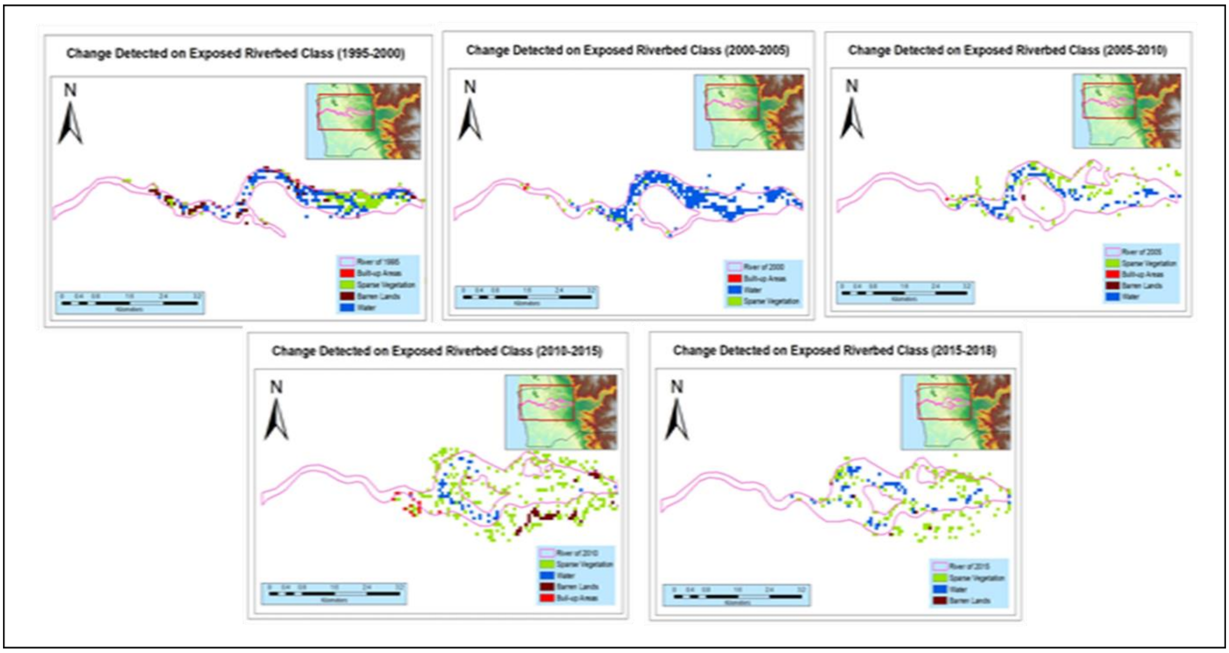

Figure 4. Change Detection Maps on Exposed Riverbed

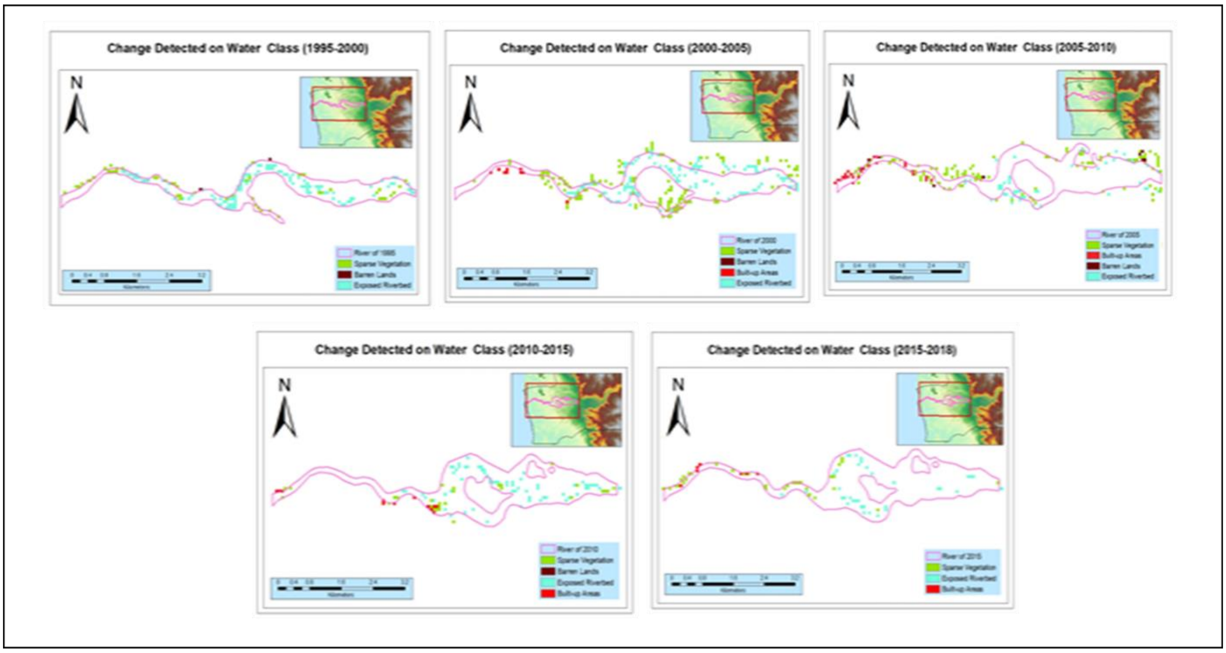

Figure 5. Change Detection Maps on Water

3.4. Evaluation of Impacts on River Geometric Characteristics

The impacts on the river geometric characteristics due to sand and gravel extraction are evaluated accordingly to the change statistics results from the generated LULC maps by performing change detection. The changes in areas were identified, and from the output change detection mas, the formation of the river geometry changes over time.

Due to sand and gravel extraction, the river's geometric characteristics impact changes in the river channel, bank erosion, and land subsidence, causing the river area to expand (Figure 6). Table 2 shows the river area change rate.

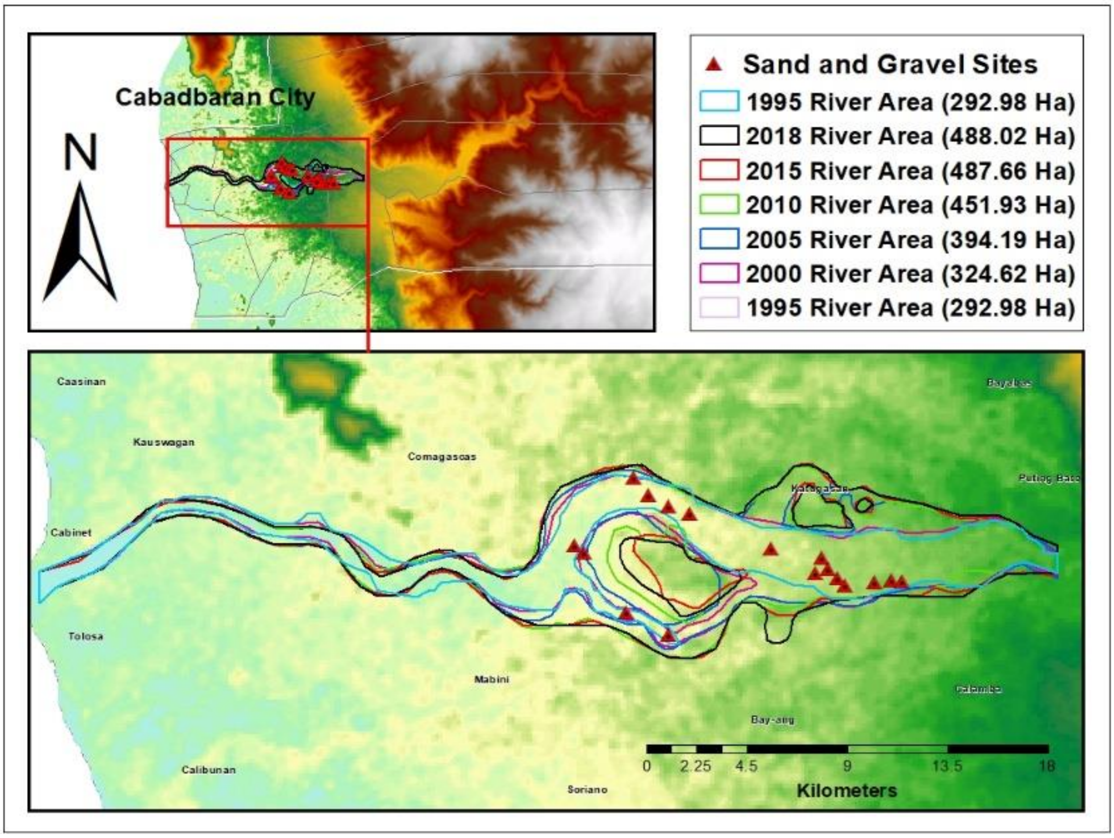

Figure 6. River Geometric Characterization Map

Table 2. River Area Change Rate

RIVER AREA (ha)						AREA CHANGE RATE				
1995	2000	2005	2010	2015	2018	1995-2000	2000-2005	2005-2010	2010-2015	2015-2018
292.98	324.62	394.19	451.93	487.66	488.02	10.8%	**21.4%**	14.6%	7.9%	0.1%

4. CONCLUSION

This study established the multi-temporal Land Use/Land Cover relationship concerning the evaluation of impacts on river geometric characteristics. Through change detection of land cover classes, particularly Exposed riverbed and water class, specifically in areas where sand and gravel are present. Also, the digitized river for each year helps in performing impact evaluation.

Spatial change detection was executed to assess and evaluate changes in land cover, particularly in the Exposed river bed. The river water classes are the primary and digitized river dimensions for each year as the second parameter for evaluating impacts on river geometric characteristics due to sand and gravel extraction. The study focuses its evaluation on the areas where there is the extraction of sand and gravel present. Through generated change detection maps, impacts on river geometric characteristics are determined. Changes in the river system, like its area, the increasing dimension, and the changes in the river channel where water flows are the persistent impacts due to sand and gravel extraction activities in Cabadbaran River. Therefore, if sand and gravel extraction activities continue without considering its resulting negative impacts, the more damage they may cause. River areas would probably continue to expand.

The results have evaluated specific findings appropriate to the desired outcome, and other factors relative to the evaluation of impacts that are out of the scope are not considered. Remote Sensing techniques and applications have also proven to be effective in evaluating effects on river geometric characteristics due to sand and gravel extraction through generating LULC maps. Change Detection methods were employed to assess river geometric characteristics' impact effectively.

Through this study, the local government of Cabadbaran City might use the results as the basis for formulating efficient and responsible extraction of natural resources and promoting sustainable and comprehensive environmental urban planning, which takes into account mitigating hazards and risks and disaster preparedness. Sand and gravel also contribute to society's urban and industrial development.

REFERENCES

E. Chaussard and S. Kerosky, "Characterization of Black Sand Mining Activities and their Environmental Impacts Using Remote Sensing," January 2016.

K. Ayenagbo, J. N. Kimatu, J. Gondwe and W. Rongcheng, "The transportation and marketing implications of sand and gravel and its environmental impact in Lome-Togo," January 7, 2011.

M. A. Devi and L. Rongmei, "Impacts of Sand and Gravel Quarrying on the Stream Channel and Surrounding Environment," 2015.

M. Prasad, M. R. Reddy and V. Sunitha, "Mapping of River Sand Mining Zones Using Remote Sensing and GIS," vol. 3, July 2016.

T. Madyise, "Case Studies of Environmental Impacts of Sand Mining and Gravel Extraction for Urban Development in Gaborne," October 2013.