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Rapid assessment of the riparian zone habitat of river

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ABSTRACT

Some riparian areas of the country are in danger of deterioration due to uncontrolled exploitation coupled with loose implementation of environmental protection policies and regulations. Muleta River, a major watershed in Bukidnon, Philippines, was assessed to determine the present condition of its riparian habitat. Abiotic and biotic conditions of the river were assessed. Other factors including land cover, population density, and river geomorphologic characteristics contributing to the river condition were also evaluated. Results revealed that Muleta Watershed is in sub-optimal condition signifying favorable condition for floral and faunal habitat. However, considerable degradation in some isolated cases was likewise spotted. Biotic condition has shown greater degradation approaching marginal condition compared to the abiotic condition which is yet in the upper sub-optimal condition. It was found out that the midstream portion of the watershed is the most disturbed, followed by the downstream area and lastly by the upstream portion. The extent of agricultural cultivation is found as one of the significant factors affecting the health of the riparian habitat areas. It is recommended that riparian protection policies must be formulated and implemented to abate, if not prevent, the impact of anthropogenic interventions resulting to overexploitation in the riparian areas especially in midstream portion of the river.

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INTRODUCTION

Riparian zones are transition between aquatic and terrestrial ecosystem and the adjacent areas to water bodies including flood plains and wetlands, and intermittent streams that are distinguished by gradients in biophysical conditions, ecological processes, and biota (National Academy of Sciences, 2002; Tampus *et al.,* 2012). It is known to have high heterogeneity due to the complex interactions between geomorphology and hydrology with surface hydrology as the major factor for vegetative diversity and water dynamics (Capon and Dowe, 2012). Riparian areas support multiple important ecological functions such as maintenance of stream bank and water quality; supply of water, nutrient and habitat for organisms; support to recreation, tourism and other human values; and regulate negative impacts related to human land use (Bedford, 2009; Alldredge and Moore, 2012; Tampus *et al.,* 2012; Dice *et al.*, 2014; Lawal, 2016). Specifically, its ability to filter sediments from adjacent agricultural lands from entering water bodies has been increasingly used in the last decade in reducing sedimentation and preventing nutrient loss

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in water (Dybkjær *et al*., 2012). Due to this, riparian areas are a common target for river management and restoration (González del Tánago and García de Jalón, 2006). The continuous anthropogenic pressures such as increase of population and conversion of land cover especially in upstream watersheds in most of Philippine rivers placed stress to riparian ecosystems altering the rate, quantity and quality of its services (Opiso *et al.,* 2015; Bernardo, Jr., 2017). Riparian area occupied by cultivated crops such as corn and rice is a common setting especially in the agricultural province of Bukidnon. Almost all the rivers in the province are also threatened by over siltation and deteriorating water quality with varying degree of severity due to continually exploited natural resources (Opiso *et al.,* 2015). Muleta River is a major watershed in Bukidnon sourced for domestic and agro-industrial uses among others. The watershed is thrived by the presence of agricultural industries and small-scale farmers. With its headwaters emanating from Mt. Kalatungan Natural Range Park (MKaNPK), Muleta is considered a significant watershed becoming one of the learning watershed of the "National Research and Development Project for Watershed Management in the Philippines" (NRDPWMP) funded by Department of Science and Technology - Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD) (Dumago *et al*., 2018). The need for effective management of this resource arises to sustain its ecological services. Understanding the hydrological and ecological functioning is necessary for restoration planning (González del Tánago and García de Jalón, 2006). To be able to formulate specific management strategies in preserving and conserving riparian resources, this paper aimed to assess the condition of the riparian habitat of Muleta watershed. Specifically, it aimed to 1) assess the abiotic condition of the riparian area, 2) assess the condition of the vegetation in the riparian area, and 3) evaluate other factors affecting the condition of the riparian area. This study has been carried out in Muleta Watershed in Bukidnon, Philippines in 2016-2017.

MATERIALS AND METHODS

Study area

The watershed of Muleta is an inland watershed in the province of Bukidnon, Mindanao, Philippines (Fig. 1). It geographically lies between 7°58'7.30" north to 7°40'33.79" north latitudes and 124°46'10.08" east to 124°57'12.66" east longitude with an approximate total area of 1,049.58 km^2. Highest elevation is 2871.65 msl and the lowest elevation is 27.50 msl. It traverses 10 municipalities and one city namely; Pangantucan, Damulog, Don Carlos, Kibawe, Dangcagan, Maramag, Kitaotao, Kadingilan, Talakag, and Valencia City in Bukidnon province and portion of Carmen in North Cotabato province. The area is under the Type III climate of Modified Corona classification of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). This type is characterized with varying season that is not well pronounced; dry season from November to April and wet for the rest of the year. Three locations were assessed in Muleta watershed. These are Portulin in the Pangantucan; Malinao in Kadingilan; and Omonay in Damulog representing the upstream, midstream and downstream sections of the watershed, respectively.

Assessment of abiotic component

A checklist developed based on Barbour *et al.* (1999) and Opiso *et al.* (2015) was utilized in the assessment of the abiotic component of the riparian habitat of the rivers. This component refers to the non-living aspect of the riparian habitat which includes landscape, physical and hydrological conditions of the river including the hydrologic connectivity, bottom substrate, embeddedness, channel alteration and bank stability of the river. Using the description in the checklist (Table 1), each parameter was rated by three evaluators with corresponding values according to its condition whether it is optimal (16-20), sub-optimal (11-15), marginal (6-10) and/or poor (1-5). Average rating of each parameter in every site (downstream, midstream and upstream) given by the three evaluators was subsequently calculated. To determine the general condition of each parameter in the watershed, rating of the three sites were averaged. Overall abiotic condition was determined by computing for the sum of the average rating of each parameter and evaluated according to the rating scheme below (Table 2).

Assessment of biotic component

The assessment of the biotic component of the riparian habitat was accomplished using a checklist developed based on Barbour *et al.* (1999) and Opiso *et al.* (2015). The assessment of this component mainly constitutes of the factors utilized as indicators of the riparian habitat status. Parameters under this component are canopy cover, bank vegetative protection, streamside cover, and riparian vegetative zone width, presence of biotic condition stressors, vegetative horizontal patch structure and vegetation vertical structure. The same with the abiotic components, biotic factors were rated from 1 to 20 according to its condition whether it is optimal (16-20), sub-optimal (11-15), marginal (6-10) and/or poor (1-5). The evaluators gave ratings based on the descriptions of the parameters according to each

Table 1: Parameters assessed under the abiotic component.

Parameter	Condition			
	Optimal (16-20)	Sub-optimal (11-15)	Marginal (6-10)	Poor (1-5)
Hydrologic connectivity	Stream provides adequate hydrology to utilize floodplain; with over-bank full flows likely to inundate a broad area of floodplain	Less frequent inundation than fully connected streams described on the left. Floodplain supporting riparian vegetation present.	Somewhat modified floodplain, regularly inundated; stream no access to natural floodplain which does not have riparian vegetation	Fully disconnected from floodplain
Landscape condition stressor	Absence of landscape stressor	Presence of major stressor checklist with less than 10 % of the assessment area	Presence of major stressor checklist with less than 10 % or more than 10 % of the assessment area	Presence of major stressor checklist with more than 10 % of the assessment area
Hydrologic condition stressor	Absence of landscape stressor	Presence of Major stressor checklist with less than 10 % of the assessment area	Presence of major stressor checklist with less than 10 % or more than 10 % of the assessment area	Presence of major stressor checklist with more than 10 % of the assessment area
Physical structure condition stressor	Absence of landscape stressor	Presence of major stressor checklist with less than 10 % of the assessment area	Presence of major stressor checklist with less than 10 % or more than 10 % of the assessment area	Presence of major stressor checklist with more than 10 % of the assessment area
Physico-chemical parameters	0-2 parameters failed to qualify criteria	3-4 parameters failed to qualify criteria	5-6 parameters failed to qualify criteria	7 parameters failed to qualify criteria
Bottom substrate/in stream cover	>50% mix of gravel, submerged logs, undercut banks, or other stable habitat	30-50% mix of gravel or other stable habitat. Adequate habitat.	10-30% mix of gravel or other stable habitat. Habitat availability less than desirable.	<10% gravel or other stable habitat. Lack of habitat is obvious.
Embeddedness (extent to which rocks are buried by fine sediment)	0-25% surrounded by fine sediment	25-50% surrounded by fine sediment	50-75% surrounded by fine sediment	>75% surrounded by fine sediment
Channel alteration	Little or no enlargement of point bars above water and/or no channelization	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present.	Moderate deposition of new gravel, coarse sand on old and new bars; and/or alterations to both banks	Heavy deposits of fine material, increased bar development; and/or extensive channelization
Bank stability (score each bank)	Bank stable. No evidence of erosion or bank failure.	Moderately stable. Infrequent, small areas of erosion only.	Moderately unstable. Moderate frequency and size of erosional areas	Unstable. Many eroded areas.

condition (Table 3). Ratings given by all evaluators were averaged to obtain the rating of each parameter on each site. Scores on all sites were subsequently averaged to determine the general condition of each parameter in the watershed. Lastly, all scores of the parameters were summed up to determine the general condition of the biotic component using the below rating scheme (Table 4).

Table 2: Rating scheme for the general habitat condition for abiotic component.

Scores	Component condition	Interpretation
0-45	Poor	Most disturbed, loss of function
46-80	Marginal	Disturbed
81-135	Sub-optimal	Less suitable, less disturbed
136-180	Optimal	Most suitable condition, least disturbed

Table 3: Parameters assessed under the biotic component.

Parameter	Condition			
	Optimal (16-20)	Sub-optimal (11-15)	Marginal (6-10)	Poor (1-5)
Canopy cover (shading)	Mixture of conditions: some areas of water surface fully exposed to sunlight, some shaded and others with various degrees of filtered light	Covered by sparse canopy: entire water surface receiving filtered light	Completely covered by dense canopy, water surface completely shaded or nearly full sunlight reaching water surface.	Lack of canopy, full sunlight reaching water surface
Bank vegetative protection (score each bank)	>90% of the streambank surfaces covered by vegetation	70-89% of the streambank surfaces covered by vegetation	50-79% of the streambank surfaces covered by vegetation	<50% of the streambank surfaces covered by vegetation
Streamside cover	Dominant vegetation is shrub, some trees may be present	Dominant vegetation is of tree form, with few shrubs	Dominant vegetation is grasses	>50% of streambank has no vegetation and dominant material is soil, rock or culverts
Riparian vegetative zone width	>18 meters (m)	12-18 m	6-12 m	<6 m
Native riparian regeneration rating	Native poles, saplings, and seedlings trees well represented; obvious regeneration, many patches or polygons with >5% cover; typically multiple size (age) classes	Native poles, saplings, and/or seedlings common; scattered patches or polygons with 1%-5% cover; size (ages) classes few	Native poles, saplings, and/or seedlings present but uncommon; restricted to one or two patches or polygons with, typically <1% cover; little size (age) class differentiation	Native poles, saplings, and/or seedlings absent (0% cover)
Biotic condition stressors	0-3 categories for this context observed	4-6 categories for this context observed	7-8 categories for this context observed	9-11 categories for this context observed
Vegetation horizontal patch structure	Diverse patch structure (> 4 patch type) and complexity	Moderate degree of patch diversity (3 patch types present) and complexity.	Low degree of patch diversity and complexity. Two or three patch types may be present	Has essentially little to no patch diversity or complexity
Vegetation vertical patch structure	Highest-structure forest (Type 1 or 3) plus shrubland (Type) 5) and/or herbaceous (Type 6) or Low-structure forest (Type 2 or 4) plus shrubland (Type) 5) and/or herbaceous (Type 6)	Highest-structure forest (Type 1 or 3) alone or Highest-structure forest (Type 1 or 3) plus only low structure forest (Type 2 or 4) or Low-structure forest (Type 2 or 4) plus shrubland (Type) 5) and/or herbaceous (Type 6)	Low-structure forest (Type 2 or 4) alone or Shrubland (Type 5) and herbaceous (Type 6)	Shrubland (Type 5) alone or Herbaceous (Type 6) alone

Water quality assessment

Water quality is assessed using a multi-parameter water quality meter probe (HORIBA U-G) which measures pH, temperature, dissolved oxygen (DO) and total dissolved solids (TDS) simultaneously. This is accomplished by dipping the probe directly into the water. Data is read and stored through a data logger. Additional parameters namely Total Suspended Solids (TSS), nitrates and phosphates were collected using sampling bottles and subsequently submitted to Unifrutti Philippines, Inc. at Alanib, Lantapan, Bukidnon for the laboratory analysis. Water quality assessment using the probe was done once a month, from April 2016 to March 2017 in upstream, midstream and downstream sites. Specifically, the measurement in each site was done in a certain and constant point and was collected three times to serve as replicates. Average was subsequently calculated for the final data. The same is true for the nitrate and phosphate assessment on which three replicates of water samples were collected in a certain point in each upstream, midstream and downstream sites from April 2016 to March 2017 for each tested parameter. The level of each parameter will be evaluated based on the DENR Administrative Order (DAO) 2016-08's water quality guidelines and general effluent standards of 2016 (DENR, 2016), DAO 34 (DENR, 1990), and Philippine National Standards for Drinking Water (PNSDW, 2007). One-way analysis of variance (ANOVA) at 0.05% level of significance was used to determine any significant difference among the sites. Regression analysis was also utilized to measure the relationship among the physico-chemical parameters.

Contributory factors

Several factors significant in contributing to the condition of the riparian habitat are considered in this assessment. The geologic and morphologic features of Muleta watershed were assessed using geographic information system (GIS) and remote sensing (RS) images. The geomorphic features include stream order and slope which are derived using the Synthetic Aperture Radar Digital Elevation Model (SAR DEM) processed using the tools of ArcGIS 10.2.2 software. Land use and land cover (LULC) is another factor

Table 4: Rating scheme for the general habitat condition for biotic component.

Scores	Component condition	Interpretation
0-34	Poor	Most disturbed, loss of function
35-80	Marginal	Disturbed
81-106	Sub-optimal	Less suitable, less disturbed
107-160	Optimal	Most suitable condition, least disturbed

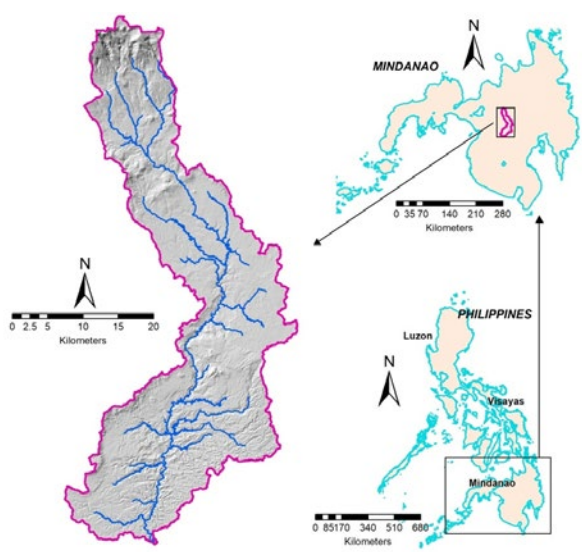

Fig. 1: The geographic location of Muleta Watershed

considered in assessing the riparian habitat of Muleta watershed. The LULC map was generated using the Sentinel-2 2016 image and eCognition software. Sentinel-2 is a multi-spectral sensor that was launched last June 2015 as part of the satellite imaging mission of European Space Agency (ESA) (Wang *et al.,* 2016). Population data obtained from Philippine Statistics Authority (PSA, 2015) were utilized in generating population density map in ArcMap software.

RESULTS AND DISCUSSION

Abiotic condition

Abiotic habitat condition which includes the landscape, hydrologic and physical characteristics of river was assessed in the upstream, midstream and downstream portions of Muleta watershed (Fig. 2). The hydrologic connectivity condition in the three sections of the watershed ranges from sub-optimal to optimal characterized by adequate hydrology fully connecting the streams and supporting riparian vegetation in the floodplain. Of the three sites, upstream has the highest score for hydrologic connectivity; followed by downstream and lastly by midstream section which falls within the borders of a sub-optimal and optimal condition. Presence of stressors to landscape, hydrology and physical habitat condition was also identified. Stressors refer to outside and unnatural forces considered as constraints in the species productivity and ecosystem development. Under the abiotic component, these stressors include non-living habitat features. Muleta watershed is considered at sub-optimal condition when it comes to the presence of stressors to landscape conditions. Some of the observed stressors were the presence of residential and transport corridors, and agricultural activities such as intensive row-crop agriculture, commercial feedlots, dry land farming, moderate and low-intensity ranching. These stressors are most evident in the midstream and downstream assessment sites where human visitation and activities are active. When it comes to presence of hydrologic condition stressors, the watershed is considered at sub-optimal condition. Of the three assessment sites, the midstream portion is observed with the most number of stressors covering larger areas. These stressors include point and non-point source discharges which are two broad categories of pollution sources. Flow diversions and other unnatural inflows which cause flow restriction, augmentations and obstructions were also observed. Portions of the channel are also modified and engineered such as the riprap. The downstream site is observed with fewer stressors while upstream site is observed with no hydrologic condition stressor. The presence of the aforementioned stressors alters the hydrology such as avoiding the infiltration of the runoff entering the stream bank giving too much floodwater (Chiogna *et al.,* 2016; Water Action Volunteers, 2006). In this study, the presence of stressors is among the significant attributor of putting

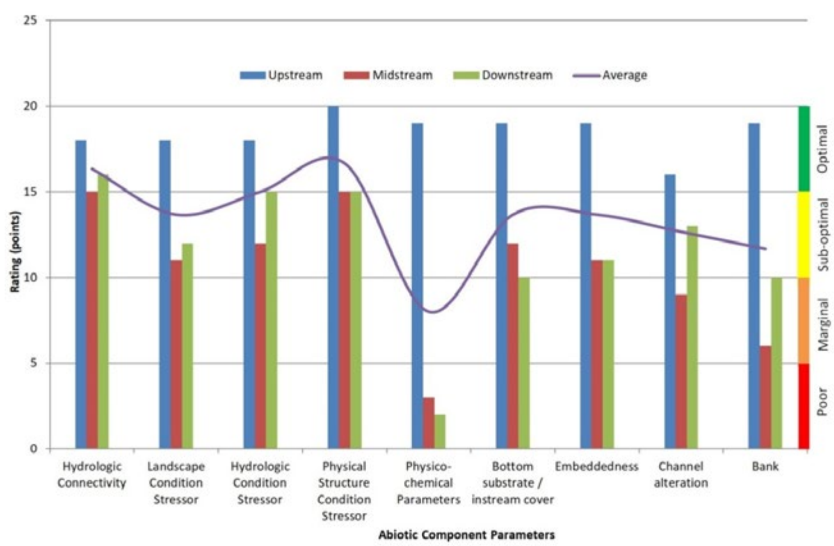

Fig. 2: Assessed parameters under the abiotic component

pressure to the physical and hydrologic aspects of the riparian areas. The physical structure condition of the watershed is considered optimal in condition. Upstream assessment site, in particular, is considered optimal with perfect rating due to absence of any landscape stressor. Meanwhile, the midstream and downstream sites are both with the same rating falling within the border of sub-optimal to optimal condition. Some of the stressors observed in the midstream and downstream sites are the presence of huge amount of sand and gravel due to the extraction activity, point and non-point-sourced water pollution, and trash and refuse. Bottom substrate is another parameter considered in assessing the abiotic component of the riparian habitat. The watershed is considered sub-optimal in condition signifying stable and adequate habitat. However, of the three sites, only the upstream site attained an optimal rating with the stream bottom characterized with presence of mix gravel, mix logs and other substrates significant for habitat stabilization for aquatic organisms. Both the midstream and downstream portions meanwhile are within the sub-optimal to marginal condition with lesser presence of substrates and lesser stable habitat. Embeddedness or the extent to which rocks are buried by fine sediments in river bed revealed to be at sub-optimal condition in the watershed. The upstream site, in particular, has achieved the highest rating of the three sites with relative absence of fine sediments. The midstream and downstream sites attaining similar rating are described with 25-50% of fine sediment burying gravels and rocks in the river bed. Fine sediments which commonly results from erosion degrade stream habitat and alter stream channels eliminating substrates for food source, shelter, and spawning areas (Khan *et al.,* 2016).

Channel alteration, which refers to the change of natural flow regime of river or stream, is generally rated sub-optimal. The upstream site compared with other sites is with higher score characterized with absence to little occurrence of channelization or the rechanneling of watercourse forming point bars in the process. Midstream site is observed with moderate deposition of gravel and sand bars as a result of rechanneling of water, considered to be at marginal condition. The downstream site, compared to the midstream has relatively lower occurrence of rechanneling though evident formation of sandbars is present. Altered hydrology may have negative impact on the water temperature and chemistry such as sediment and nutrient delivery significantly lowering habitat suitability for certain aquatic organisms (Alldredge and Moore, 2012; State of Vermont, 2017; Karbassi and Pazoki, 2015). In this study, channel alteration is not significant enough to affect water properties. Average bank stability in the watershed is considered at sub-optimal condition described as moderately stable with infrequent occurrence of erosions in small areas. Specifically, at the upstream site, bank stability is rated optimal considering it to

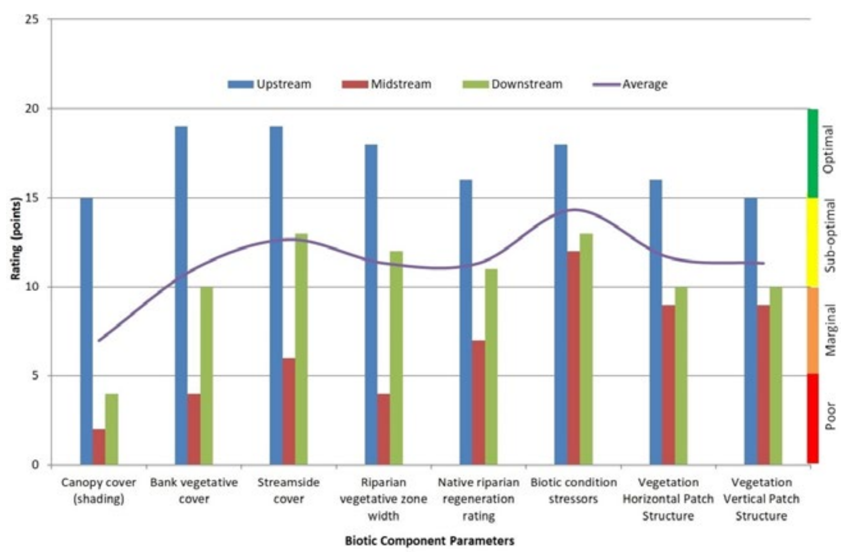

Fig. 3: Assessed parameters under the biotic component

stable without the presence of erosions. Meanwhile, the midstream and downstream sites are rated at marginal condition with the former having the lower score. Both of these sites are evaluated to have moderate unstable banks with moderate frequency and size of eroded areas. River banks are significant features of riparian condition since it control river hydraulic geometry which includes controlling of flow and sediment routing (González del Tánago and García de Jalón 2006). Bank stability signifies their potentials for erosion (Casatti *et al.,* 2006). The overall abiotic condition of the riparian area in Muleta watershed is sub-optimal interpreted as less suitable in condition with presence of minimal but prevalent abiotic disturbances. Of the three sites, upstream has the best condition for abiotic condition at optimal level, followed by the downstream and last by midstream at marginal level.

Biotic condition

Assessment of the biotic condition of the riparian areas includes the evaluation of the riparian vegetation as is one of the significant factor in determining stream ecosystem health and integrity (Khan *et al.,* 2016). Of all the parameters under biotic component, only canopy cover is averagely considered in marginal condition while the rest are averagely at sub-optimal condition (Fig. 3). Specifically, upstream site is in sub-optimal condition for canopy cover while midstream and downstream sites are considered in poor condition. In between the two, the midstream site attained lower rate described with lack of canopy along the riparian allowing full sunlight to reach the river channel. Upstream site on the other hand is characterized with presence of sparse canopy with channel receiving filtered light. Bank vegetative cover refers to the extent of the vegetation coverage in stream bank. Upstream site is rated optimal with most of the stream bank covered with vegetation. The midstream site, on the other hand, is poor with significant exposed stream bank without vegetation cover. Downstream site is rated marginal with sparsely exposed riparian strip. The watershed is considered sub-optimal in general for bank vegetation cover. Intact riparian vegetation is usually with healthy stream conditions since it filters runoffs and other contaminants that may pollute stream body (Khan *et al.,* 2016). Streamside cover refers to the group of vegetation occupying the riparian area. Streamside cover condition in the watershed is evaluated optimal which is characterized by presence of shrub and some trees. Specifically, the upstream site is considered optimal. Riparian area in midstream site is predominantly grasses and is rated marginal in condition while the downstream is rated sub-optimal with riparian area hosting a transition of shrub to grass vegetation. Vegetation width of more than 18m along riparian zone is rated optimal while vegetation width of less than 6 m is rated poor. The watershed in average is considered in sub-optimal condition. Of the three sites, upstream site consist the larger width rated optimal. The midstream and downstream sites are evaluated poor and sub-optimal having a riparian zone width of less than 6m and 12-18m, respectively. By standard, the mandated buffer width of riparian areas is 20m in both sides of the river (DENR, 2008). The midstream site failed the set standard vegetation width. Presence of vegetation saplings and seedlings in the riparian area were also evaluated. The watershed is averagely considered at sub-optimal condition. The upstream site is considered at the optimal condition with significant patches of seedlings and saplings. Midstream site, on the other hand, is evaluated poor in condition with relative absence of seedling and saplings in the riparian area. Downstream site is considered at sub-optimal condition with the presence of seedling regeneration but in moderate density. Presence of seedlings and sapling assures succession of vegetation in the riparian zone maintaining riparian vegetation cover. Activities around the riparian area considered to have adverse impact to the surrounding riparian vegetation referred to as biotic condition stressors were also evaluated. At average, the Muleta watershed is considered to be at sub-optimal condition under this parameter. Upstream site is considered to be in optimal condition with very few observed pre-identified biotic stressors. Midstream and downstream sites, however, are at sub-optimal condition with four to six observed stressors present in the sites. Among the observed stressors are excessive human visitation and the lack of vegetation management to conserve natural resources. These stressors may reduce riparian cover, community complexity, and function (Stella *et al.,* 2013). Though generally the watershed is still considered sub-optimal in this parameter interpreted to have moderate presence of stressors, it is worthy to note that unregulated increase of such stressors and the area it cover will potentially decline further vegetation cover in the watershed. Vegetation horizontal and vertical patch structures were both evaluated. Referring to the number of patches of the diversity and complexity of vegetation occupying the stretch of the river, vegetation horizontal patch structure is averagely considered sub-optimal in the watershed. Specifically, upstream site is considered to be in optimal condition with vegetation patches consisting of more than four types and in high complexity. Midstream and downstream sites, however, are at marginal condition characterized with low degree of patch diversity and complexity, consisting only two to three patch types. Vegetation vertical patch structure refers to the diversity of vegetation according to canopy heights. The watershed is considered to be at sub-optimal condition. The upstream site, in particular, is sub-optimal in condition composing a low-structure forest with shrubs and few high-canopy trees. Both midstream and downstream sites are rated marginal consisting of shrub land with presence of low-canopy trees.

Overall biotic condition of Muleta watershed's riparian area is at lower sub-optimal to marginal status characterized by diminishing coverage of vegetation cover and its condition with presence of minimal but prevalent disturbance impacting the health of riparian habitat. Of the three sites, upstream has the best condition for the biotic condition still considered at optimal level. This is followed by the downstream with sub-optimal condition and the least is the midstream considered at marginal condition which is consistently rated as the least in all of the biotic parameters. The riparian biotic health condition referring to the vegetation cover is important for filtering and absorbing upland runoff that may potentially pollute the stream water (Khan *et al.,* 2016). Moreover, streamside vegetation serves as natural resource supporting wetland species (Gomez-Roxas *et al.,* 2005; Alldredge and Moore, 2012).

Physicochemical analyses

The quality of water based on its physicochemical properties was also assessed. Water quality assessment is a common method of determining health of watershed and potential presence of introduced pollutants. The assessed parameters are nitrates, phosphates, pH, DO, TSS, TDS, temperature and turbidity. Of the three sites, only the upstream obtained an optimal condition with eight of the parameters passing the standard of DAO 2016-08, DAO 34, and PNSDW. Table 5 compares the water quality in the three assessment sites to the DAO water quality standards and PNSDW. The midstream and downstream sites failed in several parameters particularly for nitrates and TSS, both considered critical in water quality. Nitrates reached up to 15.32 mg/L and 23.99 mg/L for midstream and downstream sites exceeding the standard limit of 7 mg/L (DENR, 2016). The high concentration of nitrate substance in the water indicates traces of fertilizers that may come as non-point source pollution from agricultural lands. Other sources are anthropogenic, sewage and landfill by domestic waste (Singh, 2016). High contamination of nitrate in drinking water is hazardous to infants and pregnant women causing blue baby syndrome, prostrate and gastrointestinal cancer and illness to domestic animals (MPCA, 2008; Singh, 2016). In rivers, nitrate has a characteristic of mobilizing heavy metals contained in sediments which can be detrimental to aquatic organisms (Bedford, 2009).

Table 5: Physico-chemical parameters for water quality assessment in Muleta Watershed.

Water quality parameters	Upstream		Midstream		Downstream		Water quality guidelines (river class)		
	Level	Decision	Level	Decision	Level	Decision	Class AA	Class A	Class B
Nitrates (mg/L)	6.91	Passed	15.32	Failed	23.99	Failed	7	7	7
Phosphates (mg/L)	0.06	Failed [a] Passed [a+]	0.20	Failed [a] Passed [a+]	0.25	Failed [a] Passed [a+]	<0.003	0.5	0.5
pH	6.98	Passed	7.32	Passed	7.39	Passed	6.5-8.5	6.5-8.5	6.5-8.5
DO (mg/L)	12.41	Passed	11.02	Passed	11.43	Passed	5	5	5
TSS (mg/L)	0.00	Passed	109.45	Failed	134.22	Failed	25	50	65
TDS (mg/L)	56.67	Passed [b]	80.00	Passed [b]	173.33	Passed [b]	500[b]	1000[b]	---
Temp. (°C)	17.74	Failed	28.42	Passed	30.40	Failed	26-30	26-30	26-30
Turbidity (NTU)	0.06	Passed [c]	89.91	Failed [c]	150.56	Failed [c]		5[c]	

[a] based on DAO 2016-08 river class AA; [a+] based on DAO 2016-08 river class A and B; [b] based on DAO 34; [c] based on PNSDW

Moreover, nitrogen and phosphorus accumulating in the water may potentially result to eutrophication (Rathore *et al.,* 2016). Algal bloom that may result due to its high concentration reduces DO level destroying aesthetic and recreational values of water. However, DO concentration in Muleta watershed is high enough at 12.51mg/L, 11.02 mg/L, and 11.43mg/L surpassing the minimum acceptable limit of 5mg/L to be considered as within the standards for class AA, A, and B rivers. This implies that level of organic substances, especially in midstream and downstream sites, has not influenced the level of DO in the water. DO concentration is consistent with the study of Dumago *et al.* (2018) in the same watershed. For the TSS, concentration in midstream and downstream sites reached up to 109.45mg/L and 134.22mg/L, respectively exceeding the tolerable limit of 25mg/L, 50mg/L, and 65mg/L for class AA, A, B rivers. The TSS provides the visual quality of the water with higher concentration signifying highly turbid water. It particularly measures the amount of undissolved solid particles like level of siltation, decaying matters and wastes (Greenpeace, 2007). Though suspended solids are naturally carried along stream flows, its high concentration leads to alteration of the physical, chemical and biological properties of the water bodies such as adverse aesthetics effects, release of contaminants and nutrients, and reduction of DO in water (Bilotta and Brazier, 2008). The same with nitrates, level of TSS has not significantly influenced the DO concentration in the water and other water properties such as temperature that can affect the habitat condition of water. The turbidity in midstream and downstream is exceptionally high with 89.91NTU and 150.56NTU, respectively. This surpasses the maximum threshold level set by PNSWD for drinking water (PNSDW, 2017). For the upstream site on the other hand, turbidity is low and is within the PNSWD standard. The rest of the parameters such as the phosphates, pH, DO, and temperature are within the standard ranges of DAO 2016-08 (DENR, 2016), and the TDS of DAO 34 (DENR, 1990). Phosphate which is a salt-containing phosphorus is one of the nutrients that cause growth of algae when in high concentration in water. Phosphorus loading is mostly contributed by runoff from agricultural lands, urban runoff, non-agricultural rural runoff and individual sewage treatment systems (MPCA, 2007). The pH which refers to the basicity and acidity of water is an indicator of chemical condition of water which significantly determines the corrosive nature of water with lower pH value being more corrosive (Kale, 2016). The pH level in water bodies which depend on the water source and types of contaminants in the water among others is an important water quality parameter used to indicate effectiveness of water treatment (Kale, 2016). DO which is the concentration of oxygen molecular in water is used by aquatic organisms (Kale, 2016). The amount of decaying organic matter in water, temperature, and human activities such as industrial processes affect DO concentration in water (Kale, 2016). TDS refers to inorganic salts, organic matter and other dissolved materials in water which normally comes from industrial effluent, changes to water balance or by intrusion of salt-water (Weber-Scannell and Duffy, 2007). Its high concentration in water cause shifts in the biotic communities limiting diversity of organisms among others (Weber-Scannell and Duffy, 2007). Temperature level in upstream is very low at 17.74°C, extremely low compared to the minimum limit of 26°C. Midstream and downstream sites is with temperatures of 28.42°C and 30.40°C with the latter slightly beyond the maximum allowed level of 30°C. Temperature has a significant influence on the chemistry of water increasing the rate of chemical reactions with higher temperatures and governs the kinds of organisms that may thrive (Kale, 2016). Muleta watershed, in general, is considered marginal in condition for the water quality interpreted as having a disturbed water quality condition. Moreover, the water quality assessment revealed no serious health hazard issues as indicated by sufficient levels of DO, pH, and temperature. Of the three sites, upstream meet almost all the standards of freshwater usage for class AA river of DAO. The LULC and land management practices are among the main influencers of pollutant concentration including mobilization and delivery to receiving waters. The proximity of the river to roads and establishments commonly attribute to the quality of water (Peligro and Jumawan, 2015).

Results of ANOVA revealed significant differences ($p < 0.05$) among the different portions of the watershed (upstream, midstream, downstream) as shown in Table 6. This implies that there is specific variation with the level of TDS, temperature and turbidity. Meanwhile, there is no significant difference among the assessment sites for pH and DO.

Moreover, correlation coefficient analysis showed a perfect positive correlation (r = 1) of pH-phosphates, TSS-pH, TSS-temperature, and temperature-pH (Table 7). Other very strong positive associations (r > 0.8) between parameters are between nitrates-phosphates, pH-nitrates, TSS-nitrates, TDS-nitrates, temperature-nitrates, turbidity-nitrates, TDS-phosphates, temperature-phosphates, turbidity-phosphates, turbidity-pH, turbidity-TSS, turbidity-TDS and turbidity-temperature showing an increase of one variable as the other variable increases. Expectedly, high level of nitrates is strongly associated with the high level of phosphates, TSS, TDS, turbidity and temperature. High pH is also strongly associated with turbidity implying basicity in warm water. Strong negative correlations are the DO-phosphates, DO-pH, TSS-DO, temperature-DO, and turbidity-DO characterized by the decrease of one variable as the other one increases. Among the parameters, DO only showed negative association to all the other parameters.

Contributory factors

The LULC of Muleta watershed was derived from Sentinel-2 2016 image using eCognition software. Generated map (Fig. 4) reveals that majority of the watershed is classified as agricultural land with cultivated crops. One km radius of the upstream area is surrounded by agricultural land (39%), shrubland (11%) and forest covers (42%) (Fig. 5). The water emanates from MKaNPK, a protected area declared through Presidential Proclamation No. 305 issued on May 2000 under National Integrated Protected Areas System (NIPAS) (DENR, 2016). The proximity of station to the natural park explains its sub-optimal condition where forest is protected for preservation and conservation. The rest of the watershed is

Fig. 4: Land cover of Muleta Watershed (Sentinel-2 2016 image)

Table 6: One way ANOVA of the physico-chemical parameters for water quality assessment

Parameter	f-value	p-value	F-critical	Decision
pH	1.996300649	0.151909392	3.284918	Not significant
DO	1.137802444	0.332775435	3.284918	Not significant
TDS	29.61891738	4.31003E-08	3.284918	Significant
Temp.	147.5865368	3.46562E-17	3.284918	Significant
Turbidity	5.01203143	0.012567289	3.284918	Significant

Table 7: Correlation coefficient analysis of physico-chemical parameters

Parameters	Nitrates (mg/L)	Phosphates (mg/L)	pH	DO (mg/L)	TSS (mg/L)	TDS (mg/L)	Temp (°C)	Turbidity (NTU)
Nitrates (mg/L)	1							
Phosphates (mg/L)	0.96	1						
pH	0.93	1	1					
DO (mg/L)	-0.68	-0.85	-0.90	1				
TSS (mg/L)	0.94	1.00	1	-0.89	1			
TDS (mg/L)	0.95	0.83	0.77	-0.41	0.78	1		
Temp. (°C)	0.93	0.99	1	-0.91	1	0.76	1	
Turbidity (NTU)	0.99	0.99	0.97	-0.76	0.97	0.90	0.96	1

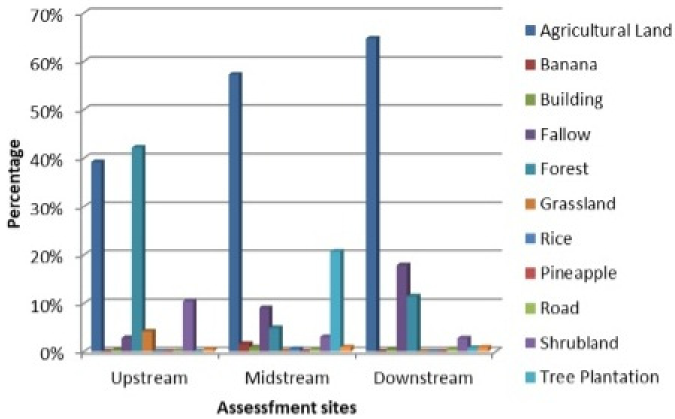

Fig. 5: Percentage of land cover classifications in each sampling site of Muleta Watershed (Sentinel-2 2016 image)

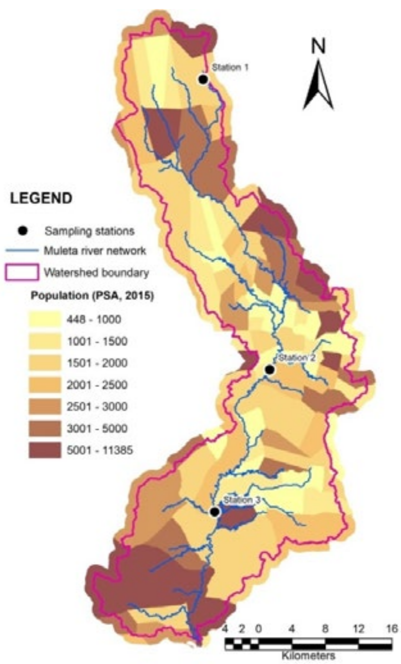

Fig. 6: Population density of Muleta Watershed (PSA, 2015)

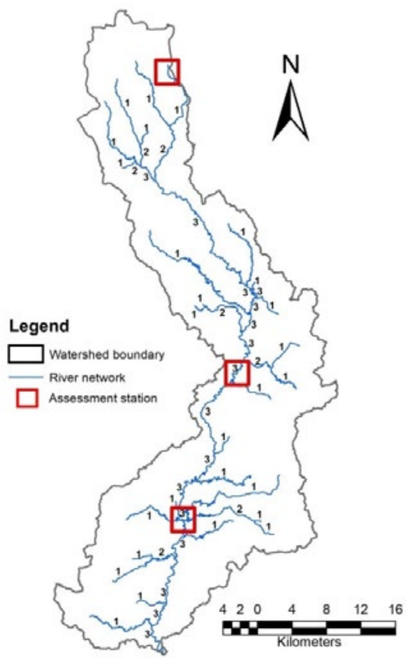

Fig. 7: Stream order of the tributaries in Muleta watershed

predominantly agricultural land cultivation based on the Sentinel-2 satellite 2016 image. The surrounding land cover composition in the midstream site is specifically composed of 57% agricultural land followed by tree plantation at 21% coverage in the 1km radius of the site. Meanwhile for the downstream site, agricultural land constitutes 65%, fallow at 18% and forest at 11%. These areas are vulnerable to various impacts such as erosion, deforestation, and domestic, industrial and agricultural effluent pollution (Tampus *et al.,* 2012). Land cover is acknowledged as one of the most significant contributor to the alteration of ecosystem and its corresponding ecological services. Specifically, land use in industrial and agricultural development impacts quality and quantity of water causing environmental and social consequences (Ahmadi *et al.,* 2018). A study of Gyawali *et al.* (2013) for example demonstrated the correlation of increasing urban areas to degrading quality of water with agricultural lands usually related to poor water quality. Land use change and expansion of agricultural cultivation makes soil more susceptible to erosion and has corresponding impact on the amount of sediment in rivers. In Cagayan de Oro River, it was found out that land use changes mainly affected species richness in riparian vegetation (Lubos *et al.,* 2015). Increased erosion in banks also removes riparian zones reducing connectivity of channel and overall ecological value of riparian habitat (González del Tánago and García de Jalón, 2006).

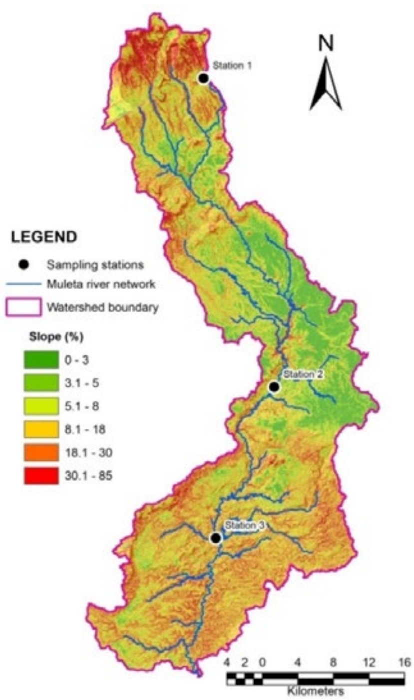

Fig. 8: Slope map of Muleta Watershed

The population distribution in Muleta watershed is aggregated. Dense population is concentrated in several portions including the lowermost part of the watershed, east side of the midstream area and central part of the upstream portion. With large population come more extensive economic activities that utilize and deplete natural resources. This includes clearing of forests and reclaiming of wetlands and greenbelts (Mittal, 2013). Growth of human number is considered as a major cause of environmental problems increasing pressure on natural resources.

Fig. 7 illustrates the dendritic drainage pattern in Muleta watershed. It indicates the stream order of each river segments which denotes for the hierarchical relationship between stream segments. Using the Strahler's ordering system, assessment station 1 is classified as 1st order stream while both midstream and downstream and 3rd order streams. First order streams originate from springs and usually found on mountains with steeper slopes. Due to its location in the watershed, streams are still considered clean, clear and cold and distant to potential sources of pollution (Pennsylvania League of Angling Youth, 2004). This explains the relatively optimal water quality conditions in this assessment site. The 3rd order streams, compared to lower stream orders, are wider with more water and longer stream length. Moreover, it also has a more viable condition to support population of aquatic organisms. Fig. 8 shows the slope in percentage of Muleta watershed categorized according to the slope classification of

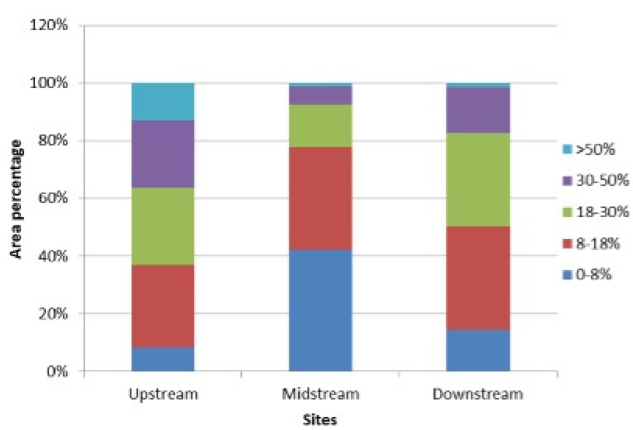

Fig. 9: Percent area of each slope classification around the 1km radius of upstream, midstream and downstream

DENR (2008) while, Fig. 9 illustrates the percent area covered by each slope classification around 1km radius of each assessment site. Around 13% of the 1km radius of upstream area near the MKaNPK is classified as rolling terrain and severely steep slope. The rest of the upstream site is within the range of moderate to very steep slopes. The midstream area is predominantly flatter with around 42% of the surrounding area characterized as level to gently sloping. Slope within the 30-50% and >50% is minimal in this area. Downstream site is generally surrounded with moderate to steep slopes. Slope is one factor that determines resistance of topographical surface (Kumar and Srivastav, 2010). Higher percent slope provides lesser area for vegetation and prone to erosion. Moreover, banks with steeper slope are more likely unstable showing signs of crumbling, exposed roots and soil, and more prevalent in non-vegetated banks (Casatti *et al.,* 2006). Very steep slopes constituting most of the upstream site are dominated by naturally growing vegetation preventing erosion. Although Muleta watershed is still at sub-optimal considered as still above average in condition, close attention must be placed to potential destructors such as extent of agricultural cover and population growth to both land and water resources.

CONCLUSION

Muleta watershed is generally considered sub-optimal in condition implying that riparian zones are lesser suitable compared to the optimal condition caused by the minimal yet prevalent ecosystem disturbances. Between the two assessed components, the biotic component which referred to the condition of the riparian vegetation is more degraded rated at lower sub-optimal to marginal condition. The abiotic component which includes landscape, physical and hydrological conditions of the riparian area is at sub-optimal condition. The watersheds upstream possess the best riparian habitat condition considering both the abiotic and biotic component while the midstream has the worse. The flatter terrain and vast agricultural land in the midstream could be cited as some of the contributing factors resulting to deteriorating condition. Implementation of the national policies and guidelines regarding settlement along the buffer zones of the Muleta watershed river network must be revisited including empowerment of the government authorities.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

%	Percent
°C	Degree Celsius
ANOVA	Analysis of variance
DAO	DENR Administrative Order
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DO	Dissolved oxygen
DOST	Department of Science and Technology
ESA	European Space Authority
f-critical	Critical value of F-statistic
f-value	F statistic
GIS	Geographic information system
km	Kilometer
km²	Square kilometer
LULC	Land use/Land cover
m	Meter
mg/L	milligrams per litre
MKaNPK	Mt. Kalatungan Natural Range Park
msl	Mean sea level
NRDPWMP	National Research and Development Project for Watershed Management in the Philippines

NIPAS	National Integrated Protected Areas System
NTU	Nephelometric Turbidity Unit
p-value	Calculated probability
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PCAARRD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
pH	Potential hydrogen
PNSDW	Philippine National Standards for Drinking Water
PSA	Philippine Statistics Authority
RS	Remote sensing
SAR	Synthetic aperture radar
Temp	Temperature
TDS	Total dissolved solids
TSS	Total suspended solids

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