Land-cover Characterization and Water Quality Assessment of the Sambunotan Watershed, Dinagat Islands in Support of the Development of the Watershed Management Plan

Meriam Makinano-Santillan
Department of Geodetic Engineering, College of Engineering and Geosciences, Caraga State University

Michelle V. Japitana
Department of Geodetic Engineering, College of Engineering and Geosciences, Caraga State University

Arnaldo C. Gagula
Department of Geodetic Engineering, College of Engineering and Geosciences, Caraga State University

Stephanie Mae S. Albores
Department of Civil Engineering, College of Engineering and Geosciences, Caraga State University

他

https://doi.org/10.5109/7323368

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.910-915, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

Land-cover Characterization and Water Quality Assessment of the Sambunotan Watershed, Dinagat Islands in Support of the Development of the Watershed Management Plan

Meriam Makinano-Santillan[1,3], Michelle V. Japitana[1,3], Arnaldo C. Gagula[1,3], Stephanie Mae S. Albores[2,3], Jahn Rey C. Bautista[1], Marjunelyn R. Llesis[1] , Jojene R. Santillan[1,3]
[1]Department of Geodetic Engineering, College of Engineering and Geosciences, Caraga State University, Butuan City
[2]Department of Civil Engineering, College of Engineering and Geosciences, Caraga State University, Butuan City
[3]Caraga Center for Geo-informatics, Caraga State University, Butuan City
Corresponding Author email: mvjapitana@carsu.edu.ph

Abstract: *The Sambunotan Watershed covers an area of 28 sq. km. within the Tubajon and Loreto municipalities in the province of Dinagat Islands, Philippines. Recently, the Sambunotan Watershed Management Plan's development was initiated within the 5-year Dinagat Islandscape Development Framework and Strategies through a collaborative effort among municipal and provincial local government units, non-government, and civil society organizations. In this paper, we present the land-cover characterization and water quality assessment to support the development of the watershed management plan. Freely available land-cover maps of the watershed from 2017-2021 were analyzed to quantify the extent and changes of the watershed's land cover. Field measurements to measure various water quality (WQ) parameters (pH, total dissolved solids, dissolved oxygen, and temperature) were conducted in May and November 2022, representing the watershed's dry and wet seasons. These WQ parameters/variables were correlated with the watershed's land cover characteristics. Major results showed that through the years, the dominant land cover classes are trees and rangeland.*
Keywords: Sambunotan watershed, watershed management, water quality assessment

1. INTRODUCTION

The Sambunotan Watershed, spanning an area of 28 square kilometers, is situated within the Tubajon and Loreto municipalities in the province of Dinagat Islands, Philippines. Recognizing the critical importance of this watershed to the region's environmental health and socio-economic development, a comprehensive Sambunotan Watershed Management Plan was recently initiated.

Water is the basis for both the beginning and continuation of humanity [1]. It is an essential natural resource that supports all living species and maintains a healthy ecosystem [2].The ecological health of water resources is endangered by the pressures arising from human activities and inadequate management [3]. Effective watershed management necessitates thoroughly understanding land-cover dynamics and water quality parameters [4] [5]. Land-cover characterization provides insights into the distribution and changes in the physical landscape, which can influence hydrological processes and water quality.

Using remote sensing and geographic information system (GIS) techniques to derive and integrate land use/land cover (LULC), water quality, and hydrological datasets is becoming popular in scientific research on water quality issues. Most of these studies map and evaluate land usage using remotely sensed data [6]. The traditional method of relating land use and land cover to water quality has expanded to include landscape patterns and other data derived from satellite data [7]. At present, remote sensing methods have become more popular among studies that are focused on characterizing watersheds [8],[9],[10] and evaluating water quality [11],[12]. Therefore, this study is aimed to support the development of the Sambunotan Watershed Management Plan by conducting detailed land-cover characterization and water quality assessments.

2. METHODOLOGY

2.1 The Study Area

The area under study is one of at least nine watershed reservoirs in the Province of Dinagat Islands, the Sambunotan Watershed, as shown in Fig. 1. It is in Barangay Carmen, Santa Cruz, Santiago in the Municipality of Loreto, and Barangays Diaz, Mabini, Navarro, San Vicente, San Roque, and Roxas in the Municipality of Tubajon. It spans a total area of 28 square kilometers. Six barangays within the Municipality of Tubajon get their potable water from this watershed, which is also used for irrigation and other household purposes. It features two significant river systems, the Maraging River and the Carac-an watershed.

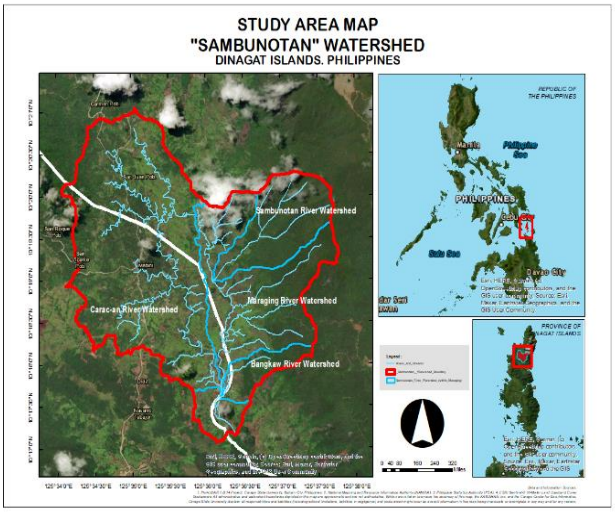

Fig. 1. The Map of Study Area

2.2 The Methodological Flow

The study's methodological workflow, shown in Fig. 2, was designed to achieve the specific objectives of this study. The methods have four major activities: Data acquisition, Data cleaning and pre-processing, GIS processing and analysis, and Statistical Analysis.

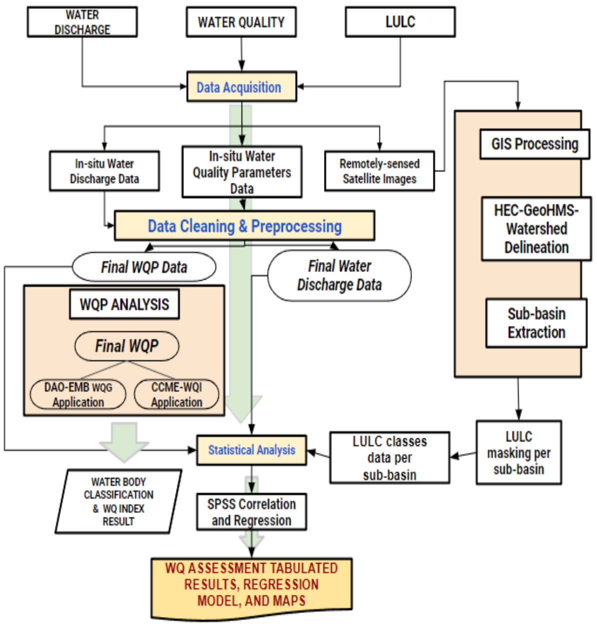

Fig. 2. The Flow Chart of the Study

2.3. Land Cover Characterization

Multitemporal Esri Land Cover data were utilized in the watershed land cover characterization. This yearly land cover data, starting from 2018 to 2021, was generated from Sentinel-2 satellite images.

A limitation of the Esri Land Cover data is that the land cover classes are generalized. Nevertheless, these limitations are not a hindrance to us visualizing and quantifying the land cover conditions of the watershed, including their changes in the last four years.

Each year, the total area of land cover classes was determined, and their changes over time were calculated. To determine how each land cover has changed from one year to another, the land cover vector files for each year were joined so that it would be easier to detect the specific changes spatially and so that land cover change or transition matrices can be generated.

2.4. Water Quality Assessment

River water quality was determined using Biobase Portable Multi-Parameter Water Quality Meter. The parameters measured are the following: pH, conductivity, total dissolved solids, salinity, temperature, and dissolved oxygen. A set of pre-selected sampling points were determined. These sampling sites were confirmed during the reconnaissance survey, during the first day of the fieldwork activity conducted last May 1 - 7, 2022, to assess the best and safest locations for acquiring the water quality data. This also ensures that the number of sampling points and their distribution along the whole river stretch has good statistical strength. The geographic locations of sampling points were determined using a handheld Global Navigation Satellite System.

The water quality data for both sampling periods were assessed based on the Department of Environment and Natural Resources thresholds, shown in Fig. 3, set for each parameter considered in this study. The table below shows the description of the water classification per beneficial use.

Water Body Classification and Usage of Freshwater	
Classification	Intended Beneficial Use
Class AA	Public Water Supply Class I. Intended primarily for waters having watersheds, which are uninhabited and/or otherwise declared as protected areas, and which require onlyapproved disinfection to meet the latest PNSDW
Class A	Public Water Supply Class II. Intended as sources of water supply requiring conventional treatment (coagulation, sedimentation, filtration and disinfection) in order to meet the 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 (Waters of the Philippines, including the territorial area and inland waters suitable for water transport)

Fig. 3. Description of the water classification per beneficial use.

2.5. Statistical Analysis

Water discharge and land use/ cover significantly contribute to water quality **[**13**].** A statistical analysis was performed to understand the relationship between water discharge and LULC and the water quality parameters for the "Sambunotan" watershed.

The IBM® SPSS® software platform provides advanced statistical Analysis, a substantial library of machine learning algorithms, text analysis, open-source extensibility, extensive data integration, and seamless application deployment. SPSS is accessible to users of all skill levels because of its simplicity, versatility, and scalability. Furthermore, it is appropriate for projects of all sizes and degrees of complexity [14].

IBM® SPSS® Statistics Software was solely used to conduct correlation analysis for the available water discharge data to determine which parameters notably correlated with the discharge. The same software was utilized to conduct the correlation and regression analysis to evaluate the relationship between water quality parameters and LULC.

3. RESULTS AND DISCUSSION

3.1. Land Cover Characterization

Fig. 3 to Fig. 6 shows the land cover maps and statistics of the Sambunotan Watershed for the years 2018 to 2021, respectively.

Through the years, the dominant land cover classes are trees and rangeland. Trees occupy more than 60% of the watershed for all years, while rangeland occupies more than 20% but never exceeds 30% of the watershed. Cropland and Built Areas are the least dominant, with their areas less than 10% of the total watershed area. The summary statistics are illustrated in Fig. 7.

As shown in Fig. 7, built areas are observed not significantly expanding, and the largest area built is in the year 2020, accounting for around 30 hectares, about 1.08% of the total area. Cropland, rangeland, and tree areas are changing, but these changes are minor. With these relatively minor changes in land cover, it can be generally stated that the land cover condition is stable.

Land cover change or transition matrices help quantify the changes in land cover within the watershed and, at the same time, provide information on the type and area of change from one land cover class to another. The spatial quantification of land cover transitions presents some insights about the actual changes for the Trees, for example, in the watershed.

Taking as an example, the changes in Built Area from 2018 to 2021 can be quantified as follows:

- If the Built Area is crossmatched with the Built Area column, an area of 204,700.00 sq.m. is obtained, this is the area of “Built Area” that did not change (i.e., was retained as “Built Area” in 2021).
- If the Built Area row is crossmatched with the Cropland column, we obtain a value of 25,300 sq.m. This is the “Built Area” area that has changed to “Cropland” in 2021.
- If the Built Area row is crossmatched with the Rangeland column, an area of 4,100 sq.m is obtained. This is the “Built Area” area that has changed to “Rangeland” in 2021.
- If the Built Area row is crossmatched with the Trees column, a value of 18,400 sq.m. is obtained. This is the “Built Area” area that has changed to “Trees” in 2021.
- The changes from Built Areas to rangeland, cropland, and trees implies that landowners may have opted to relocate, cultivated, and/or abandoned the area.
- The transitioning of Built Areas to rangeland, cropland, and trees can have significant benefits for the watershed's ecological health, enhance local communities' resilience, and provide sustainable economic opportunities.

By employing the same method on determining land cover changes, major transitions for 2018-2021 correspond to the Rangeland and Tree classes. For the year 2018, the total area of rangeland is 6,555,550 sq.m., but large portions of it have become “Trees” (720,775 sq.m.) and “Cropland” (362,825 sq.m.) in the year 2021; the remaining 5,466,950 sq.m. has been retained as “Rangeland.” On the other hand, the major land cover classes in 2018 that have become “Rangeland” in 2021 are “Cropland” (582,075 sq.m.) and “Trees” (858,850 sq.m.). For the “Tree” class, there was a total of 19,208,100 sq.m. of “Trees” in 2018, but major portions of it have become “Rangeland” (858,850 sq.m.) in 2021. Only 18,253,575 sq.m. of “Trees” in 2018 has been retained as “Trees” in 2021. On the other hand, the major land cover classes in 2018 that have become “Trees” in 2021 are “Rangeland” (720,775 sq.m.) and “Cropland” (226,375 sq.m.).

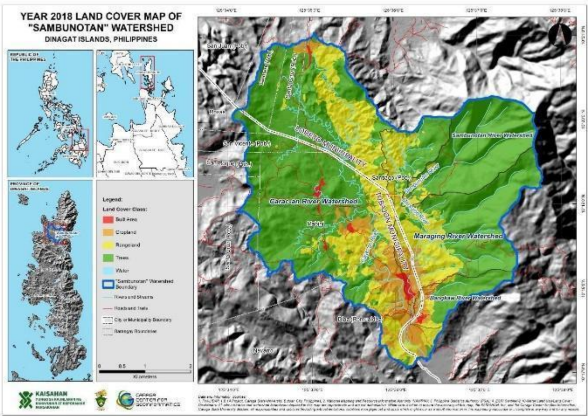

Fig. 3. Year 2018 land cover map of the Sambunotan Watershed.

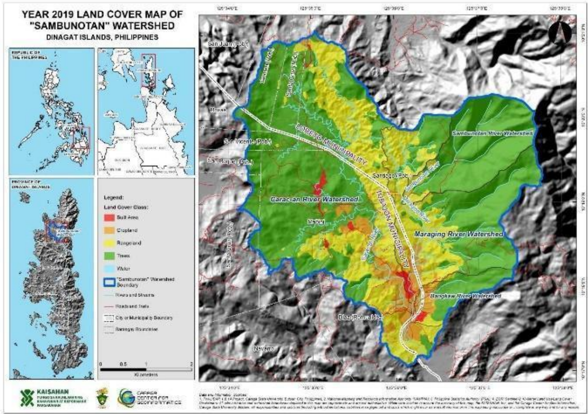

Fig. 4. Year 2019 land cover map of the Sambunotan Watershed.

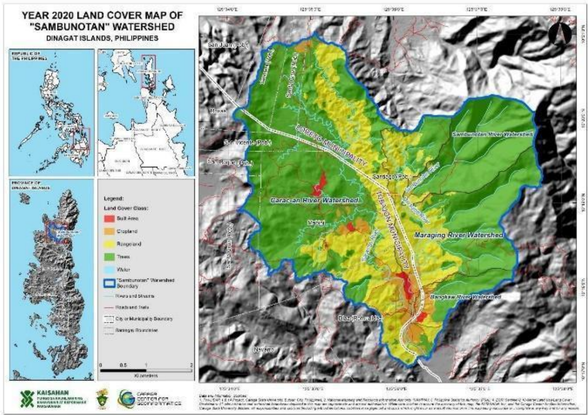

Fig. 5. Year 2020 land cover map of the Sambunotan Watershed.

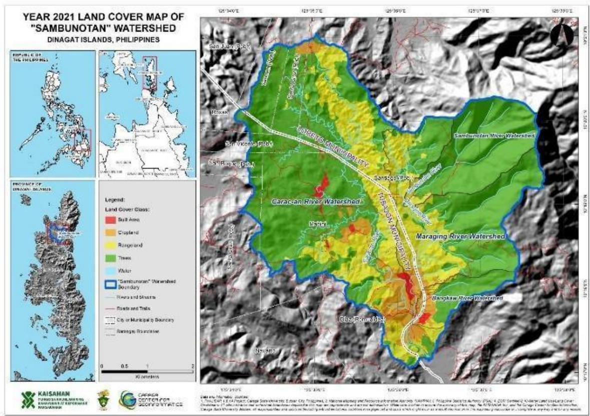

Fig. 6. Year 2021 land cover map of the Sambunotan Watershed.

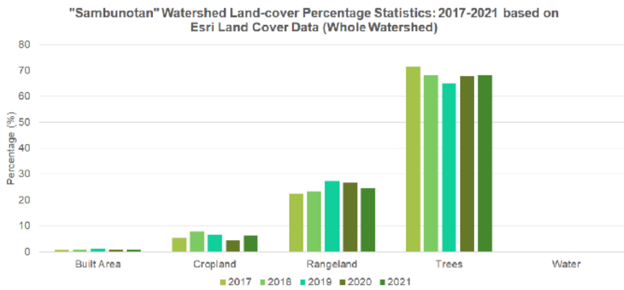

Fig. 7. Percentages of land cover in the Sambunotan Watershed.

On average, the land cover composition of the watershed implies a considerable amount of trees, rangeland, and cropland with minimal change throughout the 4-year period. Overall, the transitioning of land cover into trees and cropland have significant benefits for the watershed's ecological health, enhance local communities' resilience, and provide sustainable economic opportunities. However, careful planning and community engagement are essential to manage potential challenges and ensure a smooth transition.

3.2. Water Quality Data Collection

There are two (2) water sampling periods conducted in the Sambunotan Watershed. The month of May sampling aims to represent the dry season, and the month of November sampling represents the wet season. Fig.8 is the map showing the locations of the sampling stations within the study area.

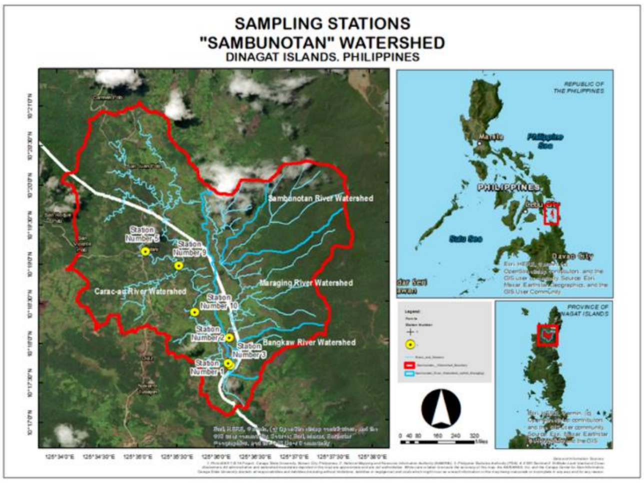

Fig. 8. Map of the Sambunotan watershed showing the Sampling Points.

Based on the results obtained from the in-situ water quality measurements in May 2022, as shown in Fig. 9, the study area’s temperature increased downstream from 25.6°C to 27.95°C.

The TDS levels observed at all sampling sites did not exceed the 500 mg/L limits for Class AA surface waters set by the DENR Administrative Order 34 series 1990. The TDS levels varied significantly across sampling locations due to the various anthropogenic activities at the different sampling sites, such as quarrying, construction, livestock farming, clothes washing, and garbage dumping, some common activities at the riverbank in the study area. High TDS levels in surface waters increase biological and chemical oxygen demand, eventually depleting the water's dissolved oxygen level.

The DO levels in stations 5 and 11, located upstream, passed the 2 mg/L limits set by DENR for Class C water bodies. The remaining sampling sites have DO values within the acceptable DENR limit for Class AA to Class C surface waters and can adequately sustain aquatic lives. The decreasing DO level at Stations 5 and 11 could be attributed to the consumption of DO in the oxidation of organic matter from domestic wastewater, discharges from pigpens, and human wastes.

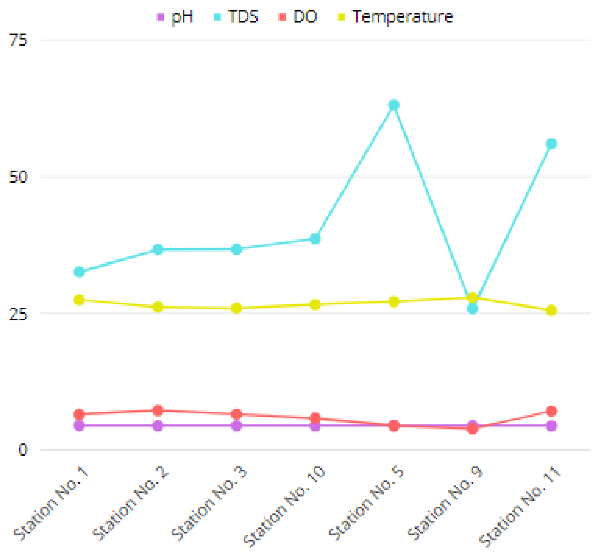

Fig. 9. May 2022 Water Quality Sampling Data.

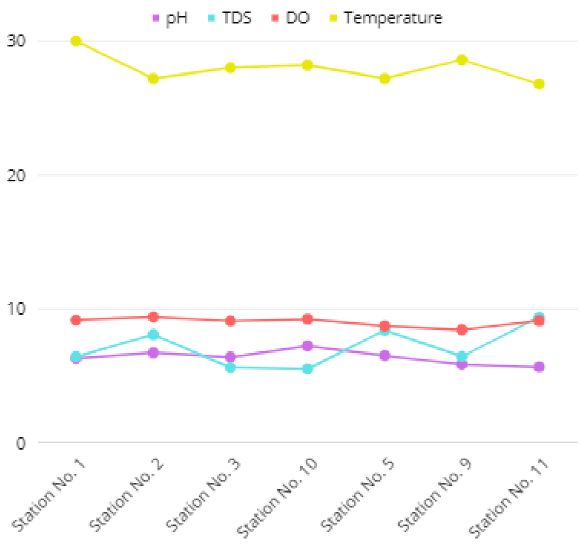

Fig. 10. November 2022 Water Quality Sampling Data.

As shown in Fig. 10, TDS and DO levels observed in November 2022 at all sampling sites passed the Class AA surface waters set by the DENR. The diverse human activities and natural sources at each site may have caused significant variations in TDS levels between sampling sites. The increase in TDS levels in Sampling 2 and 5 could be attributed to the noticeable human settlement in the area. In contrast, natural sources, like soils and rocks, which may also contain TDS, could contribute to a high TDS in Sampling 8 despite the site being surrounded by trees and away from human dwellings.

Temperature levels in Station Number 11, located upstream, passed the 25°C-31°C limit set by DENR for Class C water bodies. The decrease in Temperature level at Sampling 8 could be attributed to the area where the sampling was acquired. The area is filled with trees which could be a significant contributing factor to the decrease in temperature since trees help reduce heat energy, thus lowering the surrounding temperature.

3.3. Water Body Assessment

In the DAO 2016-08, the available water parameter with set thresholds does not include Salinity and Conductivity.

Hence, the water body classification per sampling point was done only for pH, TDS, DO, and temperature.

In May 2022 (Fig. 11), all sampling points did not pass any standards for water body classification of DENR for temperature. However, during the second sampling in November 2022 (Fig. 12), stations 2, 10, and 5 passed the Class AA criteria.

All the waters sampled for TDS levels passed the Class AA standards for both sampling periods. For DO, Sampling points 5 and 11 were only classified as Class C. Its water quality level was improved during the second sampling in November, passing the Class AA water body classification.

Parameters	Water Body Classification per Sampling Point (May 2022)						
	SN 1	SN 2	SN 3	SN 10	SN 5	SN 9	SN 11
pH	Not within the standards set by any Water Body Classification of DENR						
TDS	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA
DO	Class AA	Class AA	Class AA	Class AA	Class C	Class C	Class AA
Temperature (°C)	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA	Class C

Fig. 11. Water body classification per Sampling Point for November 2022.

Parameters	Water Body Classification per Sampling Point (November 2022)						
	SN 1	SN 2	SN 3	SN 10	SN 5	SN 9	SN 11
pH	Not within the standards...	Class AA	Not within the standards...	Class AA	Class AA	Not within the standards set by any Water Body Classification of DENR	
TDS	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA
DO	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA
Temperature (°C)	Class AA	Class AA	Class AA	Class AA	Class AA	Class AA	Class C

Fig.12. Water body classification per Sampling Point for November 2022.

3.4. Statistical Analysis: Correlation and Regression Modeling

The Correlation Analysis was implemented and resulted in two water quality parameters highly correlated to the percent coverage of Rangeland and Trees within the contributing area of the Stations.

		Builtup_%	Cropland_%	Rangeland_%	Trees_%
TDS_s1	Pearson Correlation	0.691	-0.358	**-.960****	**.934****
	Sig. (2-tailed)	0.086	0.431	0.001	0.002
	Covariance	22.083	-10.532	-191.801	180.257
	N	7	7	7	7
pH_s2	Pearson Correlation	0.089	-0.132	-0.747	**.778***
	Sig. (2-tailed)	0.85	0.778	0.054	0.039
	Covariance	0.103	-0.142	-5.432	5.47
	N	7	7	7	7

**Correlation is significant at the 0.01 level *Correlation is significant at the 0.05 level

Fig. 13. Correlation Analysis result of TDS and pH.

The TDS levels in the first sampling period, as shown in Fig. 13, show contrasting relationships with the area compositions of Rangeland and Trees, whose significant values are -0.960 and 0.934. The TDS is negatively correlated to the percent coverage of Rangeland but positively correlated to the percent coverage of Trees.

Dependent Variables	R Square (%)	Std. Error of the Estimate	Predictors	Regression Model (Predictors and Coefficients)
pH_s2	72.71	0.357	% Trees, % Cropland, %Built-up	ph_s2 = 3.800 - 0.066 x Builtup_% + 0.043 x Cropland_% + 0.03 Trees_%
TDS_s1	96.18%	3.668	% Trees, % Cropland, %Built-up	TDS_s1 = -16.601 + 1.855 x Builtup_% + 0.110 x Cropland_% + 0.720 x Trees_%
TDS_s2	90.20%	0.668	% Trees, % Cropland, %Built-up	TDS_s2 = 14.813 + 0.335 x Builtup_% - 0.544 x Cropland_% - 0.0 x Trees_%
Temperature_s1	76.64%	0.585	% Trees, % Cropland, %Built-up	Temperature_s1 = 31.207 + 0.187 x Builtup_% - 0.232 x Croplan 0.056 x Trees_%
Dissolved Oxygen_s1	81.61%	0.793	% Trees, % Cropland, %Built-up	Dissolved Oxygen_s1 = -0.010 -0.402 x Builtup_% + 0.337 x Cropland_% + 0.077 x Trees_%

Fig. 14. Correlation results showing the Regression models for each Dependent Variable.

As shown in Fig. 14, land use classes like Cropland, Built-up, and number of trees consistently predict the water quality parameters. The number of trees within the contributing area was significant in describing the variance of the pH model, with a positive correlation to pH. This implies that the presence (or increase of trees) influenced the pH level of water in the area. TDS yielded a high R square value for both seasons with the same predictors. DO also yielded a high R square value with the same predictors.

4. CONCLUSIONS AND RECOMMENDATIONS

Land Cover Characterization results showed that trees occupied the largest area, approximately 60% of the watershed area throughout the four years. In contrast, Built areas are the least dominant, with areas less than 10% of the watershed area. Cropland, rangeland, and tree areas are changing, but these changes are Minor stating that the land cover condition is stable.

On the other hand, water quality measurements were conducted within the Sambunotan Watershed. The water sampling results imply that human activities within the watershed can affect the quality of the surface waters in the area. The statistical analysis confirmed the importance of trees in the area and the practices within the cropland and built-up areas.

Per assessment, the sampling sites passed the Class AA standards in the majority. The LGUs just need to intensify their watershed protection programs to improve water quality in the area.

The regression analysis further identifies potential stressors impacting the watershed, which are crucial considerations for developing an effective watershed management plan. These insights can guide the creation of policies focused on safeguarding and improving the watershed's natural resources. Additionally, they can inform the formulation of regulations to control deforestation, manage land conversion, and enforce sustainable agricultural practices.

5. REFERENCES

[1] Talukder, R., & Proshad, P. K. (2023). Desalination of Seawater Using Reverse Osmosis Method. *International Exchange and Innovation Conference on Engineering and Sciences*, 9. https://doi.org/10.5109/7157961

[2] Singha, B., & Eljamal, O. (2021). Exploring Attitudes and Household Culture to Encourage Water Conservation Behavior. *International Exchange and Innovation Conference on Engineering and Sciences*. https://doi.org/10.5109/4738581

[3] Allahverdiyev, E., 2022, May. The Importance of Watershed Management in Sustainable Development. In International Scientific Conference on Agricultural Machinery Industry "Interagromash"" (pp. 3210-3218). Cham: Springer International Publishing.

[4] A. K. Hua, "Land Use Land Cover Changes in Detection of Water Quality: A Study Based on Remote Sensing and Multivariate Statistics," *J Environ Public Health*, vol. 2017, 2017, doi: 10.1155/2017/7515130.

[5] J. Lu, H. Cai, X. Zhang, J. Lu, H. Cai, and Y. Fu, "Water quality in relation to land use in the Junshan Lake watershed and water quality predictions," *Water Supply*, vol. 21, no. 7, 2021, doi: 10.2166/ws.2021.123.

[6] M. V. Japitana and E. C. Paringit, "A Remote Sensing and gis-based Capture Zone (CapZone) approach to assessment of fecal contamination on groundwater: A

case study of Butuan City, Philippines," in *32nd Asian Conference on Remote Sensing 2011, ACRS 2011*, 2011.

[7] W. T. Peterjohn and D. L. Correll, "Nutrient dynamics in an agricultural watershed: observations on the role of riparian forest.," *Ecology*, vol. 65, no. 5, 1984, doi: 10.2307/1939127.

[8] X. Wang and W. Yang, "Water quality monitoring and evaluation using remote-sensing techniques in China: A systematic review," *Ecosystem Health and Sustainability*, vol. 5, no. 1. 2019. doi: 10.1080/20964129.2019.1571443.

[9] Wang, J., Wu, Y., Hu, Z. and Zhang, J., 2023. Remote Sensing of Watershed: Towards a New Research Paradigm. *Remote Sensing*, *15*(10), p.2569.

[10] Santillan, J., Makinano, M. and Paringit, E., 2011. Integrated Landsat image analysis and hydrologic modeling to detect impacts of 25-year land-cover change on surface runoff in a Philippine watershed. *Remote Sensing*, *3*(6), pp.1067-1087..

[11] Japitana, M.V., Demetillo, A.T., Burce, M.E.C. and B. Taboada, E., 2019. Catchment characterization to support water monitoring and management decisions using remote sensing. *Sustainable Environment Research*, *29*, pp.1-10.

[12] Sun, X., Zhang, Y., Shi, K., Zhang, Y., Li, N., Wang, W., Huang, X. and Qin, B., 2022. Monitoring water quality using proximal remote sensing technology. *Science of the Total Environment*, *803*, p.149805.

[13] W. Ahmad et al., "Impact of land use/land cover changes on water quality and human health in district Peshawar Pakistan," Sci Rep, vol. 11, no. 1, 2021, doi: 10.1038/s41598-021-96075-3.

[14] SPSS Software. (n.d.). IBM. https://www.ibm.com/spss

Talukder, R., & Proshad, P. K. (2023). Desalination of Seawater Using Reverse Osmosis Method. *International Exchange and Innovation Conference on Engineering and Sciences*, *9*. https://doi.org/10.5109/7157961