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RESEARCH PAPER

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Assessing the effect of upland vegetation fragmentation in Carrascal Bay: Basis for crafting community environmental education programs and alternative livelihood training

Sheila Kylene A. Tawas*, **Margarita M. Ladanan, Jeonedy A. Sarsonas**

Department of Mathematics and Natural Sciences, North Eastern Mindanao State University, Philippines

Department of General Teacher Training, North Eastern Mindanao State University, Philippines

North Eastern Mindanao State University, Main Campus, Tandag City, Philippines

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Abstract

This study presents the result of class metrics derived from remotely sensed data which aims to assess the changes in upper vegetation cover from 1997-2019 in Brgy. Adlay, Carrascal Bay, Surigao del Sur Philippines. The land cover were classified using SAGA GIS (3.2.3), for the period 2013 to 2018 (LANDSAT 8) through object based segmentation and ground validation. Class level metrics were derived from the classified satellite images in FRAGSTATS 4.2. A total of six (6) for class metrics level viz. total area (CA), percentage of landscape (PLAND), total edge (TE), fractal dimension mean (FRAC_MN), perimeter area fractal dimension (PAFRAC), and clumsiness (CLUMPY) respectively to uncover the influence of upper vegetation fragmentation to water quality. The class metrics of the study area revealed that the total area of sparse vegetation (908.55m in 1997, 484.29m in 2019) , bare ground (485.64 m in 1997, 524.16m in 2019) , vegetation, (195.03m in 1997, 669.51m in 2019). Fragmentation analysis revealed that the percentage of non-vegetative cover is 48.56% (1997) while the vegetation cover is 51.43% (2019). The study also showed that there is a notable change in land cover of the area from 1997 to 2019.

*__Corresponding Author:__ Sheila Kylene ✉ skyarreza@yahoo.com

Introduction

The suspended sediment concentration effect on water quality is important for environmental concern around the globe (Colina, 2018). Sediment yield is the net result of soil erosion and processes of sediment accumulation; it depends on variables that control water and sediment discharge to reservoirs. Typically, sediment yield reflects the influences of climate (precipitation), catchment properties (soil type, topography), land use/cover, and drainage properties (stream network form and density) (Apodaca, 2018). In this situation, the common water sampling techniques are time consuming, through the advantage of remote sensing have been used effectively on environmental pollution application to monitor the water quality parameter, and collect wide satellite image to shorten the time period on data gathering (Lim, 2015).

Due to human modifications, erosion rates have been raised above natural levels, a phenomenon known as accelerated erosion. The effects of soil erosion go beyond the loss of fertile land. Soil erosion has led to increased pollution and sedimentation in streams and rivers, clogging these waterways and causing declines in fish and other species (Kwasi, 2018). Moreover, degraded lands are also commonly less able to hold onto water, which can worsen flooding. Sustainable land use can help to reduce the impacts of agriculture and livestock, preventing soil degradation, erosion and the loss of valuable land to desertification as well as the loss of reservoir volume by sediment deposition. Sedimentation in a reservoir can be defined by trap efficiency, which is the ratio of the deposited sediment quantity to the total sediment inflow. Trap efficiency is a function of the volume and grain-size distribution of sediment, outlet works, and method of reservoir operation (Zablotski, *et al.,* 2018). The smallest sediment particles may be transferred through the reservoir without settling. Larger particles may be retained; depending on how completely suspended sediment settles into the reservoir. During peak flow, in flowing water with large volumes of sediment can enter a large reservoir and cannot be subsequently redistributed. Trap efficiency of a reservoir decreases with age as the reservoir capacity is depleted by sediment accumulation (Paradis *et al.,* 2018).

Through the advantages of remote sensing techniques many researcher has been applied the remotely sense data in the study due to the relationship of landsat data and suspended sediment concentration (SSC). This study in Carrascal Bay aims to shed light on how Geographic Information System (GIS) and Remote Sensing (RS), can be utilized to assess vegetation fragmentation in Carrascal Bay from 2012-2019. Also, it will explore on how the livelihood of fishers were affected by the changes in the body of water, and the adaptation strategies and alternative livelihood they have done to survive despite the situation.

Materials and methods

The research is descriptive-investigative in nature, it investigates the cause-effect relationship of upper vegetation fragmentation and total suspended solid concentration in Carrascal Bay. Geographic Information system (GIS) and Remote Sensing (RS) are also included to detect the physical features of the surface sediment in Carrascal Bay from 2013-2019. Landsat 8 scenes in the year 2013-2019 were used for delineation of the area, and image processing to detect changes. The satellite image was processed in QGIS 3.12 and GIS SAGA 2.3.

Study Area

The study was conducted in Municipality of Carrascal a coastal community situated at 9° 22' North, 125° 57' East the municipality is known for the mining economy. It is the home of large and small scale mining firms in Surigao del Sur Province. The municipality of Carrascal is one of the coastal municipalities of Surigao del Sur with a rich-fishing ground. In fact, Carrascal Bay is considered as a “key priority” sites for biodiversity. The municipality has a land area of 265.80 square kilometers or 102.63 square miles which constitutes 5.39% of Surigao del Sur's total area. Its population as determined by the 2015 Census was 22,479. This represented 3.80% of the total population of Surigao del Sur province, or

0.87% of the overall population of the Caraga region. Based on this fig., the population density is computed at 85 inhabitants per square kilometer or 219 inhabitants per square mile. The population of Carrascal grew from 7,898 in 1960 to 22,479 in 2015, an increase of 14,581 people. The latest census fig. in 2015 denote a positive growth rate of 6.03%, or an increase of 5,950 people, from the previous population of 16,529 in 2010. This migration and influx of people is mainly due to job opportunities in the mining industry. *The main location of the study site is in Barangay Adlay,* is a barangay in the municipality of Carrascal, in the province of Surigao del Sur. Its population as determined by the 2015 Census was 6,332. This represented 28.17% of the total population of Carrascal. According to the 2015 Census, the age group with the highest population in Adlay is *5 to 9*, with 745 individuals. Conversely, the age group with the lowest population is *75 to 79*, with 26 individuals. The population of Adlay grew from 2,203 in 1990 to 6,332 in 2015, an increase of 4,129 people. The latest census figs. in 2015 denote a positive growth rate of 8.43%, or an increase of 2,193 people, from the previous population of 4,139 in 2010.

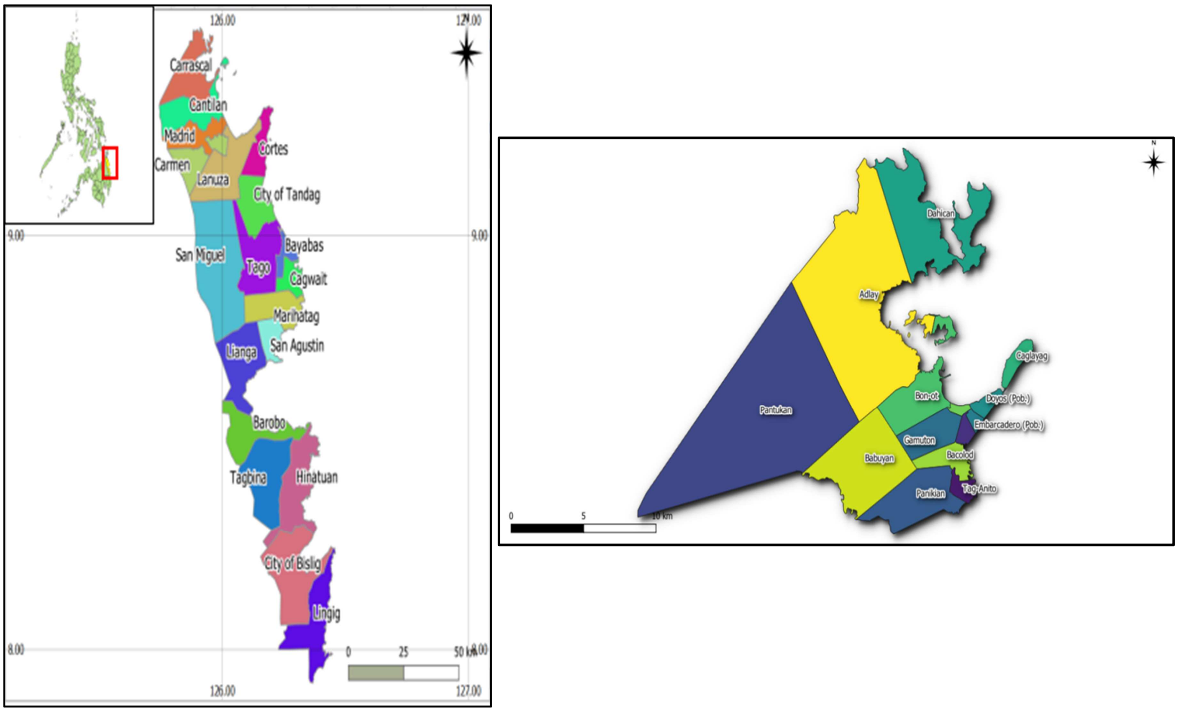

Fig. 1. Map of the Study Area.

Data Gathering Procedure

The researcher utilized QGIS 3.12 Bucuresti and QGIS SAGA 2.3. in the image processing of the satellite image. Satellite images were downloaded from Earth Explorer USGS. The satellite images of Landsat 8 from 2013-2019 were carefully selected in areas where there are less to no clouds.

Image Classification

Satellite images from 2013-2019 was downloaded using the Landsat 8, where it uses the RGB Composite. The automatic atmospheric calibration was performed on each image separately.

Fragmentation Analysis

A spatial pattern analysis program i.e., Fragstats 4.2. offers a comprehensive choice of landscape metrics and have been used to quantify landscape structure. It is implemented by decision maker and ecologists to analyze landscape fragmentation and to describe the characteristics and components of those landscapes. These statistics facilitates the comparison of landscapes and the evaluation of processes. The advantage of Fragstats is that the calculations are implemented in a fully integrated fashion in a GIS and consequently easy to apply to digital map.

Treatment of Data

In the treatment of data, the study will use Fragmentation Statistics Software Version 4.2.1. This computer software able to calculate a large variety of statistics for every patch and class (patch type) in the landscape as well as for the total area of the landscape. At the class and landscape level, some metrics quantify landscape composition of landscape can influence ecological processes. The study used landscape analysis Class Metrics through Fragstat 4.2. The following metrics was used:

Total Area (CA)

Is the sum of the areas of all patches of the corresponding patch type.CA approaches 0 as the patch type becomes increasing rare in the landscape.

Percentage of Landscape (PLAND)

It is the sum of the areas of all patches of the corresponding patch type. When the PLAND reaches 0, the patch type becomes increasing rare in the landscape and when it reaches 100, the Landscape is occupied by a single patch type.

Total Edge (TE)

The total length of edge in the landscape involving patch type. TE = 0 when there is no class edge in the landscape; that is, when the entire landscape and landscape border.

Fractal Dimension Mean (FRAC_MN)

Reflects shape complexity across a range of spatial scales (patch sizes). It equals the sum, across all patches of the corresponding patch type, of the corresponding patch metric values, divided by the number of patches of the same type.

Perimeter Area Fractual Dimension (PAFRAC)

Reflects shape complexity across a range of spatial scales (patch sizes).PAFRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters.

Clumpiness (CLUMPY)

The frequency with which different pairs of patch types (including like adjacencies between the same patch types) appear side-by-side on the map. CLUMPY equals -1 when the focal patch type is maximally disaggregated; CLUMPY equals 0 when the focal patch type is distributed randomly,and approaches 1 when the patch type is maximally aggregated.

Fragmentation Equation

The study adapted the Matheron Index (in Lambin and Ehrlich 1997) to quantify the fragmented landscape.

$$M = \frac{\text{number of unlike adjacent pixels}}{\text{SQRT(number of focal pixels)} \times \text{SQRT(total number of pixels)}} \quad (1)$$

The fragmentation equation above, is the Martheron Index used to quantify the landscape fragmentation. 30x30 m is the measure of Landsat image used in the study, with 15m pancromatic image, used for image sharpening. With the classified image, in geotiff file, the image was then processed in FRAGSTATS to assess changes in the landscape from 1997 to 2019. The measurements in FRAGSTATS, using the Class Metrics were tallied in table form to see significant changes in 22 years.

Results

Table 1 below, shows the fragmentation analysis of Adlay, Carrascal in 1997. Results revealed that the percentage of non-vegetative cover is 48.56% while the vegetation cover is 51.43%. The fragmentation of the vegetation cover nearly reaches 1 which indicates that the area is more fragmented and the vegetation class is near to disappearance.

Table 2 below, shows the fragmentation analysis in 2019 shows that the non-vegetative cover is 46.69% and the vegetative cover is 53.30%. The clumpiness the grass and water has change from 1997 to 2019. While the bare ground and open-pit has increased in the area, it denotes that more soil are prone to erosion and sedimentation especially during rainy season. The bare soil when eroded in the bodies of water can cause sediment loading in the Carrascal Bay which has the potential to alter inputs in the river system and functioning.

Table 1. Fragmentation Result of 1997.

Type	CA	PLAND	TE	FRAC_MN	PAFRAC	CLUMPY	f	M
Bare ground	485.64	13.2586	136410	1.0441	1.4573	0.7629		
Sparse vegetation	908.55	24.8047	371220	1.0612	1.5399	0.5950	0.16442	0.0000113
Open-pit	410.04	11.1947	210330	1.0475	1.5621	0.5734		
Grass	780.21	21.3008	35310	1.0339	1.2786	0.9616	0.00841	0.0000156
Water	883.35	24.1167	292470	1.0451	1.5485	0.6772		
Vegetation	195.03	5.3246	122940	1.0636	1.5211	0.5095	0.94675	0.0006989
Total	3662.82	51.4301						
%nv	0.485699	48.5699						

Table 2. Fragmentation Result of 2019.

Type	CA	PLAND	TE	FRAC_MN	PAFRAC	CLUMPY	f	M
Bare ground	524.16	14.3103	133620	1.0511	1.378	0.7804		
Sparse vegetation	484.29	13.2218	248010	1.0572	1.5536	0.564	0.20945	0.0002604
Open-pit	386.19	10.5435	107940	1.0454	1.3987	0.774		
Grass	798.84	21.8094	340230	1.0633	1.522	0.5941	0.16567	0.0001360
Water	799.83	21.8365	46740	1.0493	1.3338	0.9486		
Vegetation	669.51	18.2785	320940	1.0609	1.5549	0.5659	0.43773	0.000273
Total	3662.82	53.3097						
%nv	0.466903	46.6903						

The connectedness and compaction of the patches has decreased, which denotes that the patches appears to have been disintegrated from each other and considers being a process of fragmentation. The fragmentation in the open pit mining area in Barangay Adlay, Carrascal, Surigao del Sur indicates landscape modification. This modification brought by the human activity can can hinder the delivery of ecosystem services in the area if not properly addressed. Table 3 below, shows the result of the FRAGSTATS 4.2. in the Class metrics, as seen from 1997 to 2019 the CA for sparse vegetation, have decreased while some other vegetative cover like grass and vegetation have increased. This can be attributed to the on-going mangrove plantation in the coastal area of Adlay, Carrascal. The PLAND for sparse vegetation have decreased while bare ground and open pit increased in the percentage it occupies the landscape.

Table 3. FRAGSTATS Result of Class Metrics of 1997 and 2019.

Land Cover Type	CA		PLAND		TE		FRAC_MN		PAFRAC		CLUMPY	
	1997	2019	1997	2019	1997	2019	1997	2019	1997	2019	1997	2019
Bare ground	485.64	524.16	13.2586	14.3103	136410	133620	1.0441	1.0511	1.4573	1.378	0.7629	0.7804
Sparse vegetation	908.55	484.29	24.8047	13.2218	371220	248010	1.0612	1.0572	1.5399	1.5536	0.5950	0.564
Open-pit	410.04	386.19	11.1947	10.5435	210330	107940	1.0475	1.0454	1.5621	1.3987	0.5734	0.774
Grass	780.21	798.84	21.3008	21.8094	35310	340230	1.0339	1.0633	1.2786	1.522	0.9616	0.5941
Water	883.35	799.83	24.1167	21.8365	292470	46740	1.0451	1.0493	1.5485	1.3338	0.6772	0.9486
Vegetation	195.03	669.51	5.3246	18.2785	122940	320940	1.0636	1.0609	1.5211	1.5549	0.5095	0.5659

Satellite image of the location year 1997 and 2019

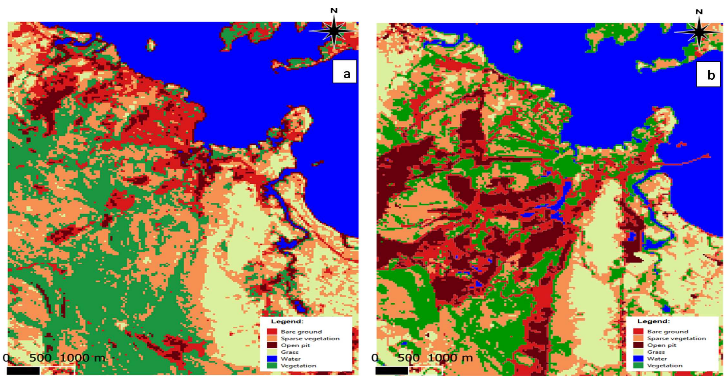

Fig. 2. Classified satellite images of Adlay, Carrascal 1997 (a) and (b).

Conclusions

Fragstats result in the Class metrics, as seen from 1997 to 2019 the CA for sparse vegetation, have decreased while some other vegetative cover like grass and vegetation have increased. This can be attributed to the on-going mangrove plantation in the coastal area of Adlay, Carrascal. The PLAND for sparse vegetation have decreased while bare ground and open pit increased in the percentage it occupies the landscape. The fragmentation analysis of Adlay, Carrascal in 1997. Results revealed that the percentage of non-vegetative cover is 48.56% while the vegetation cover is 51.43%. The fragmentation of the vegetation cover nearly reaches 1 which indicates that the area is more fragmented and the vegetation class is near to disappearance. The fragmentation analysis in 2019 shows that the non-vegetative cover is 46.69% and the vegetative cover is 53.30%. The clumpiness the grass and water has change from 1997 to 2019. While the bare ground and open-pit has increased in the area, it denotes that more soil are prone to erosion and sedimentation especially during rainy season. The bare soil when eroded in the bodies of water can cause sediment loading in the Carrascal Bay which has the potential to alter inputs in the river system and functioning. In 1997, fragmentation on the vegetative cover is 0.0.373193 to 0.270950 in 2019. While the percent in the non-vegetative cover slightly decrease by 2% in 2019. Also, satellite images from 2013 to 2018 of Carrascal Bay shows sediment loads deposited in the area, and increase of bare soil. Vegetation plays an important role as a protection for the soil against vulnerability of being swept away by wind and water. The vegetation provides a protective cover on the land by slowing down the flow of the water and allows the rain to soak into the ground. It also reduces the soil's ability to erode and the roots of the plants bind the soil to prevent erosion. When vegetative cover becomes fragmented, the water becomes the medium to detached and transport vulnerable soil through rain splash or gully erosion. The water from the catchment flows directly into the Carrascal bay where sediments are deposited. The sediments can cause physical, chemical and biological functioning of the River.

The freedom of choice of the human beings accompanied by its need for economic progress can be a driver of changing the landscape. In this study, the mining activity is an anthropogenic activity putting direct pressure on the land use and resource extraction leading to land modification. This land modification can alter ecosystem functioning and ecosystem services. As a response, the degraded ecosystem could no longer support the basic need of man when it comes to provision, regulation, support and aesthetics.

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