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Water quality assessment in various land use and land cover of Muleta Watershed Bukidnon, Philippines

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Abstract

Changes in the land cover and land management practices in Muleta watershed have been considered as one of the key influencing factors behind threats affecting the water quality. The study aims to assess and analyze useful evidence on the influence of various land use/cover on the stream physico-chemical properties of Muleta River based on water quality monitoring data with the water quality guidelines for classification of the DENR Administrative Order No. 2016-08 (DAO 2016-08). Major LULC was delineated using satellite data specifically Landsat 8 OLI of year 2015 and was downloaded from USGS Earth Explorer. The watershed has six (6) existing land cover: forest, agricultural land, bareland, built-up area, grassland and water. The upstream was found to be covered with perennial vegetation; the midstream is used for agriculture and covered with least forest; the downstream was mainly used for residential and utilized for different forms of agriculture. The results obtained from the water quality were compared with existing land use/cover of the watershed at $\alpha=0.01$ significance level. The result shows that temperature, TSS, nitrates and phosphates are significantly different water quality result in parallel to the LULC of the sampling site. On the other hand, the pH, turbidity, dissolved oxygen, and TDS are not significantly different from each other regardless land cover/land use surrounding the water system. Generally, the result is of great help in developing and implementing watersheds plans to protect land and water resources and improve the overall quality of the watersheds.

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Introduction

Proper watershed protection is necessary as foods, fiber, manufactured goods, and tourism depend on clean, healthy watersheds (USEPA, 2017). Healthy watersheds provide many ecosystem services such as nutrient cycling, carbon storage, erosion / sedimentation control, increased biodiversity, and improved water quality. Unfortunately, watershed is often unrecognized when making land use decisions. Different land uses caused by humans affect the ecosystem services a healthy watershed provides.

Muleta watershed is recognized as one of the major watersheds in Bukidnon. Muleta River is one of the important tributaries of Pulangi Rivers and the much bigger Rio de Grande. Muleta watershed is surrounded by municipalities and a city where agriculture is the major industry. Huge land area operated by agricultural companies caused fertilizer and sediment runoff problems of Muleta River today. Moreover, leaching of agricultural toxic substances and its residues into the ground water will degrade geophysical resources, particularly in water, through the continued application of pesticides containing nitrates and phosphorus. This will also lead to contamination of water source and cause water-related health risk to humans.

As one of the learning watershed of the Integrated National Watershed for Research and Development (INWARD) Project funded by DOST-PCAARD, this study generally evaluates the level of the physico-chemical properties of the water of Muleta River and determines the different land use/land cover with respect to the water quality assessment. Specifically, this study aims to: (1) Determine the different land uses/ land cover within Muleta Watershed; (2) Determine the level of physico-chemical properties of the water in Muleta River such as water temperature, pH, turbidity, dissolved oxygen (DO), and total dissolved solids (TDS), total suspended solids (TSS), nitrate, phosphate in various land use/land cover and (3) Compare the physico-chemical properties of water with respect to its existing land use/ land cover. The results of the study will serve as inputs on the over-all watershed protection and management of Muleta Watershed.

Materials and methods

Locale of the study

Muleta Watershed is situated in the southern portion of Bukidnon Province, Philippines. The watershed is under the jurisdiction of Valencia City and municipalities of Pangantucan, Don Carlos, Kitaotao, Dangcagan, Kibawe, Kadingilan, and Damulog. Muleta River is an important tributary of Pulangi River and flows southward in the boundary of Bukidnon and Cotabato Province. Three sampling station was established in three sub river areas in Muleta watershed. The upstream station was situated at Upper Baguik-ikan River, Portulin, Pangantucan, Bukidnon at the latitude of 7.91927°N and 124.8655 °E longitude. The midstream station is in Malinao River at Kadingilan, Bukidnon lies at latitude of 7.58887 °N and the longitude of 124.93805 °E and downstream sampling station is located at Omonay River, Damulog, Bukidnon at latitude of 7.43495°N and the longitude of 124.87775°E (Fig. 1).

Water Quality Sampling

On-site analysis of water quality parameters was measured such as temperature, pH, turbidity, Dissolved Oxygen (DO), and Total Dissolved Solids (TDS) using the multi-parameter probe (HORIBA). Water sampling was done from August-October 2017. Data collection has been done within 3 consecutive months. The amount of the other physico-chemical parameters of water such as nitrates and phosphates were determined through the collection of water samples. Three replicates in every sampling area were collected. Samples were brought to UNIFRUTTI Tropical Philippines Inc. for laboratory analysis. Gravimetric procedure was used to determine the Total Suspended Solid (TSS) of the study.

Classification of Land use/Land cover

Satellite data was utilized to obtain land use/land cover of Muleta watershed in the year 2015. Landsat 8 OLI was downloaded from USGS Earth Explorer (http://earthexplorer.usgs.gov/) that was relatively cloud-free or contained minimal cloud cover. The major LULC classes delineated were Forest, Agricultural Land, Bareland, Built-Up Areas, Grassland and Water. Maximum Likelihood algorithm was applied for supervised classification of the image using ENVI. In addition, post-classification refinement was applied using ArcGIS to reduce misclassifications. A classified image was produced into map for year of acquisition (Table 1).

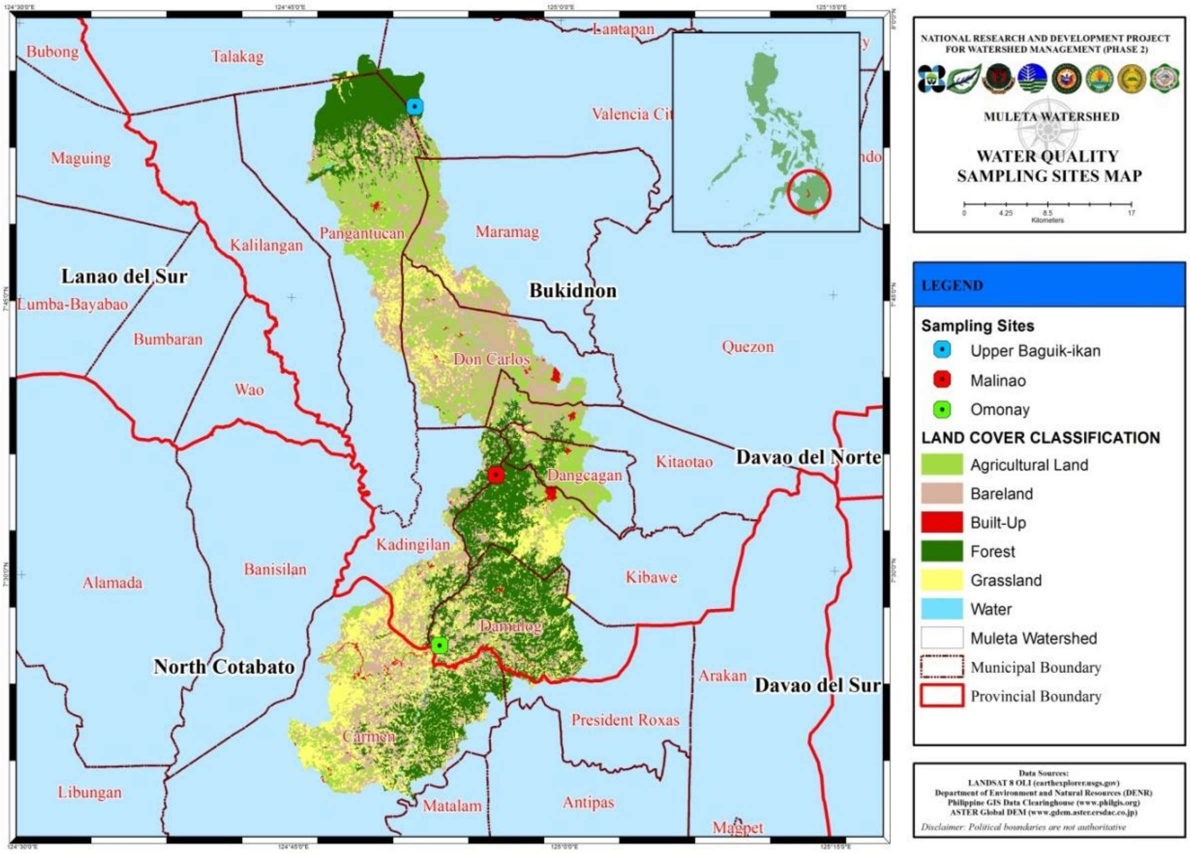


Fig. 1. Location Map of the Study Area.

Table 1. Classes delineated on the basis of supervised classification.

Class Name	Description
Forest	Mixed forest lands
Agricultural Land	Crop fields
Bareland	Land areas of exposed soil and barren/fallow area
Built-Up Areas	Residential, commercial, industrial, transportation, roads
Grassland	Upland grasses/forbs and shrubland
Water	River, lakes and reservoirs

Data Analysis

Comparative assessment of the dominant land use and land cover (LULC) on water quality in Muleta watershed was done and was based on eight (8) physico-chemical properties of water that were tested. These parameters are all considered relevant to the determining the quality of water and how water bodies are affected by LULC. The parameters were also compared with the standards as per DENR-DAO 2016-08 to assess its current suitability considering its present uses (Table 2 and 3).

Statistical Analysis

Analysis of Variance (ANOVA) and post-hoc analysis (Tukney's HSD) was used to determine the significant difference in terms of water quaily parameter result among the existing land use and land cover of Muleta watershed.

Table 2. Water Body Classification and Usage of Freshwater Bodies.

Classification	Beneficial USE
Class AA	Public Water Supply Class -. Intended primarily for waters having watersheds, which are uninhabited and/or otherwise declared as protected areas, and which require only approved disinfection to meet the latest PNSDW
Class A	Public Water Supply Class II- Intended as source of water supply requiring conventional treatment (coagulation, sedimentation, filtration and disinfection) to meet the latest PNSDW
Class B	Recreational Water Class I-Intended for primary contact recreation (bathing, swimming, etc.)
Class C	1. Fishery Water for the propagation and growth of fish and other aquatic resources. 2. Recreational water class II- For boating, fishing or similar activities. 3. For agriculture, irrigation and livestock watering
Class D	Navigable waters

Note: For unclassified water bodies, classification shall be based on the beneficial use as determined by the Environmental Management Bureau (EMB).
Source: DENR Administrative Order No. 08 Series of 2016.

Table 3. Water quality standard guidelines for primary parameters.

Parameter	UNIT	LEVEL		
		Class a	Class b	Class c
Nitrates	mg/L	7	7	7
Phosphates	mg/L	0.5	0.5	0.5
pH		6.5-8.5	6.5-8.5	6.5-8.5
Dissolved Oxygen	mg/L	5	5	5
Total Suspended Solid	mg/L	50	60	80
Total Dissolved Solid	mg/L	--	--	--
Temperature	°C	26-30	26-30	26-30
Turbidity	NTU	--	--	--

Source: DENR Administrative Order No. 08 Series of 2016.

Result and discussion

Land Use and Land Cover of Muleta Watershed

Muleta watershed has a total land area of approximately 104, 965.96 hectares and was classified into six (6) land cover and land uses namely: forest, agricultural land, bareland, built-up areas, grassland and water. As seen in Table 4, bareland has obtained the most prevalent land area with 305.32km2 which is 29.07% of the watershed total land area. The increase in bareland cover is also associated with the increase of areas that are cultivated for agricultural purposes. This was followed by forest land with 284.67km2 which is 27.10% of the total land area. About 228.58km2 or 21.76% of the total watershed is agricultural land. Grass land, build-up area, stream water has a total area of 218.59 (20.18%), 8.62km2 (0.82%) and 4.61km2 (0.44%), respectively.

Table 4. Muleta Watershed land use/land cover area.

Land Use/Cover Classes	2015	
	km^2	%
Forest	284.67	27.10
Agricultural Land	228.58	21.76
Bareland	305.32	29.07
Built-Up Areas	8.62	0.82
Grassland	218.59	20.81
Water	4.61	0.44

Variation in terms of land use/land cover between the upper and lower parts of the watershed is significantly observed in the study. Fig. 2 shows the major LULC of Muleta Watershed that was identified in terms of its distribution within the watershed. The map shows that Upper Bagik-ikan (Upstream) is mostly covered with forest and dense vegetation. Malinao (Midstream) is bounded by agricultural and forested areas and Omonay (Downstream) are found to be prevalently surrounded by built-up, bareland and agricultural land.

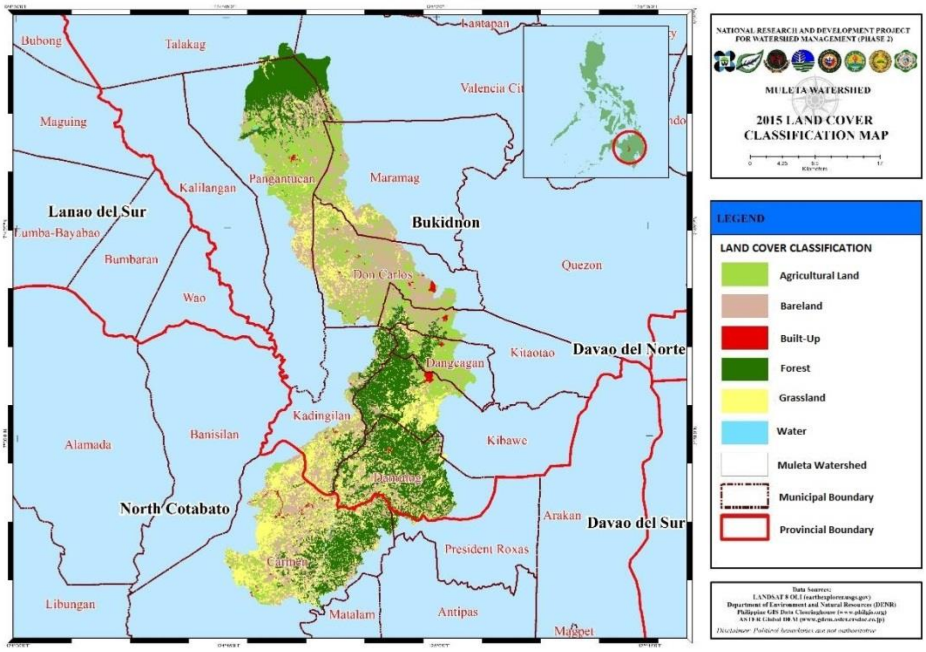


Fig. 2. 2015 Land Cover Classification Map.

The physico-chemical properties of Muleta River

Fig. 3 shows the measures of temperature in water across Muleta watershed which shows relatively lower value in Upper Baguik-ikan (Upstream) with an average temperature of 17.84°C compared to Malinao (Midstream) and Omonay (Downstream) with higher average temperature rate of 28.25 to 28.91°C. Based on the obtained results, the water temperature in the midstream and downstream portion of the watershed is relatively higher which also shows significantly higher values as compared to the maximum limit for class C water as per DENR DAO 2016-08. Water temperature is an indicator of other water quality parameters such as turbidity and transparency. As such, it is necessary to consider the maximum temperature at which organisms will live or oppositely the optimum temperature at which organisms will thrive.

pH is an important limiting chemical factor for aquatic life. Streams that are excessively acidic or basic may disrupt aquatic organisms' biochemical reactions which result in either harming or killing the stream organisms. Data for pH showed a similar pattern across Muleta watershed as the collection of data every month progresses (Fig. 4). Throughout the collection period, Upper Bagik-ikan (upstream) has the lowest average pH of 7.35 followed by Malinao (midstream) with 7.65 and Omonay (downstream) to have the highest pH value of 7.74. All sampling sites are considered to be neutral falling within the optimum pH range for the thriving of fish of 6.5 to 9.0 pH level. In addition, pH values generally place Muleta watershed within the minimum standards for Class A and C water of the DENR DAO 2016-08. Turbidity determines the amount of light scattered off of particles and sediments in the water. It is an optical determination of water clarity. With the data shown in Fig. 5, Omonay (downstream) obtained the highest turbidity with an average 93.58 NTU and Upper Bagik-ikan with the lowest turbidity with 0.06 NTU.

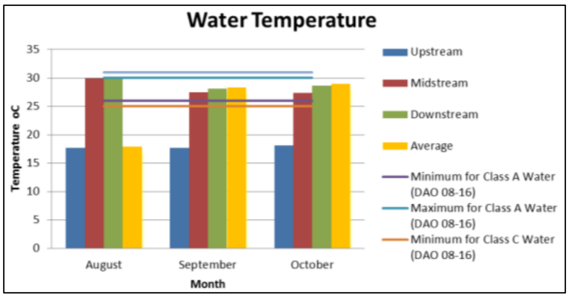


Fig. 3. Water temperature across Muleta watershed.

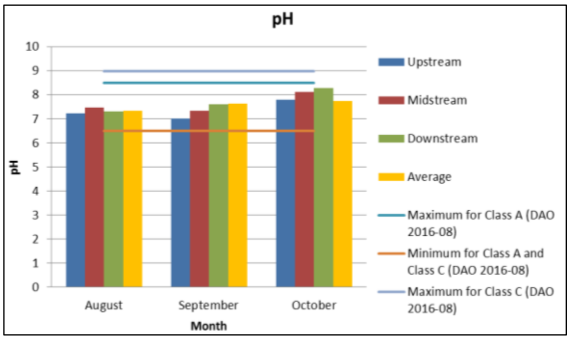
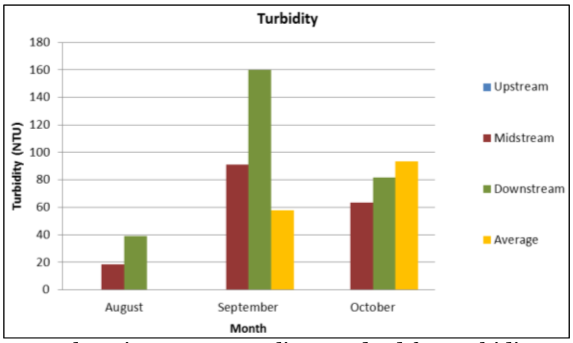


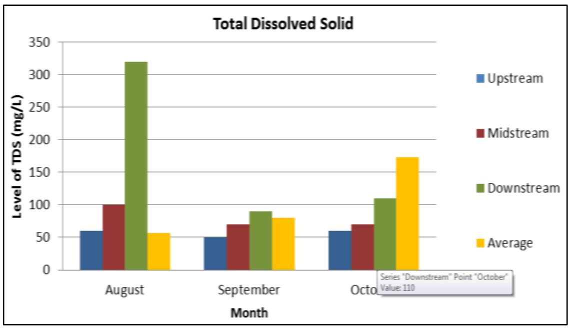
Fig. 4. pH across Muleta watershed.



Note: There is no water quality standard for Turbidity.

Fig. 5. Turbidity across Muleta watershed.

The amount of dissolved oxygen in water influences the condition of living organisms in the water. Dissolved oxygen is positively influenced by temperature. According to Chu *et al.* (2013), water temperatures generally have an inverse correlation with dissolved oxygen; as temperatures increase, dissolved oxygen decreases. The pattern for the dissolved oxygen across the watershed reveals Omonay (downstream) to have the lowest at an average of 11.49mg/L and Upper Bagkik-ikan (upstream) with the highest DO with an average of 12.16mg/L (Fig. 6). The average value of dissolved oxygen in all sites of the watershed is above the DENR DAO 2016-08 water quality standards for class A and C. Thus, the overall result of the dissolved oxygen (DO) across the watershed shows a good indicator for the survival of aquatic organisms. Total Dissolved Solid (TDS) are the mineral and salt impurities dissolved in the water and are measured in parts per million. Fig. 7 shows that Omonay (downstream) obtained the highest Total Dissolved Solids (TDS) with an average of 173.33mg/L, while Upper Bagik-ikan reveals the lowest TDS with an average rate of 56.67mg/L.Total Suspended Solids can affect the color of the water because of the greater concentration of TSS in the water, the higher the turbidity that worsens the clarity of the water. Higher concentration of TSS in the midstream (Malinao) and downstream (Omonay) portion of the watershed with 134.22mg/L and 109.45mg/L while Upper Bagik-ikan showed zero concentration of TSS (Fig. 8). Thus, only the upstream portion is within the DENR DAO 2016-08 water quality standards.



Note: There is no water quality standard for Total Dissolved Solid.

Fig. 6. Total Dissolved Solid across Muleta Watershed.

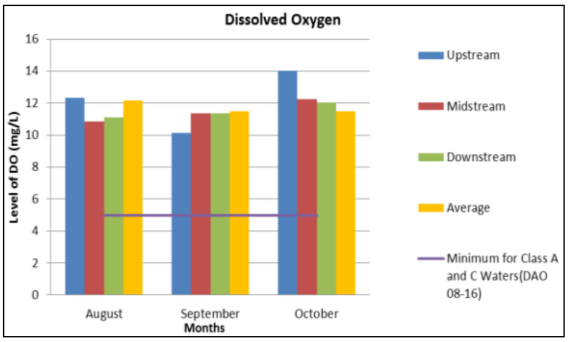


Fig. 7. Total Dissolved Solid across Muleta watershed.

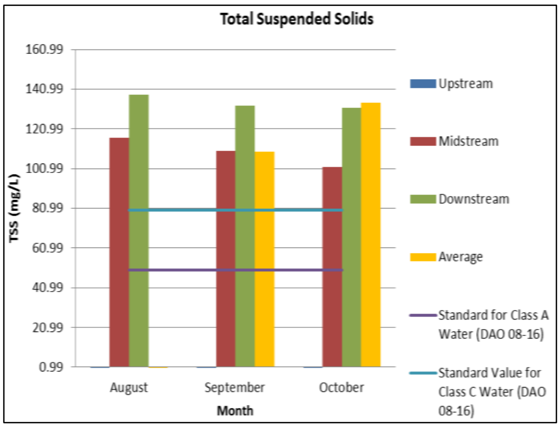


Fig. 8. Total Suspended Solid across Muleta watershed.

Nitrate is present in organic fertilizers. The nitrate concentration in the surface water is normally low but it can reach high levels elevated by agricultural run-off, refuse dump runoff or contamination with human and animal waste. Nitrates have shown significantly higher values in the midstream and downstream part of the watershed with 15.32 mg/L and 23.99mg/L average result. However, Upper Bagik-ikan obtained 6.91mg/L average results which is within the standard value of class A and Class C water of the DENR DAO 2016-08 shown in Fig. 9. Fig. 10 reveals the lower concentration of phosphates in the three sampling stations with 0.053mg/L (upstream), 0.200 (midstream) and 0.250 (downstream) which articulates below-standard results based on the DENR DAO 2016-08. Although the result in the study shows a low concentration of phosphorus in all study sites, this must be seized in water quality monitoring because a large amount of this nutrient in the water bodies leads to water pollution or commonly known as eutrophication. The possible sources of such nutrient are urban agricultural activities, stormwater and from the body washed used during bathing and laundry in streams.

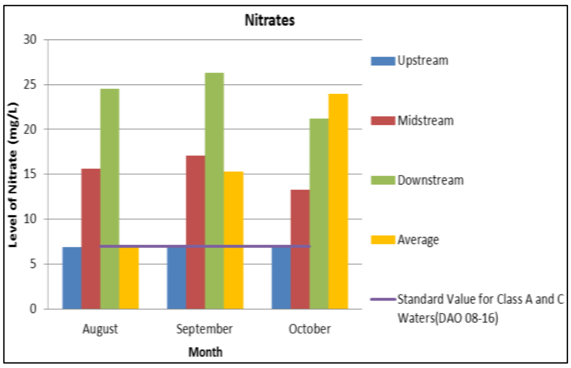


Fig. 9. Nitrates across Muleta watershed.

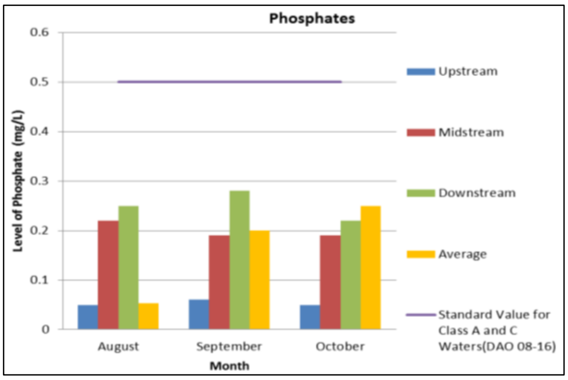


Fig.10. Phosphates across Muleta watershed.

Comparison of the over-all watershed average level of the water quality parameter with the DENR water quality standard value

Table 4 shows the average level of physicochemical results for the three sampling station as compared to the DENR standard for water quality. The present valuable use of Upper Bagik-ikan River (upstream) falls within Class A as per DENR standards for water quality. However, Malinao River is currently of beneficial use for agriculture and livestock and was classified under Class C water as compared to the DENR water quality standard value. The surface waters of Omonay River (downstream) are presently on beneficial used for agriculture, irrigation, and livestock watering. Thus, are not safe for human consumption. Generally, the the over-all watershed falls within Class A and Class C water of the DENR standards for water quality standard (DAO 2016-08).

The Physico-chemical Properties of Muleta River in Relation to Land Use / Land Cover (LULC)

Variation in terms of land use/land cover between the upper and lower part of the watershed is significantly observed in the study. Table 4 shows the analysis of variance (ANOVA) between water quality parameters in relation to its existing land use. At $\alpha=0.01$ level of significance, the result shows that there is a significant difference between water quality parameters particularly in terms of temperature, TSS, nitrates and phosphates between groups of different LULC specifically on the forested land cover on upstream sampling station as compared to the midstream and downstream area which consist of agricultural and mixed used area.

Upper Bagik-ikan is mostly covered with forest and dense vegetation. Water temperature in the upstream area is significantly lower compared to midstream and downstream areas which presumably have less point source runoffs that may have resulted in the higher water temperature. Conversely, as the temperature is affected by sunlight, the absence of vegetation and canopy in the downstream portion of the watershed is one significant factor in the increase of water temperature in midstream and downstream areas. According to Michaud (1991), water temperature fluctuations in streams may be further worst by cutting down trees, which provide shade, and by absorbing more heat from the sun due to an increase of water turbidity. Intensive agricultural activities are most common in areas at which higher water temperature occurs. The study of Duxbury *et al.* (2012) indicates that forests play significant roles in water quality management within a watershed. Forests act as sponges by soaking up rainfall and filtering nutrients before they are released into a stream, decreasing the number of harmful pollutants entering watershed streams and reduces sediment yield to rivers.

Excess nutrients such as nitrogen and phosphorus can be filtered by up to 90% in forested areas. Moreover, hardwood forest can eliminate up to 80% of phosphorus and nitrates from runoff (Boesch *et al.*, 2001). By contrast, the lower section of the watershed usually has high population density, relatively dense road networks and intensive land use that can cause variations of sediment load in river (Kebede *et al.,* 2014). Thus, commercial fertilizers are introduced to the area which can certainly cause increase of the temperature, nitrates, TSS and phosphates in the river systems. Conversely, the table shows that there is no positive difference on the water quality result in terms of pH, turbidity, Dissolved Oxygen and Total Dissolved Solids among sampling sites. As pH and Dissolved Oxygen shows insignificant difference in terms of results although upstream shows lower concentration as to the turbidity compared to the downstream areas which are dominantly used for agricultural and industrial purposes.

TDS are thought to be consequential from runoffs from construction, agricultural practices, logging activities, sewage treatment plant discharges and other sources. This could be observed in the downstream part of the watershed in which sub-river obtained high TDS concentration while upstream sampling sites obtained the lowest TDS for the reason that it could be due to minimal human activities that alter river systems.

With the result obtained within the three (3) rivers of Muleta Watershed, policies or regulation in improving and maintaining the water quality of the watershed must be a priority.

Table 5. One-way ANOVA of water quality of different Land Use Land Cover of Muleta Watershed.

Parameter	Forested	Agricultural	Agricultural and Build-up	F-Value	P-Value (α=0.01)
Temperature	17.83^{a}	28.25^{a}	28.91^{a}	111.810	0.000
pH	7.35^{b}	7.65^{b}	7.74^{b}	.664	0.549
Turbidity	0.000^{b}	57.64^{b}	93.58^{b}	3.923	0.081
Dissolved Oxygen	12.16^{b}	11.50^{b}	11.49^{b}	.291	0.758
TDS	56.67^{b}	80.00^{b}	173.33^{b}	2.070	0.207
TSS	0.000^{a}	109.26^{a}	134.22^{a}	682.479	0.000
Nitrates	6.91^{a}	15.32^{a}	23.99^{a}	62.561	0.000
Phosphates	0.06^{a}	0.20^{a}	0.25^{a}	149.471	0.000

Note: Means with the same letter superscript within a column are not statistically different from each other.

Conclusion

It is extremely recommended that continuous monitoring of physico-chemical parameters in Muleta Watershed in order to generate useful data and information to be used as a future basis in management actions that would help in mitigating problems in water resource. The result will be utilized as best measures to attain sustainability in the protection and conservation of the watershed. Policies and regulation in improving and maintaining the water quality and making land use decisions are needed to recognize the importance of the watershed.

By developing and implementing watershed plans, communities will work together to protect the water resources and realize land use decisions and eventually helps in improving the overall quality and health of the watershed.

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