IDENTIFICATION OF RIPARIAN ZONE ENCROACHMENT USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT: Riparian zones are areas that exist between terrestrial and aquatic ecosystems consisting of vegetation and soils of higher slope grade. They are important in protecting aquatic ecosystems when water level rises, in supporting a diverse set of vegetation, and in making considerations for land use management. For the protection of these areas, the Philippines' Water Code (Article 51) states that easements along rivers should be defined and shall not have any human activity that may destroy the natural biodiversity in the area. Considering how important these areas are, identifying them should be among the priority tasks of the local government. However, this can be tedious and expensive because traditional techniques use field-based methods. In this paper, a geoprocessing model for the identification of the riparian zone of a river system and the encroachment within these areas was developed. The model was implemented in the Ampid River, located in San Mateo, Rizal, Philippines. The framework of the processing model is based on remote sensing and Geographic Information Systems (GIS) principles. Remote sensing was used to classify PlanetScope Ortho Analytic Scene satellite images from three consecutive years, 2016 to 2018. Supervised classification was used to classify the images into different land cover types wherein the annual crops and built-up areas were assigned to represent agricultural and urban development areas in the riparian zone. The GIS model was used to identify and map the riparian zone and to evaluate the area encroached using the buffer distances based on the land cover type. The resulting total encroachment areas of built-up areas for both banks for a 3-meter urban buffer were 13,309.62 sqm for 2016, 14,942.70 sqm for 2017 and 11,910.42 sqm for 2018. Using the 20-meter agricultural buffer, the encroached areas by annual crops for 2016, 2017 and 2018 were 63,944.72 sqm, 96,147.55 sqm, and 86,033.82 sqm respectively. Linear regression was performed on these images to create a general linear projection of the encroachment to predict the possible area encroached for the succeeding two years.

1. INTRODUCTION

1.1 Background

The Philippine archipelago is among the countries in the Pacific visited by an average of 20 typhoons per year (Asian Disaster Reduction Center, 2013). In 2018, there have been 21 storms, typhoon Usman being the last one entering the Philippine waters on December 25, 2018 (Yap, 2018), with accompanying rains affecting the country until the midnight of January 1, 2019. Aside from typhoons, the country is also affected by rains brought about by the Southwest Monsoon, also known as hanging Habagat. These storms and torrential rains bring forth floods in areas that are prone to soil erosion and areas that are badly managed, especially populated areas alongside the rivers, which puts lives at risk to landslides and floods.

Riparian zones are ecosystems existing between aquatic and terrestrial ones and are surrounded by much drier soils with higher slope grades. They are important in making considerations for land use and management as well as in protecting aquatic ecosystems by "removing sediments from surface runoff, decreasing flooding, maintaining appropriate water conditions for aquatic life, and providing organic material vital for productivity and structure of aquatic ecosystems." Moreover, they are also considered home for wildlife providing water source, food, and shelter (Machtinger, 2007). In general, riparian zones or corridors are important because they are the most fertile part of the area that can support a diverse set of vegetation and are also the first line of defense when water level rises in the aquatic ecosystem. Riparian zones are prone to degradation and damage especially in areas that are highly urbanized. These damages can affect the ecological and economic productivity of the riparian areas, and worse, it can affect the lives of people living near these areas by putting them at risk of flooding. With this in mind, it is important to account for these damages done in the riparian zones.

Performing a large-scale research study on the riparian zones of Philippine rivers will not only be costly, it will also be time consuming considering the number of rivers flowing within the country if traditional field-based methods will be used. Thus, this research aims to develop an alternative way in identifying riparian zones through utilizing

Remote Sensing (RS) and Geographic Information Systems (GIS), and through assessing one river at a time. Delineating riparian zone encroachment using a GIS processing model following the Philippines' Water Code is developed which can help in identifying and understanding how these areas are affected by increasing urbanization. Statistical analysis of the rate of encroachment is also performed to estimate future encroachment scenarios.

1.2 Riparian zones and water easements

The Philippine constitution has set rules and regulations through the Water Code in order to preserve our water bodies as well as the areas around them. Article 51 under Chapter IV of The Water Code of the Philippines (Presidential Decree No. 1067) states that the "banks of rivers and streams and the shores of the seas and lakes throughout their entire length and within a zone of three (3) meters in urban areas, twenty (20) meters in agricultural areas and forty (40) meters in forest areas, along their margins are subject to the easement of public use" (Presidential Decree No. 1067, 1976). However, the lack of stringent implementation of the law as well as the lack of knowledge of these guidelines amongst the people living near water bodies both impacts how ecosystems in our rivers and water bodies thrive.

This section of the Water Code defines the parameters in which this research will base the buffers to identify the riparian zone of Ampid River. Furthermore, one of the administrative orders of the Department of Environment and Natural Resources (DENR) has solidified the importance of Article 51 of the Water Code in the preservation of biodiversity. In DAO No. 99-21, issued on June 11, 1999 as a response to the geodetic engineering profession's clamor to ensure the preservation of ecological balance and protection. Strict implementation of Article 51 of PD 1067 was promulgated in the processing, verification, and approval of isolated and cadastral surveys (DAO No. 99-21, 1999)

1.3 Study Area

The province of Rizal, shown in Figure 1, is located in the CALABARZON Region. It is bounded by Metro Manila, Bulacan, Quezon Province, and Laguna to the west, north, east, and southeast respectively (Salonga, 1934). The province is streaked through by a number of rivers notable of which are Angono River, Marikina River, Pasig River, and Taytay River among others. The Province of Rizal is a mountainous region with a total area of 1,191.94 square kilometer and a population density of 2,400/km^2; the highest among all the 81 provinces in the country based on the 2015 census (Rizalprovince.ph., 2013). Six rivers passing through the province are tributaries of the Laguna Lake, these are Morong River, Tanay River, Sapang Baho River, Marikina River, Taytay River which intersect with the Mangahan Floodway, and Pasig River (Greenpeace, 2010). Ampid River, which has a length of 11. 48 kilometers and traversing barangays Ampid I, Ampid II, Gulod Malaya, Sto. Niño, and barangay Silangan of San Mateo, will be the focus of this study. It drains the southern hilly areas of Barangays Silangan, Sto. Niño, Gulod Malaya and Ampid and unsafely flows through the populated portions of the municipality.

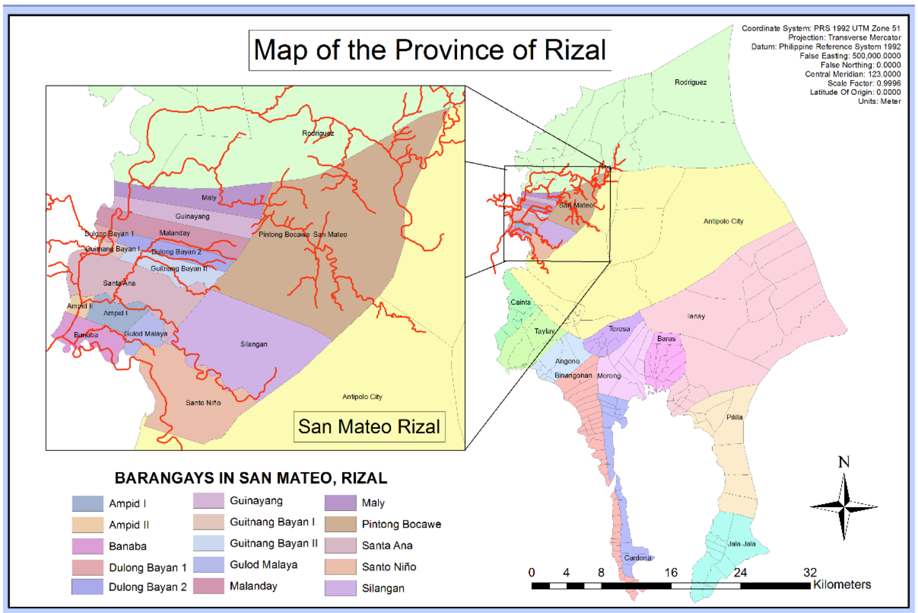


Figure 1. Location of the rivers in San Mateo, Rizal, Philippines

2. MATERIALS AND METHODS

2.1 Creation of the riverbank shapefile for Ampid River

A DEM of the study area derived from 2013 Airborne Interferometric Synthetic Aperture Radar (IfSAR) was obtained from the National Mapping and Resource Information Authority (NAMRIA). The Terrain Analysis Using Digital Elevation Models (TauDEM) toolbox developed by David G. Tarboton of Utah State University was utilized for the analysis and extraction of hydrologic information from the DEM, specifically, to determine the riverbanks of the Ampid River. The left and right riverbanks are delineated separately as line features.

2.2 Image processing

Three 4-band PlanetScope Scene satellite images were downloaded from Planet Labs, with acquisition dates October 2016, 2017, and 2018. These images are already geometrically, radiometrically, and atmospherically corrected, thus may already be used for supervised image classification. Using Maximum Likelihood Classification, the land cover identified were annual crop, brush or shrubs, built-up, grassland, and inland water, based from the 2015 Land Cover of San Mateo. Only one set of ROIs was used for the three images for temporal analysis. The resulting land cover classifications per year are then converted in GIS feature layers for further analysis.

2.3 GIS model for riparian zone encroachment

A GIS model was developed using the ModelBuilder feature in ArcGIS 10.3. The model involves getting the classified images and the river boundaries as inputs. These are projected to the Philippine Reference System of 1992 (PRS 92) as prescribed by the mapping authorities in the country, and the land cover is clipped to the extent of the area of interest. Buffers are generated based on the Philippine Water Code: 3-meter for urban areas, 20 meters for agricultural areas, and 40 meters for forest areas. Spatial overlay using Intersect is used to determine encroaching areas in the buffer zones. Then the Dissolve and Table to Excel functions were used to output a table with the values of the encroached areas of the built-ups and/or agricultural land within each specified buffer zone.

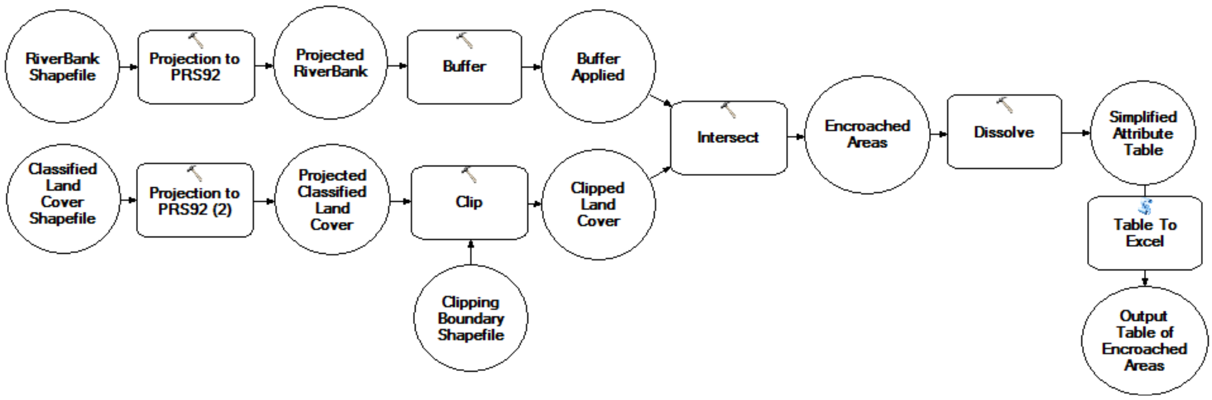


Figure 2. Riparian Zone and Encroachment Processing Model

2.4 Statistical Analysis

A statistical analysis was then be performed to determine the rate of encroachment in the area using the three satellite images, taking note that the rates are based on land cover and not the specific land use. This rate was used to project the time it will take for the riparian buffer zone to be completely encroached. The projection of area occupancy will be solved using least squares linear regression method with equations:

$$\sum Y = na + b\sum X \qquad \textit{(Eqn. 1)}$$

$$\sum \mathrm{XY} = \mathrm{a}\sum \mathrm{X} + \mathrm{b}\sum \mathrm{X}^2 \qquad \textit{(Eqn. 2)}$$

$$\mathrm{Y_c} = \mathrm{a} + \mathrm{bX} \qquad \textit{(Eqn. 3)}$$

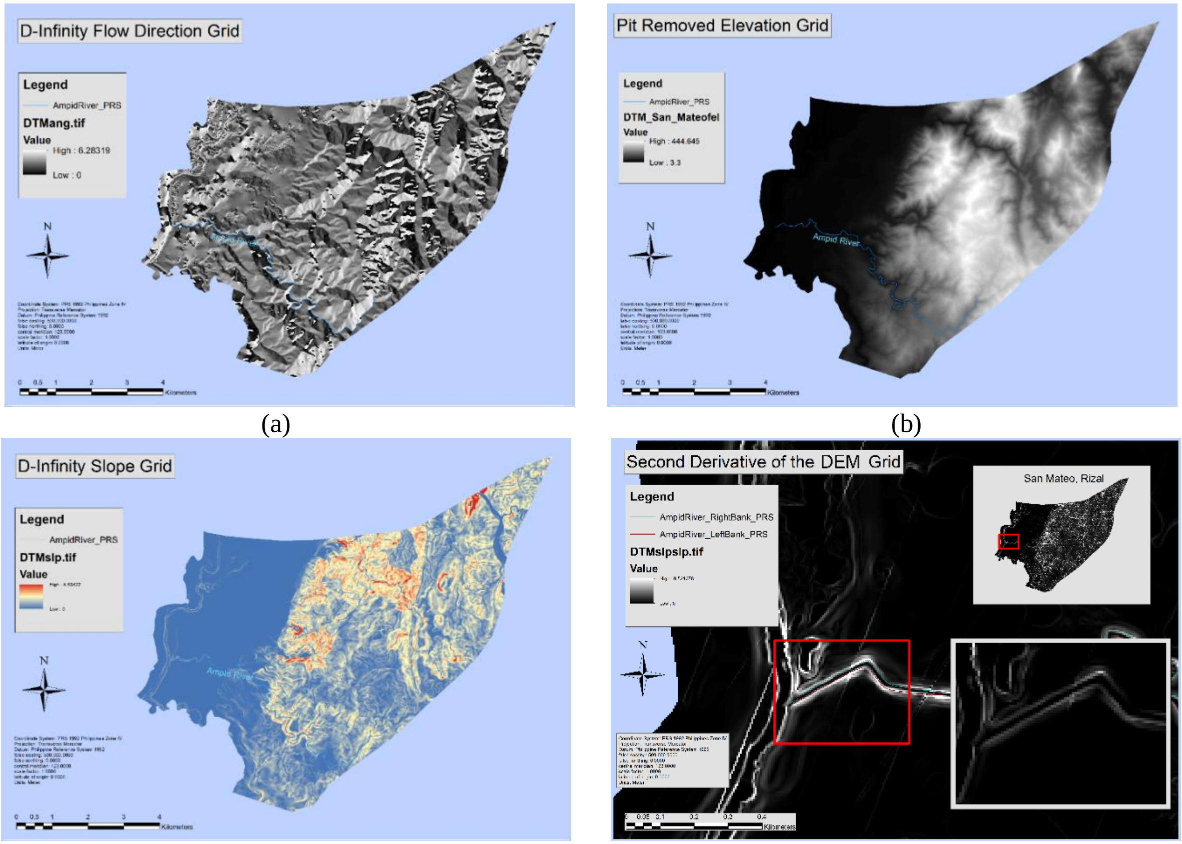
Where Y will be the encroached area for different years and Y_c will be the projected area occupancy.

3. DISCUSSION OF RESULTS

3.1 Delineation of riverbanks

Using the TauDEM, the DEM was first run through the Pit Remove function to raise the elevation of pits into points where they overflow their pour points and creates a hydrologically correct DEM, shown in Figure 3a, below. The riverbanks or bank full limits were identified by implementing the D-Infinity Flow Direction function that generates a direction grid (Figure 3b) and a slope grid (Figure 3c) of the area from the hydrologically correct DEM. Using the resulting slope grid as input, the same TauDEM function to generate a slope grid was implemented again to generate a grid with pixel values equal to the slope of the slope, or the second derivative of the DEM (Figure 3d).

The point at which the highest water level occurs is assumed as the beginning of the riverbank. The resulting grid showing the second derivative of the DEM was used as a basis for the manual delineation of the riverbank.



(a) (b)

(c) (d)

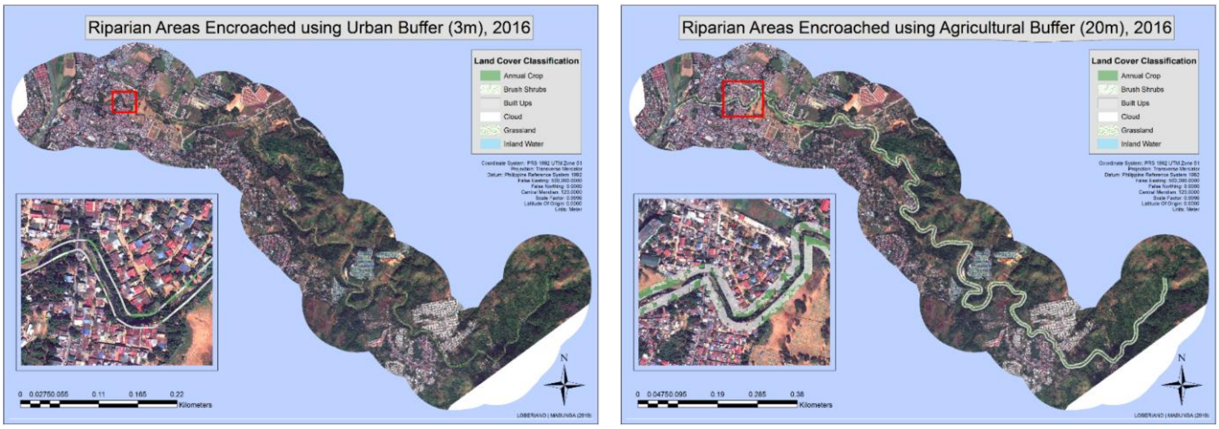
Figure 3. Resulting grids from TauDEM: (a) Pit removed elevation grid, (b) D-Infinity Flow Direction Grid, (c) D-Infinity Slope Grid, and (d) Second Derivative of the DEM Grid

3.2 Identification of riparian zone encroachment

Using the GIS processing model created, the riparian zone encroachment may be identified. The user inputs the shapefiles for the classified land cover obtained from image processing, the delineated river's left bank, river's right bank, and the clipping boundary polygon of the study area. The model creates three (3) buffers set by the Philippine Water Code. But for the interest of this paper only urban and agricultural buffer results are discussed due to the absence of forests in the study area. Figure 4 show the maps of the encroached riparian areas using each buffer on the classified image of year 2016. Table 1 on the next page summarizes the calculated areas.

Table 1. Summary of Riparian Area Encroached in Ampid River for the year 2016

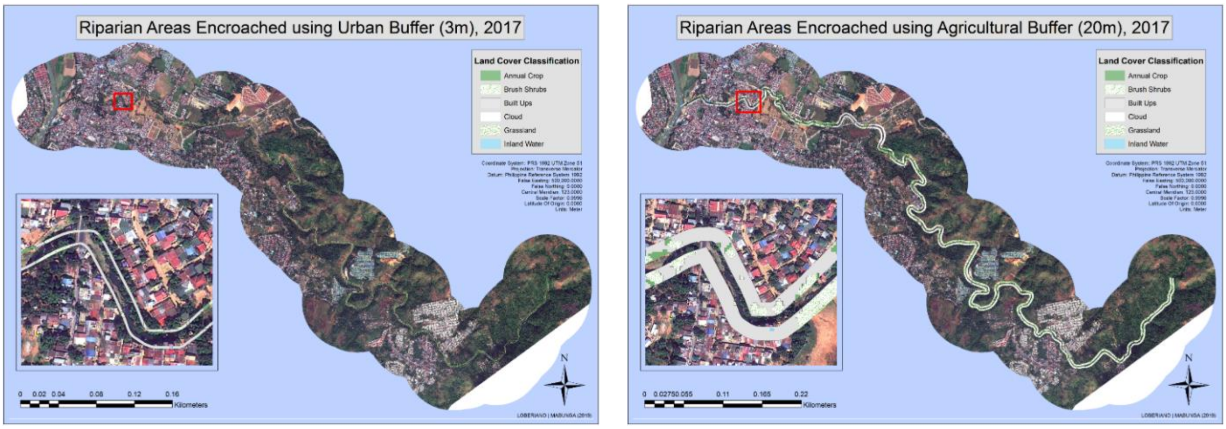
Bank Side	Class Name/Buffer Type	Area Encroached (sqm)	
		Urban	Agricultural
Left	Annual Crop	4,701.68	31,774.62
	Brush Shrubs	18,636.28	12,6045.68
	Built-up	6,917.23	44,463.95
	Grassland	2,309.13	14,680.68
Right	Annual Crop	4,813.05	32,170.09
	Brush Shrubs	18,642.14	123,464.08
	Built-up	6,654.81	45,525.73
	Grassland	2,581.10	16,943.74



(a) (b)

Figure 4. Maps of riparian areas encroached for the year 2016: (a) 3-m urban buffer, (b) 20-m agricultural buffer

Similarly, Figures 5 and 6 show the maps of the encroached riparian areas using each buffer on the classified images of years 2017 and 2018, respectively. Tables 2 and 3 on the succeeding page, summarizes the corresponding calculated areas.

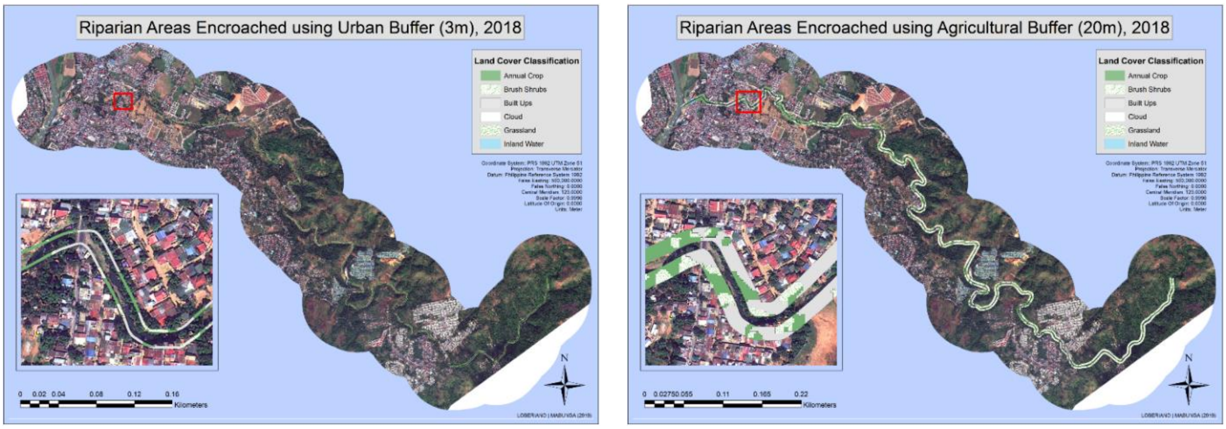


(a) (b)

Figure 5. Maps of riparian areas encroached for the year 2017: (a) 3-m urban buffer, (b) 20-m agricultural buffer

Table 2. Summary of Riparian Area Encroached in Ampid River for the year 2017

Bank Side	Class Name/Buffer Type	Area Encroached (sqm)	
		Urban	Agricultural
Left	Annual Crop	7,168.48	46,879.32
	Brush Shrubs	14,538.34	98,147.27
	Built-up	7,827.24	51,244.76
	Grassland	3,135.71	21,379.07
Right	Annual Crop	7,763.26	49,268.22
	Brush Shrubs	14,383.71	93,993.36
	Built-up	7,115.46	50,724.51
	Grassland	3,513.18	24,228.72



(a) (b)

Figure 6. Maps of riparian areas encroached for the year 2018: (a) 3-m urban buffer, (b) 20-m agricultural buffer

Table 3. Summary of Riparian Area Encroached in Ampid River for the year 2018

Bank Side	Class Name/Buffer Type	Area Encroached (sqm)	
		Urban	Agricultural
Left	Annual Crop	6,857.68	43,763.22
	Brush Shrubs	14,757.13	101,930.76
	Built-up	6,369.60	42,580.10
	Grassland	4,630.97	28,970.76
Right	Annual Crop	6,489.73	42,270.60
	Brush Shrubs	15,434.63	10,0380.16
	Built-up	5,540.83	38,741.57
	Grassland	5,293.12	36,924.55

Based from Table 1 shown from previous page, there is a greater number of built-up areas encroaching both the left and right bank using the urban and agricultural buffer compared to the annual crop areas for the year 2016. However, Tables 2 and 3 show that the left bank still exhibits the same trend, but the right bank has greater number of annual crop areas compared to the built-up areas for the year 2017 and 2018.

3.3 Prediction of future encroachment

The areas encroached using each buffer for the three (3) years was plotted. Based from the graphs as shown in Figures 7 and 8, for the left bank there was a decrease in areas of the brush/shrub and built-up land cover, while the annual crops and grassland increased in area. This trend was also observed for the agricultural and forest buffers, both for the left and right banks. Given this result, it was found out that most riparian areas were encroached by agricultural development.

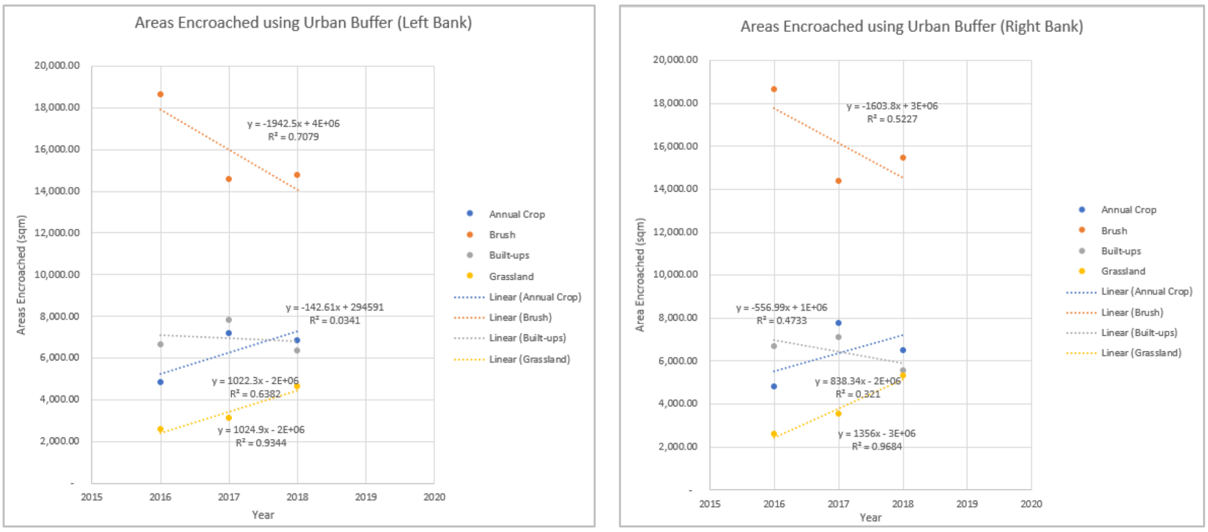


Figure 7. Plot of areas encroached for the three years, using Urban Buffer: (a) Left Bank and (b) Right Bank

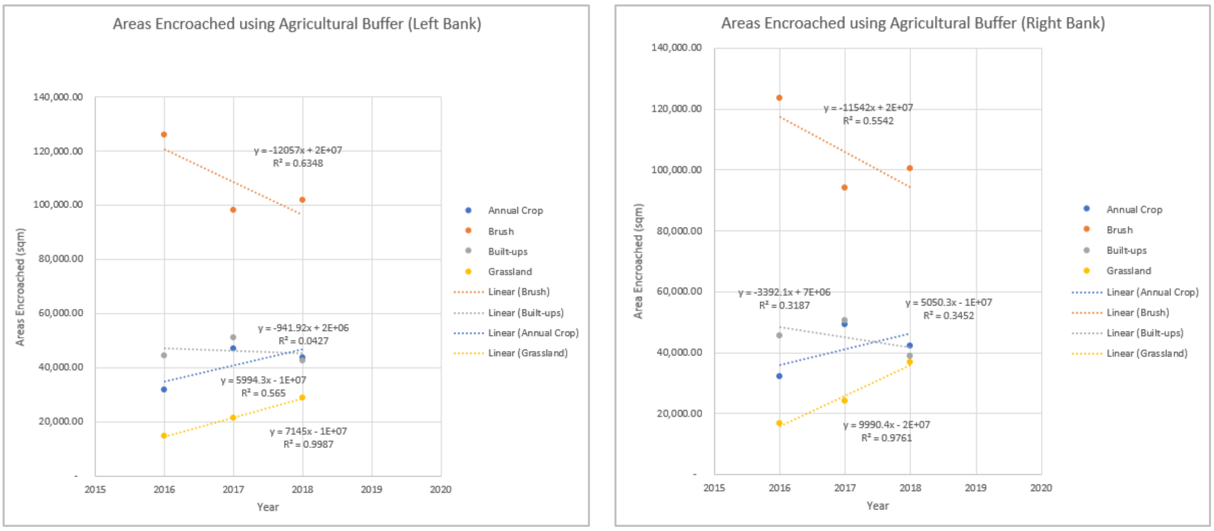


Figure 8. Plot of areas encroached for the three years, using Agricultural Buffer (a) Left Bank and (b) Right Bank

A linear regression was also done to derive the equation that will be used for the prediction of area encroached by 2020. Based from the graphs for the left bank, the values of R^2 obtained for the two land cover were low with R^2 values of 0.6382 and 0.0341 for annual crop and for the built-ups, respectively. This observation was also seen for the agricultural buffer. For the urban buffer of the right bank, the values of R^2 obtained for the rate of increase for annual crop and rate of decrease of built-up, were of 0.3452 and 0.3187 respectively.

The low values of R^2 were also observed for the agricultural buffer. The low values of R^2 have been affected by the fact that the change in areas encroached per land cover was abrupt and inconsistent. For example, the annual crop using urban buffer in the left bank, there was an increase in area of 2,355.44 sqm, but from 2017 to 2018, there was a decrease of 310.81 sqm.

With the obtained R^2 for all buffers, both in the left and right bank, the use of linear regression equations to predict the area encroached by built-ups and annual crops may not yield the best result. Other statistical model may be applied to predict the future land cover change, but for the purpose of simple estimation, the equations were used to compute the probable area encroached by 2020. Tables 4 and 5 show the estimated area encroached by 2019 and 2020 using the equations for annual crop and built-ups.

Table 4. Estimated Area Encroached by Annual Crop and Built-up using Urban Buffer

Land Cover	Area Encroached in Left Bank (sqm)		Area Encroached in Right Bank (sqm)	
	2019	**2020**	**2019**	**2020**
Annual Crop	64,023.70	65,046.00	-30,7391.54	-306,553.20
Built-up	6,661.41	6,518.80	-130,132.71	-124,562.80

Table 5. Estimated Area Encroached by Annual Crop and Built-up using Agricultural Buffer

Land Cover	Area Encroached in Left Bank (sqm)		Area Encroached in Right Bank (sqm)	
	2019	**2020**	**2019**	**2020**
Annual Crop	2,102,491.70	2,108,486.00	196,555.70	247,058.70
Built-up	98,263.52	97,321.60	151,350.10	117,429.10

4. SUMMARY AND CONCLUSION

An alternative way in delineating riparian zones was developed using RS and GIS techniques. Riparian zone encroachment was identified using a GIS processing model which implements buffer zones following the Philippines' Water Code. Given that not only the brush/shrub and grasslands were observed within the buffer zones, the encroachment of other land covers were determined, where the total values of area encroached by built-ups for both banks using the urban buffer for 2016, 2017 and 2018 were 13,309.62 sqm, 14,942.7 sqm and 11,910.42 sqm respectively. On the other hand, the total values of area encroached by annual crops using agricultural buffer were 63,944.72 sqm, 96,147.55 sqm, and 86,033.82 sqm for the three succeeding years, respectively. Performing the statistical analysis showed that the changes in land cover for three years were not consistent and the use of linear regression to model the changes is not the best option. However, the resulting equation was used to compute for estimated two-year encroachment area of each buffer zone. For future studies, ground sampling can be done to compare if the result using this study is consistent with the gathered field data. Improvements in the methodology of utilizing remote sensing and GIS can such as incorporating NDVI maps as basis in selecting ROIs for the image classification.

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