Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 05 May-2026, Page No.-10103-10113

DOI: 10.47191/etj/v11i05.46, I.F. – 8.595

GIS-Based Assessment of Land Use and Water Quality Compliance of Selected Class C Rivers in Central Luzon, Philippines

Cassandra Trixxe L. Bani[1], Lawrence E. Gayla[2], Richard DC. Gonzales[3], Erwin N. Mendoza[4], Ken Denver A. Vasquez[5], Rosel V. Babalcon[6]

[1,2,3,4,5,6,] College of Engineering, Nueva Ecija University of Science and Technology, Cabanatuan City 3100, Nueva Ecija, Philippines

ABSTRACT: This study examines observed spatial associations between land use and land cover (LULC) and water quality compliance of selected Class C rivers in Central Luzon using Geographic Information Systems (GIS) and secondary data from the Department of Environment and Natural Resources (DENR). The researchers used Geographic Information Systems (GIS) to analyze LULC patterns that exist within 500-meter buffer zones which surround river monitoring stations. The research results show that the selected rivers display three main land use patterns which include built-up areas in Marilao and fishponds in Meycauayan and Obando and agricultural land in Pampanga and Talisay. All rivers which tested for Class C water quality standards failed to meet the requirements because every testing location showed both dissolved oxygen and fecal coliform results that did not meet standards. Results revealed that Marilao and Meycauayan Rivers contained the highest levels of pollution but Pampanga and Talisay showed better water quality. The research shows that urban areas which contain aquaculture facilities are associated with higher levels of organic and microbial pollution. The findings indicate that urban and aquaculture-dominated areas are associated with higher levels of organic and microbial pollution, highlighting the need for improved land use planning and wastewater management strategies.

KEYWORDS: Central Luzon, Class C Rivers, Geographic Information System, Land Use and Land Cover, Water Quality

INTRODUCTION

I.I Background of the Study

Rivers play an important role in everyday life and in the natural environment. They help drain excess water from the land and are used for irrigating farms, especially in Central Luzon, which is one of the main rice-growing areas in the Philippines. Rivers also support fishing, which provides food and income for many local communities. They serve as habitats for various plants and animals that depend on clean and flowing water. Over time, rivers have also influenced where people choose to build their homes and communities, as having access to fresh water has always been a basic necessity. As stated by NOAA Fisheries, rivers play a vital role in supporting both human life and ecosystems. They provide water for drinking, agriculture, and industry, while also helping in flood control and transportation. In addition, rivers serve as habitats for many plants and animals. Because of these benefits, many human settlements have developed near rivers throughout history (NOAA Fisheries, 2020).

However, rivers in the Philippines are increasingly threatened by human activities that affect their water quality. The rapid growth of urban areas near rivers increases the amount of water runoff that carries pollutants into the water. Farming activities contribute to water pollution through the runoff of fertilizers and pesticides from fields. Many communities also lack proper waste disposal systems, causing household wastewater to flow into rivers and raise levels of harmful bacteria. Factories and other industrial establishments near rivers add to the problem by releasing harmful chemicals and other waste materials. When the land around rivers is cleared or built upon, it also loses its natural ability to filter pollutants before they reach the water. Based on information from UN-Water, water quality is increasingly threatened by human activities such as population growth, urbanization, and industrialization. These factors lead to higher wastewater production, much of which is discharged untreated into rivers. Agricultural and industrial pollutants further contribute to water contamination, especially in developing regions (United Nations, 2023).

The way land is used near a river has a strong effect on how much pollution enters it. Areas with many buildings and roads tend to produce more runoff carrying bacteria, nutrients, and other contaminants. Farmlands can release large amounts of nutrients like nitrogen and phosphorus into nearby rivers. Industrial areas may introduce different types of harmful chemicals. Knowing what kinds of land use exist around a river can help explain why water quality is good or poor in certain areas, and can guide efforts to reduce pollution at its source. According to findings published in Scientific Reports, land use significantly affects river water quality. Agricultural areas often introduce nutrients like fertilizers into water systems, while urban areas contribute pollutants from various human activities. The study also highlights that the impact of land use varies depending on location and time, emphasizing the need for proper land management (Zhang, X. et al., 2019).

Geographic Information Systems, or GIS, is a useful tool for examining how land is used around rivers. It allows researchers to map and analyze what types of land cover exist within a given distance of a river using satellite images and spatial data. This kind of analysis makes it easier to see which land uses are located near water quality monitoring points and whether those land uses might be connected to pollution problems. GIS is especially helpful when studying many rivers at the same time across a wide area, as it can combine different types of data into a single analysis. As explained by Springer Nature, Geographic Information Systems (GIS) and remote sensing technologies are important tools in river management. Remote sensing provides detailed environmental data, while GIS allows for analysis and integration of this information. These tools help researchers monitor river conditions and identify patterns and changes that affect water quality (Chatrabhuj et al., 2024).

Despite these advantages, there are very few local studies in Central Luzon that combine official water quality data from the Department of Environment and Natural Resources (DENR) with a GIS-based look at land use around rivers. Most studies either focus on water quality data alone or on land cover mapping without connecting the two. This makes it difficult to fully understand what is driving water quality problems across the rivers of the region. As discussed in Environmental Health Perspectives, studies on river water quality in the Philippines, such as in the Meycauayan River, focus mainly on specific locations using monitoring data. However, these studies do not include a broader GIS-based analysis or comparisons across multiple rivers. This shows a gap in research that combines spatial analysis with water quality assessment (Pleto et al., 2020).

This study assesses the land use patterns surrounding selected Class C rivers in Central Luzon and evaluated whether their water quality met DENR standards. It used GIS to map land use around water quality monitoring stations and analyzed DENR monitoring data to check compliance with Class C water quality criteria. The goal was to provide a clearer picture of the condition of these rivers and the land use factors that may be affecting them.

I.II Statement of the Problem

This study aims to examine how land use affects the water quality of selected Class C rivers in Central Luzon. Specifically, it seeks to answer the following questions:

1. What are the dominant land use and land cover classes surrounding the selected rivers?
2. What are the water quality conditions of the selected rivers in 2020?
3. Which parameters comply or do not comply with Class C standards?
4. How do river conditions vary among study sites?
5. What possible relationship exists between surrounding LULC and observed water quality conditions?

I.III Objectives of the Study

General Objective:

To assess land use patterns and water quality compliance of selected Class C rivers in Central Luzon.

Specific Objectives:

1. To map surrounding LULC of selected rivers.
2. To evaluate DENR water quality data against DAO 2016-08 Class C standards.
3. To compare river conditions across sites.
4. To examine possible associations between LULC and water quality patterns.
5. To recommend management actions.

I.IV Significance of the Study

This study is important because it provides a clearer understanding of how land use and land cover (LULC) influence river water quality in Central Luzon. By combining Geographic Information Systems (GIS) analysis with water quality data from the Department of Environment and Natural Resources (DENR), the study helps identify patterns between human activities and river conditions.

The findings of this study will benefit several groups:

To the Department of Environment and Natural Resources (DENR)

The results can support improved monitoring strategies and policy-making for water quality management, especially in Class C rivers.

To Local Government Units (LGUs)

LGUs can use the findings to guide land use planning, zoning regulations, and environmental protection programs in areas near rivers.

To River Management Agencies

The study provides insights that can help in designing more effective river rehabilitation and pollution control measures.

To Environmental Planners

The relationship between land use and water quality can serve as a basis for sustainable development planning and environmental impact assessments.

To Students and Researchers

This study contributes to existing literature by integrating GIS and water quality analysis, serving as a reference for future studies related to environmental monitoring and spatial analysis.

I.V Scope And Limitations

This study focuses on analyzing the relationship between land use and land cover (LULC) and water quality in selected Class C rivers in Central Luzon using Geographic Information Systems (GIS) and secondary data. It utilizes water quality monitoring data from the Department of Environment and Natural Resources (DENR) for the year 2020 and LULC data derived from Geoportal maps for 2025. The study involves mapping and examining land use patterns within a standardized 500-meter buffer distance from river monitoring stations and identifying descriptive and comparative relationships between LULC types and selected water quality parameters.

However, this study has several limitations. It relies solely on secondary data and does not include direct field sampling or validation, which may affect the accuracy of the findings. Moreover, the study relies on secondary LULC data that may not correspond exactly with the timing of water quality measurements. As such, the findings are interpreted as indicative of general land use conditions rather than precise temporal relationships. Although water quality data are from 2020 and LULC data are from 2025, the selected river systems are located in areas with relatively stable dominant land use patterns such as long-established urban zones, fishpond areas, and agricultural lands. Major land conversion in these areas is generally gradual rather than abrupt, making the 2025 LULC data still useful for identifying dominant surrounding land use conditions. Furthermore, the analysis is limited to descriptive and spatial relationships and does not establish direct cause-and-effect conclusions. The study also considers only selected monitoring stations and parameters, which may not fully represent the overall condition of the rivers. Other influencing factors, such as seasonal variations, weather conditions, and unrecorded pollution sources, are not included in the analysis.

I.VI Conceptual Framework (IPO)

This study is based on the Input-Process-Output (IPO) model. It presents the flow of the research, where input data such as DENR water quality records, LULC maps, and river locations are processed through GIS analysis and assessment methods to produce outputs including LULC maps, compliance results, and river comparisons.

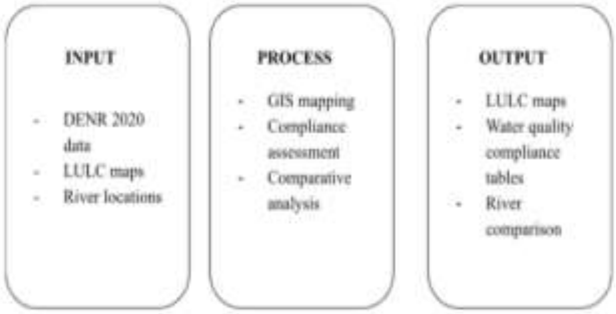

Figure 1. Input-Process-Output Framework

REVIEW OF RELATED LITERATURE

II.I River Water Quality Indicatorz

As noted by Chidiac et al. (2023), water quality in rivers is commonly measured using key indicators such as dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, total suspended solids (TSS), coliform bacteria, and nutrients, all of which help identify the level of pollution in a body of water. These indicators are used in different parts of the world to build water quality index (WQI) models that give an overall picture of how clean or polluted a river is. Without regularly checking these parameters, it becomes difficult for governments and communities to manage water resources and protect public health.

According to Mahe et al. (2024), various physical and chemical measures including DO, BOD, pH, TSS, fecal coliform, and nutrients are essential tools for checking whether water is safe and suitable for different uses. Each parameter plays a specific role in showing the condition of the water, such as how much oxygen is available for aquatic life or how much harmful bacteria is present. When these values go beyond safe limits, they serve as clear signs that the water has been affected by pollution from human activities or natural sources.

As reported by Leong et al. (2018), the health of river water can be evaluated through a combination of biological and physical tests, including coliform counts, DO, BOD, and TSS, which together reveal the presence and degree of contamination in a water system. Their study found that rivers located near industrial and residential areas tend to have lower oxygen levels and higher bacteria counts, pointing to the strong influence of human activity on water conditions. These findings highlight the need for regular water testing, especially in areas where land development continues to grow.

II.II Effects of Land Use on Water Quality

As emphasized by Kent Anson Locke (2024), the way land is used whether for cities, farming, or kept as natural vegetation greatly affects the quality of nearby rivers and streams, with urban zones and agricultural areas being the leading sources of water pollution. The study explains that built-up surfaces like roads and rooftops prevent water from soaking into the ground, causing runoff to carry pollutants directly into rivers. In contrast, natural vegetation such as forests and riparian buffers can slow down this process and filter out harmful substances before they reach the water.

According to Cheng et al. (2022), farming activities and urban development are closely tied to the rise of nitrogen, phosphorus, and BOD levels in river water, while forested areas tend to improve water conditions by acting as natural filters. The research reveals that aquaculture operations also contribute to nutrient pollution, as excess feed and waste from fish farms can flow into nearby water bodies and lower their quality. These results show that managing land use wisely, especially near rivers and watersheds, is a key step in reducing water pollution.

As highlighted by Shiferaw et al. (2025), changes in land use particularly the expansion of residential areas and croplands significantly alter water flow patterns and increase the amount of harmful substances entering rivers over time. The study used simulation models to predict how continued urbanization and agricultural growth would further reduce water quality in the coming decades. Their findings stress that protecting natural land cover and restoring riverside vegetation are important actions to help maintain healthy water systems in the future.

II.III GIS in River Monitoring

As demonstrated by Yan et al. (2015), geographic information systems (GIS) serve as a powerful tool for mapping pollution levels in rivers, allowing researchers to see where contamination is most severe and track how it moves across a watershed. By combining water sample data with spatial analysis techniques like interpolation, the study was able to produce detailed maps showing the distribution of pollutants such as nitrogen and phosphorus across the study area. This kind of visual and spatial information is very useful for environmental managers who need to decide where to focus clean-up efforts and monitoring stations.

II.IV Philippine River Water Quality Studies

According to the Mercado et al. (2024), water quality in Philippine rivers tends to decline from the upper to the lower portions of the waterway, with pollution becoming worse in sections closer to populated and heavily developed areas. The study on the Mananga River in Cebu showed that both biological and physical water quality indicators deteriorated significantly as the river passed through more urbanized stretches. This pattern is common in many Philippine rivers where population growth and lack of wastewater treatment put constant pressure on river systems.

As observed by Laranjo et al. (2023), the rivers of Zamboanga del Norte in the Philippines show varying levels of pollutants associated with human and industrial activity, with most measured parameters still within the acceptable range set by DENR and WHO standards. However, the study noted that certain areas near populated zones showed signs of elevated nutrient and sediment levels, which may worsen if no action is taken. The researchers stressed that ongoing water quality monitoring is necessary to catch early signs of pollution and guide local government decisions on river protection.

II.V Central Luzon Urbanization/Watershed Pressures

As shown by Mapili (1996), the Pampanga River Basin in Central Luzon has gone through major shifts in land use over the decades, with growing residential areas and farming activities leading to a steady drop in river water quality as revealed through GIS-based analysis of nitrate, phosphate, dissolved oxygen, and other water indicators. The study found that streams in catchments dominated by the same type of land use showed similar patterns in water quality, confirming that land cover is a strong driver of river conditions in the basin. These findings remain relevant today,

especially as Central Luzon continues to face rapid population growth and land conversion.
According to Robles & Monjardin (2025), the rapid expansion of urban areas in Central Luzon and surrounding regions has placed increasing strain on both groundwater and surface water systems, with contamination from pathogens, heavy metals, and other pollutants posing a growing risk to public health. The review found that areas in Pampanga and nearby provinces have recorded elevated levels of harmful substances near landfills and former industrial sites, highlighting how urban growth often goes hand in hand with environmental degradation. The study calls for stronger monitoring systems and better coordination among local agencies to address these water quality challenges before they worsen further.

METHODOLOGY

III.I Research Design

This study uses a descriptive-comparative GIS-based environmental assessment design to describe and compare the environmental conditions of the selected study areas. It analyzes spatial data such as land use, land cover, and water quality, while GIS is used to map and interpret environmental patterns. This approach enables a clear and systematic comparison of similarities and differences across the study sites.

III.II Study Area

Location Map of Selected Rivers in Central Luzon

This study focuses on selected river systems in Central Luzon, such as the Marilao, Meycauayan, Obando, Pampanga, and Talisay Rivers. These rivers were chosen due to their environmental significance and the presence of varying land use and land cover (LULC) types along their riverbanks.

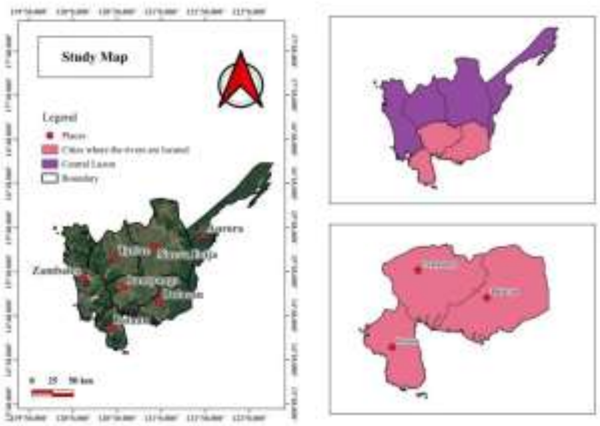

Figure 2. Location Map of the Study Area

Figure 2 illustrates the geographical location of the study area, located in Central Luzon.

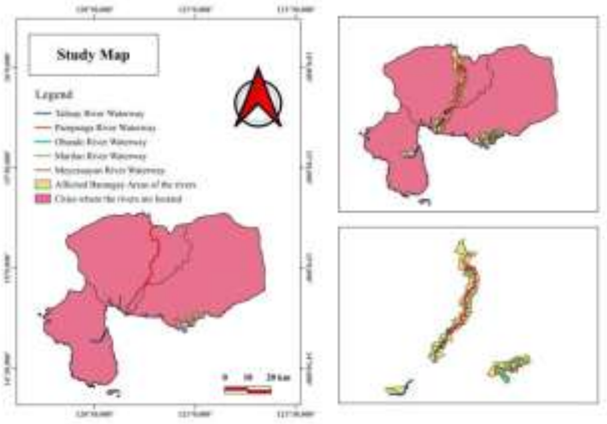

Figure 3. Study Area Map

As shown in Figure 3, this map presents the detailed boundaries of the selected river systems and the affected barangays along it.

III.III Data Sources

Table 1. Data Sources Used in the Study

Dataset	Source	Year	Purpose
Water Quality	DENR	2020	Compliance Assessment
LULC	Geoportal PH	2025	Surrounding Land Use
River Layers	Geoportal PH	Latest	Mapping

Table 1 presents the datasets used in the study, including water quality data obtained from the Department of Environment and Natural Resources (DENR) for the year 2020 and land use and land cover (LULC) data sourced from Geoportal Philippines for 2025. Land use and land cover (LULC) data were obtained from Geoportal Philippines and used to represent the dominant surrounding land use conditions of the study areas. The temporal alignment between LULC data and water quality data may not be exact; therefore, the analysis is based on general spatial patterns.

III.III GIS Procedure

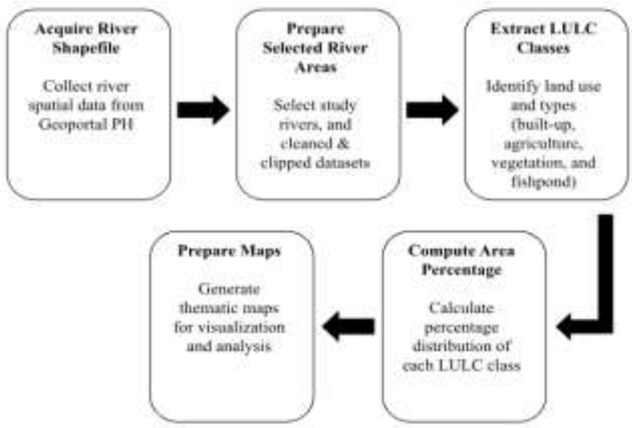

Figure 4. GIS Procedure of the Study

Figure 4 presents the GIS workflow of the study, illustrating the systematic process used to analyze the relationship between land use and water quality. It outlines the key steps, from data acquisition and preparation to spatial analysis and map generation, providing a clear overview of how GIS techniques were applied to produce reliable and organized results.

III.V Water Quality Standard Reference

According to DENR-Administrative Order 2016-08 (2016). Classification of Water Bodies. For purposes of maintaining water quality according to its intended beneficial usage, the following classification of water bodies shall be adopted.

Table 2. Classification of Water Bodies According to DAO 2016-08 (2016)

Class	Meaning/Intended Use
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 only approved disinfection to meet the latest PNSDW
A	Public Water Supply Class II – Intended as sources of water supply requiring conventional treatment (coagulation, sedimentation, filtration and disinfection) to meet the latest PNSDW
B	Recreational Water Class I – Intended for primary contact recreation (e.g., swimming, bathing)
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
D	Navigable waters

Table 3. Class C Water Quality Standard Used in the Study

Parameter	Standard
Dissolved Oxygen (DO)	≥ 5
Biochemical Oxygen Demand (BOD)	≤ 7
pH	6.5-9.0
Total Suspended Solid (TSS)	≤ 80
Fecal Coliform	≤ 200
Nitrate (NO3-N)	≤ 7
Phosphate (PO4-P)	≤ 0.5

III.VI Data Analysis

The analysis in this study focused on evaluating the relationship between land use and land cover (LULC) and water quality compliance of selected Class C rivers in Central Luzon using Geographic Information System (GIS) techniques and descriptive statistical methods. The process involved organizing both spatial and non-spatial data to generate interpretable results and meaningful environmental insights.

Parameter Compliance Checking

Water quality data for 2020 were obtained from the Department of Environment and Natural Resources (DENR). Each measured parameter, including Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), pH, Fecal Coliform, Nitrate (NO3-N), and Phosphate (PO4-P) was compared against the DENR Administrative Order No. 2016-08 standards for Class C waters. These standards were used to determine whether the observed values complied (/) or did not comply (X) with acceptable thresholds. For each river, compliance frequencies were tabulated and summarized to identify which parameters commonly exceeded allowable limits.

Comparison of Rivers

Inter-river comparisons were made to assess differences in water quality across sites. The frequency and degree of non-compliance were computed to rank rivers according to overall water quality condition. Rivers with higher numbers of non-compliant parameters were considered more environmentally stressed. Descriptive interpretation was provided to highlight spatial variations in pollution levels among the rivers.

LULC Interpretation

Using GIS, land use and land cover data from Geoportal PH (2025) were clipped to standardized 500-meter buffer zones surrounding each selected river. This buffer distance was applied to represent the immediate land use conditions around each monitoring station, consistent with standard spatial analysis practices. Area statistics of each LULC class (e.g., built-up, agriculture, fishpond, vegetation, and others) were computed and expressed as percentages of the total buffer area. The resulting spatial layers were visualized in LULC maps to illustrate dominant land uses per river catchment, which may be associated with the observed water quality conditions and suggest general spatial patterns within the study areas.

Exceeding Analysis

To explore possible relationships between surrounding land use and water quality, a descriptive spatial comparison was performed. The proportion of built-up, agricultural, or fishpond areas near each river was compared with patterns of parameter exceedance. Trends and associations, such as high built-up coverage with low DO and high BOD or Fecal Coliform levels, were identified qualitatively. These interpretations were used to infer potential sources of pollution attributable to particular land use types.

Interpretation and Synthesis

The results of spatial analysis and compliance checking were synthesized to evaluate how varying LULC patterns may contribute to observed differences in water quality among the rivers. Findings were summarized in tables and maps to facilitate visual comparison and policy-oriented interpretation. The overall analysis provided a spatially grounded basis for recommending management actions that align land-use planning with water quality protection objectives.

RESULTS AND DISCUSSIONS

IV.I LULC Maps of Selected Rivers

Marilao River

Figure 5 shows the spatial distribution of land use and land cover types within the Marilao River.

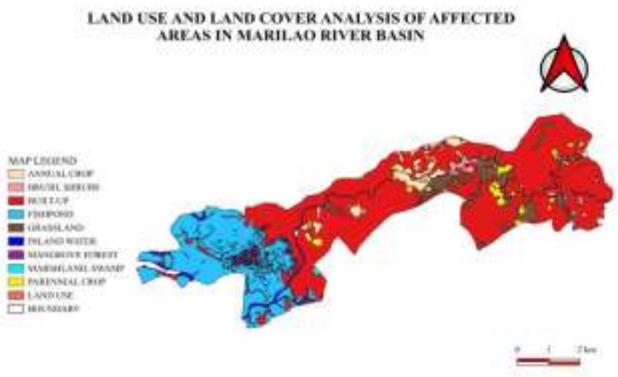

Figure 5. LULC Map Near Marilao River

The map indicates that built-up areas dominate the Marilao River, covering approximately 59% of the total area. This suggests a high level of urbanization, which may contribute to increased runoff and pollution.

Meycauayan River

Figure 6 illustrates the arrangement of different land use and land cover categories across the Meycauayan River basin.

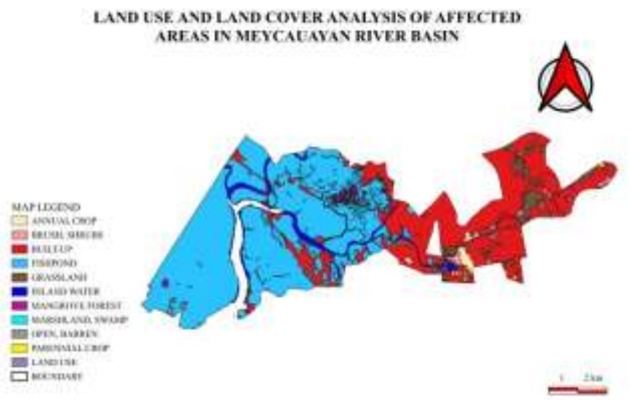

Figure 6. LULC Map Near Meycauayan River

The map indicates that fishpond areas dominate the Meycauayan River, reflecting extensive aquaculture activities within the area. This suggests that the river system is heavily influenced by economic land use, which may affect natural water flow and ecological balance.

Obando River

Figure 7 presents the geographic distribution of land use and land cover types in the Obando River.

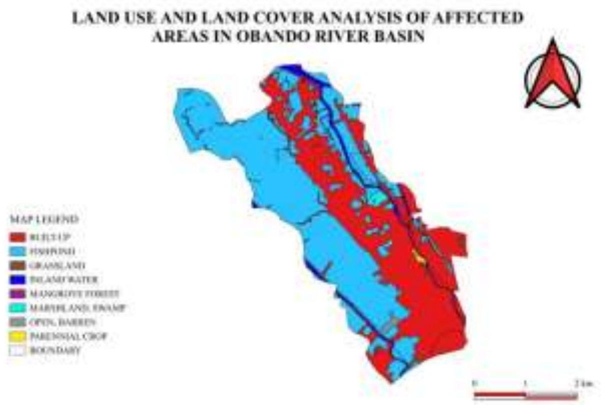

Figure 7. LULC Map Near Obando River

The map shows that fishponds and built-up areas dominate the Obando River, indicating strong coastal and aquaculture influence. This suggests that the area is primarily utilized for fish production and is closely connected to nearby coastal ecosystems.

Pampanga River

Figure 8 shows the spatial pattern of land use and land cover across the Pampanga River basin.

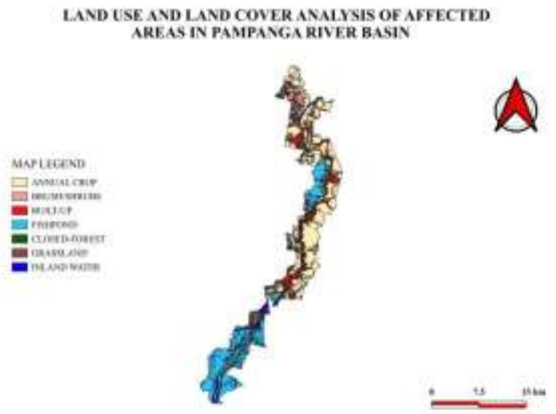

Figure 8. LULC Map Near Pampanga River

The map indicates that annual crops and built-up areas dominate the Pampanga River, suggesting a less urbanized environment compared to other rivers. This reflects the presence of rural landscapes and farming activities within the area.

Talisay River

Figure 9 highlights the distribution and extent of land use and land cover types in the Talisay River area.

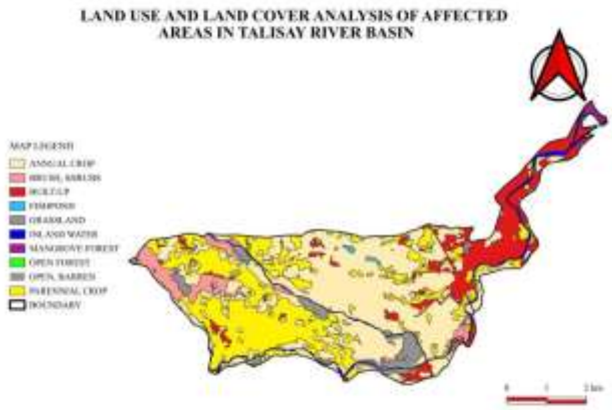

Figure 9. LULC Map Near Talisay River

The map shows a mixed distribution of land use and land cover in the Talisay River, with both built-up and annual crops areas present. This indicates moderate development and a balance between natural and urban land uses.

IV.II LULC Summary

Table 4. Dominant Land Use and Land Cover Classes of Selected River Areas

Selected Rivers	Built-up (%)	Agriculture (%)	Fishpond (%)	Vegetation (%)	Other Land Cover (%)	Total (%)	Dominant LULC
Marilao River	59.0	5.9	22.5	10.1	2.5	100.0	Built-up
Meycauayan River	31.7	1.2	55.7	7.1	4.3	100.0	Fishpond
Obando River	41.9	0.2	52.2	2.4	3.3	100.0	Fishpond
Pampanga River	9.8	54.9	7.1	19.5	8.7	100.0	Agriculture
Talisay River	13.3	73.2	0.3	9.3	3.9	100.0	Agriculture

IV.III Water Quality Compliance per River

Table 5. Water Quality Compliance of Marilao River Based on Class C Standards

Parameter	Mean Value	Standard	Compliance
DO	2.026	≥5	X
BOD	39.723	≤7	X
TSS	24.125	≤80	/
pH	7.795	6.5-9	/
Fecal	3761650.0	≤200	X
NO3	0.397	≤7	/
PO4	1.885	≤0.5	X

Table 5 presents the water quality parameters of Marilao River based on Class C standards. The results indicate multiple non-compliant parameters, particularly dissolved oxygen (DO), biochemical oxygen demand (BOD), fecal coliform, and phosphate.

The low DO level suggests oxygen depletion, commonly associated with high organic pollution. Similarly, the elevated BOD value indicates a significant presence of biodegradable organic matter. Fecal coliform concentrations are extremely high and far exceed the Class C standard, pointing to severe microbiological contamination likely originating from domestic sewage, industrial discharge, and urban runoff. Phosphate levels also exceed the allowable limit, suggesting nutrient enrichment.

In contrast, total suspended solids (TSS), pH, and nitrate comply with Class C standards. The recomputed pH value falls within the acceptable range (6.5–9.0), confirming that the river does not exhibit abnormal acidity or alkalinity.

Overall, Marilao River is classified as highly environmentally stressed, with primary concerns related to organic and microbial pollution.

Table 6. Water Quality Compliance of Meycauayan River Based on Class C Standards

Parameter	Mean Value	Standard	Compliance
DO	0.781	≥5	X
BOD	64.8	≤7	X
TSS	33.7	≤80	/
pH	7.648	6.5-9	/
Fecal	13809250.0	≤200	X
NO3	0.195	≤7	/
PO4	1.947	≤0.5	X

As shown in Table 6, Meycauayan River exhibits significant water quality degradation. The data reveal non-compliance in DO, BOD, fecal coliform, and phosphate.

The very low DO and extremely high BOD indicate intense organic pollution. Fecal coliform levels are critically elevated, confirming contamination from untreated wastewater sources. Phosphate exceedance further suggests nutrient loading from aquaculture and urban discharge.

However, TSS, nitrate, and pH are in acceptable limits. The pH values indicate normal conditions.

These findings indicate that the Meycauayan River is severely impacted by organic pollution and microbial contamination, making it one of the most environmentally stressed rivers in the study.

Table 7. Water Quality Compliance of Obando River Based on Class C Standards

Parameter	Mean Value	Standard	Compliance
DO	17.35	≥5	/
BOD	31.029	≤7	X
TSS	19.04	≤80	/
pH	7.138	6.5-9	/
Fecal	427430.642	≤200	X
NO3	0.451	≤7	/
PO4	0.49	≤0.5	/

Table 7 summarizes the water quality data for the Obando River. The results show a mixed compliance pattern.

Dissolved oxygen meets the Class C standard, suggesting relatively adequate oxygen levels. However, BOD exceeds the allowable limit, indicating the presence of organic pollutants. Fecal coliform levels significantly above the standard, pointing to persistent microbial contamination.

Meanwhile, TSS, nitrate, and pH comply with the standards. The pH value falls within the acceptable range.

Overall, Obando River demonstrates moderate environmental stress, with key issues involving organic matter, nutrient enrichment, and bacterial contamination.

Table 8. Water Quality Compliance of Pampanga River Based on Class C Standards

Table 8. Water Quality Compliance of Pampanga River Based on Class C Standards

Parameter	Mean Value	Standard	Compliance
DO	2.999	≥5	X
BOD	13.067	≤7	X
TSS	66.733	≤80	/
pH	8.032	6.5-9	/
Fecal	46706.667	≤200	X
NO3	0.657	≤7	/
PO4	0.252	≤0.5	/

The water quality results for Pampanga River are presented in Table 8. Compared to other rivers, Pampanga River shows relatively better conditions, although some parameters remain non-compliant.

Dissolved oxygen and BOD do not meet the required standards, indicating moderate organic pollution and oxygen depletion. Fecal coliform levels exceed the allowable limit, confirming microbial contamination.

On the other hand, TSS, pH, nitrate, and phosphate comply with Class C standards. The calculated pH value falls within the acceptable range.

These results suggest that Pampanga River is in a relatively better condition, although microbial pollution and oxygen imbalance remain in concern.

Table 9. Water Quality Compliance of Talisay River Based on Class C Standards

Parameter	Mean Value	Standard	Compliance
DO	4.694	≥5	X
BOD	13.432	≤7	X
TSS	15.868	≤80	/
pH	7.189	6.5-9	/
Fecal	1105454.175	≤200	X
NO3	0.212	≤7	/
PO4	0.068	≤0.5	/

Table 9 presents the water quality parameters for Talisay River. The river exhibits partial compliance with Class C standards.

TSS and nitrate are within acceptable limits. However, DO, BOD, fecal coliform, and phosphate are non-compliant. The low DO and elevated BOD indicate moderate organic pollution. High fecal coliform levels suggest contamination from domestic and agricultural sources. The pH value is within the acceptable range

Overall, Talisay River is classified as having moderate environmental stress, primarily due to organic, nutrient, and microbial pollution.

IV.IV Comparative River Summary

Table 10 presents a side-by-side comparison of the water quality compliance status of the five selected Class C rivers in Central Luzon based on seven key parameters. The comparison uses a simplified relative condition rating Poorer or Moderate to describe each river's overall standing in relation to the others. This is a comparative classification only and does not represent an official DENR water quality status.

Table 10. Comparative Compliance Summary of Selected Rivers

River	DO	BOD	TSS	Fecal Coliform	Nutrients (NO3/PO4)	Relative Condition
Marilao	X	X	/	X	X / X	Poorer
Meycauayan	X	X	/	X	/ / X	Poorer
Obando	X	X	/	X	/ / /	Poorer
Pampanga	X	X	/	X	/ / /	Moderate
Talisay	X	/	/	X	/ / /	Moderate

Note: **/** = Compliant; **X** = Non-compliant. Relative conditions are comparative only, not official DENR status.

The results indicate that all rivers exhibit non-compliance in multiple parameters, although the degree of environmental stress varies. Marilao and Meycauayan Rivers are identified as the most environmentally stressed, characterized by high BOD, extremely elevated fecal coliform levels, and low DO.

Obando River shows moderate stress, with compliance in DO but continued issues in BOD, phosphate, and fecal coliform. Pampanga and Talisay Rivers demonstrate relatively better conditions, with more parameters meeting standards; however, both exhibit consistent fecal coliform exceedance and low DO.

A key finding from the data is that pH values across all rivers fall within the acceptable range, indicating that acidity is not a dominant issue.

Overall, fecal coliform and dissolved oxygen emerge as the most critical parameters, highlighting widespread sanitation and wastewater management concerns.

IV.V LULC and Water Quality Observed Patterns

Table 11 summarizes the observed relationships between the dominant land use and land cover (LULC) classifications surrounding each river and the water quality parameters that consistently failed to meet Class C standards. These associations are descriptive and based on spatial proximity and observed data patterns; they do not establish direct causal relationships.

Table 11. Observed Land Use and Water Quality Patterns

River	Dominant LULC	Common Non-Compliant Parameters	Notable Pattern
Marilao	Built-up (59%)	DO, BOD, Fecal Coliform, PO4	High urbanization associated with elevated organic load, bacteria, and phosphate; consistent with BOD and coliform stress from residential/industrial runoff
Meycauayan	Fishpond (55.7%)	DO, BOD, Fecal Coliform, PO4	Aquaculture dominance linked to nutrient enrichment; very high BOD and coliform values may reflect fish waste and effluent discharge
Obando	Fishpond (52.2%)	BOD, Fecal Coliform	Fishpond-dominated area contributing to elevated BOD and fecal coliform levels, likely due to organic waste accumulation and untreated aquaculture discharge. Coastal fishpond influence is evident, with pollution primarily linked to effluent runoff.
Pampanga	Agriculture (54.9%)	DO, BOD, Fecal Coliform	Agricultural land may contribute runoff with sediment and bacteria; BOD remains non-compliant, although overall organic pollution is lower compared to highly urbanized rivers
Talisay	Agriculture (73.2%)	DO, BOD, Fecal Coliform	Predominantly agricultural with better nutrient compliance; moderate DO deficiency and coliform exceedance may be linked to livestock or irrigation practices

Rivers dominated by built-up land use, such as Marilao River with 59% urban cover, showed the most severe exceedances in organic pollution indicators including BOD, fecal coliform, and phosphate. The high density of impervious surfaces in urbanized areas reduces infiltration and increases surface runoff, allowing domestic wastewater, sewage, and solid waste to flow more readily into river channels (Kent Anson Locke, 2024). This pattern is consistent with Marilao's elevated BOD of 39.725 mg/L and fecal coliform levels that are orders of magnitude above the standard.

Rivers where fishponds are the dominant land use, specifically Meycauayan (55.7%) and Obando (52.2%), also recorded severe non-compliance in DO, BOD, pH, and fecal coliform. Aquaculture activities introduce organic waste through uneaten feed and fish excretions, which decompose in the water and deplete dissolved oxygen levels (Cheng et al., 2022). The very high BOD recorded in Meycauayan (64.8 mg/L) is consistent with this pattern of organic enrichment associated with intensive aquaculture.

In contrast, rivers surrounded predominantly by agricultural land use Pampanga (54.9% annual crops) and Talisay (73.2% annual crops) displayed relatively better compliance in BOD and nutrient parameters, though DO deficiency and fecal coliform exceedance persisted. Agricultural areas may contribute lower volumes of dissolved organic waste compared to urban or aquaculture zones, but they remain sources of microbial contamination through livestock waste and irrigation return flows (Shiferaw et al., 2025). The presence of some vegetation cover (19.5% in Pampanga; 9.3% in Talisay) may also offer partial buffering against runoff-driven pollutant loading.

IV.VI Discussion

The findings of this study reveal that all five selected Class C rivers in Central Luzon failed to meet DENR DAO 2016-08 water quality standards across multiple parameters in 2020, with dissolved oxygen deficiency and fecal coliform exceedance being the most consistent concerns across all sites. These results align with documented patterns of water quality degradation in Philippine rivers, where inadequate wastewater management, rapid urbanization, and agricultural intensification have collectively contributed to declining river health (Pleto et al., 2020; Robles & Monjardin, 2025).

Low dissolved oxygen levels observed in several rivers suggest the presence of high organic loads, which consume oxygen during decomposition processes. This condition is commonly associated with the discharge of untreated domestic wastewater, industrial effluents, and organic wastes from surrounding land uses. Elevated biochemical oxygen demand (BOD) values further support this observation, indicating significant levels of biodegradable organic matter in the water.

Fecal coliform exceedance was observed across all study sites, pointing to persistent contamination from human and animal waste. This pattern suggests inadequate wastewater treatment and sanitation infrastructure in areas surrounding the rivers. The consistent presence of fecal contamination across different land use types indicates that microbial pollution is a widespread concern and not limited to a specific environment.

In contrast, most rivers showed compliance with total suspended solids (TSS) and nitrate, suggesting that sediment loads and certain nutrient levels are generally within acceptable limits. Phosphate levels, however, were elevated in some rivers, particularly those influenced by aquaculture and urban activities, indicating localized nutrient enrichment.

A key finding of this study is that pH values across the selected rivers generally fall within the acceptable range for Class C waters. This indicates that acidity or alkalinity is not a dominant factor affecting water quality in the study area. Instead, the primary concerns are related to organic pollution and microbial contamination.

The spatial analysis of land use and land cover (LULC) provides further insight into the observed water quality patterns. Rivers surrounded by highly urbanized areas, such as Marilao River, tend to exhibit higher levels of BOD and fecal coliform, reflecting the influence of domestic sewage, commercial activities, and surface runoff from impervious surfaces. These findings are consistent with previous studies indicating that urban land use contributes significantly to organic and microbial pollution in river systems. Similarly, rivers dominated by fishponds, such as Meycauayan and Obando, show elevated levels of BOD and phosphate. This suggests that aquaculture activities contribute to nutrient and organic loading through fish waste, uneaten feed, and pond effluents. These inputs can lead to increased oxygen demand and nutrient enrichment in receiving water bodies. Rivers surrounded by agricultural land, such as Pampanga and Talisay, generally demonstrate better compliance in terms of BOD and nutrient parameters. However, the persistence of fecal coliform exceedance and low DO levels indicates that agricultural practices, including livestock farming and irrigation runoff, still contribute to water quality degradation.

Overall, the results of this study support the conclusion that land use patterns are associated with variations in water quality conditions. However, it is important to note that these relationships are observational and do not establish direct causation. Other factors, such as hydrological conditions, seasonal variation, and upstream pollution sources, may also influence river water quality. The findings highlight the need for integrated water resource management strategies that address both land use planning and wastewater management. Improving sanitation infrastructure, regulating effluent discharge, and promoting sustainable land use practices are essential steps toward enhancing water quality in the rivers of Central Luzon.

CONCLUSION

V.I Summary

This study assessed the relationship between land use and land cover (LULC) and water quality compliance of selected Class C rivers in Central Luzon using Geographic Information Systems (GIS) and secondary data from the Department of Environment and Natural Resources (DENR). The analysis showed that the selected rivers are characterized by distinct dominant land use patterns. Marilao River is primarily built-up, covering 59.0% of the surrounding area, indicating a highly urbanized environment. Meycauayan and Obando Rivers are dominated by fishponds, accounting for 55.7% and 52.2%, respectively, reflecting strong aquaculture influence. In contrast, Pampanga and Talisay Rivers are largely agricultural, with 54.9% and 73.2% of their surrounding areas devoted to agricultural land use.

The water quality results indicate that none of the five rivers fully comply with Class C standards. Dissolved oxygen (DO) and fecal coliform are the most consistently non-compliant parameters across all sites. Marilao and Meycauayan Rivers exhibit the most severe water quality conditions, characterized by low DO levels, high biochemical oxygen demand (BOD), and elevated fecal coliform concentrations. Obando River shows moderate conditions, while Pampanga and Talisay Rivers demonstrate relatively better compliance in several parameters, particularly TSS and nitrate.

The findings further indicate that land use patterns are associated with observed water quality conditions. Rivers with high proportions of built-up and fishpond areas tend to exhibit greater levels of organic and microbial pollution, while agricultural areas show comparatively lower organic pollution but still contribute to microbial contamination.

V.II **Conclusions**

Based on the findings of the study, the following conclusions are drawn:

1. The selected rivers exhibit distinct land use characteristics, with built-up areas dominating Marilao River (59.0%), fishponds dominating Meycauayan (55.7%) and Obando (52.2%), and agricultural land dominating Pampanga (54.9%) and Talisay (73.2%). These variations reflect different types of human activities influencing river conditions.
2. None of the five rivers fully meet the Class C water quality standards, indicating widespread environmental stress across the study area.
3. Dissolved oxygen deficiency and fecal coliform contamination are the most consistent and critical issues across all rivers, highlighting problems related to organic pollution and inadequate wastewater management.
4. Marilao and Meycauayan Rivers are the most environmentally stressed due to their high levels of urbanization and aquaculture activity, while Pampanga and Talisay Rivers are in relatively better condition but still show signs of contamination.
5. The findings suggest a possible observable association between surrounding land use patterns and river water quality conditions. Rivers with higher percentages of built-up and fishpond areas tend to exhibit more severe organic and microbial pollution, while agricultural areas show moderate impacts but still contribute to contamination.

V.III Recommendations

1. The Department of Environment and Natural Resources (DENR) should strengthen monitoring and enforcement of wastewater discharge regulations, particularly in Marilao and Meycauayan Rivers, where pollution levels are most severe.
2. Local Government Units (LGUs) should improve land use planning and zoning regulations, especially in highly urbanized (59.0% built-up) and aquaculture-dominated areas (over 50% fishpond), to reduce pollutant inputs into river systems.
3. The establishment and rehabilitation of riparian buffer zones of at least 20–50 meters are recommended, especially in highly urbanized sections of Marilao and Meycauayan Rivers, to help reduce surface runoff and filter pollutants before they enter river systems.
4. Regular water quality monitoring should be conducted using consistent and accurate data handling methods to ensure reliable results.
5. Future studies should incorporate field sampling and laboratory validation to strengthen the accuracy of findings and better identify pollution sources.
6. Efforts should be made to align land use and water quality datasets to improve the reliability of environmental assessments.

ACKNOWLEDGMENT

The researchers would like to express their sincere gratitude to the individuals and institutions who contributed to the completion of this study entitled "**GIS-Based Assessment of Land Use and Water Quality Compliance of Selected Class C Rivers in Central Luzon, Philippines**".

To their course instructor and adviser **Engr. Rosel Verdadero-Babalcon** who provided guidance and support and delivered essential feedback during the study process. The research findings improved through her expertise and research supervision that she provided throughout the investigation.

To the **Department of Environment and Natural Resources** (DENR) for supplying the water quality data used in this study, and to **Geoportal Philippines** for providing the land use and spatial data which enabled the GIS analysis to take place.

The researchers would like to recognize the efforts and cooperation of **each member of the group** for their collaboration, dedication, and shared effort in completing this study.

In addition, the researchers extend their gratitude to all the **unspoken names** behind this project who contributed in little ways that this study made it possible. To their classmates, friends, and families for their encouragement and support throughout the research process.

Above all, the researchers offer their deepest thanks to **God** for His guidance, strength, and wisdom, which made the completion of this study possible.

Finally, the researchers are grateful for the opportunity to conduct this study, which contributed to their knowledge and understanding in the field of civil engineering and environmental analysis.

REFERENCES

1. Chatrabhuj, Meshram, K., Mishra, U., & Omar, P. J. (2024). Integration of remote sensing data and GIS technologies in river management system. Discover Geoscience, 2(1). https://doi.org/10.1007/s44288-024-00080-8
2. Cheng, C., Zhang, F., Shi, J., & Kung, H.-T. (2022). What is the relationship between land use and surface water quality? A review and prospects from remote sensing perspective. Environmental Science and Pollution Research, 29. https://doi.org/10.1007/s11356-022-21348-x
3. Chidiac, S., El Najjar, P., Ouaini, N., El Rayess, Y., & El Azzi, D. (2023). A Comprehensive Review of Water Quality Indices (WQIs): history, models, Attempts and Perspectives. Reviews in Environmental Science and Bio/Technology, 22(2). https://doi.org/10.1007/s11157-023-09650-7
4. Department of Environment and Natural Resources. (2016). Water quality guidelines and general effluent standards of 2016 (Administrative Order No. 2016-08). https://pab.emb.gov.ph/wp-content/uploads/2017/07/DAO-2016-08-WQG-and-GES.pdf
5. NOAA Fisheries. (2020). River Habitat | NOAA Fisheries. https://www.fisheries.noaa.gov/national/habitat-conservation/river-habitat
6. Kent Anson Locke. (2024). Impacts of land use/land cover on water quality: a contemporary review for

researchers and policymakers. Water Quality Research Journal of Canada. https://doi.org/10.2166/wqrj.2024.002

7. Laranjo, R. D., Naguit, M. R. A., Jamolod, F. C., Jambre, K. G. E., Cabornay, N. I., Bernido, V. B., & Gahisan, M. D. S. (2023). Evaluation of the physicochemical parameters on the water quality of the major rivers of Zamboanga del Norte, Philippines. AIMS Environmental Science, 10(3), 382–397. https://doi.org/10.3934/environsci.2023022
8. Leong, S., Ismail, J., Denil, N., Sarbini, S., Wasli, W., & Debbie, A. (2018). Microbiological and Physicochemical Water Quality Assessments of River Water in an Industrial Region of the Northwest Coast of Borneo. Water, 10(11), 1648. https://doi.org/10.3390/w10111648
9. Mahe, A., Nasiru Salihu, & Sani, M. M. (2024). Perspective Chapter: Physicochemical Parameters and Water Quality. IntechOpen EBooks. https://doi.org/10.5772/intechopen.1006354
10. Mapili, M. C. (1996). Land-use and water quality : a GIS evaluation of the problems, interaction, and initiatives, in the Pampanga River Basin, Central Luzon, Philippines. Open.library.ubc.ca. https://open.library.ubc.ca/soa/cIRcle/collections/ubctheses/831/items/1.0087872
11. Mercado, M. J., Cai, W., Futalan, C. C., Ligaray, M., & Choi, A. E. S. (2024). Water Quality Assessment of Mananga River Using Principal Component Analysis. Philippine Journal of Science, 153(2). https://philjournalsci.dost.gov.ph/wp-content/uploads/2024/04/water-quality-assessment-of-Mananga-River-using-principal-component-analysis_.pdf
12. Pleto, J. V., Migo, V., & Arboleda, M. D. (2020). Preliminary Water and Sediment Quality Assessment of the Meycauayan River Segment of the Marilao-Meycauayan-Obando River System in Bulacan, the Philippines. Journal of Health and Pollution, 10(26), 200609. https://doi.org/10.5696/2156-9614-10.26.200609
13. Robles, K. P. V., & Monjardin, C. E. F. (2025). Assessment and Monitoring of Groundwater Contaminants in Heavily Urbanized Areas: A Review of Methods and Applications for Philippines. Water, 17(13), 1903. https://doi.org/10.3390/w17131903
14. Shiferaw, N., Habte, L., & Waleed, M. (2025). Land use dynamics and their impact on hydrology and water quality of a river catchment: a comprehensive analysis and future scenario. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-025-35946-y
15. United Nations. (2023). Water Quality and Wastewater. UN-Water. https://www.unwater.org/water-facts/water-quality-and-wastewater
16. Yan, C.-A., Zhang, W., Zhang, Z., Liu, Y., Deng, C., & Nie, N. (2015). Assessment of Water Quality and Identification of Polluted Risky Regions Based on Field Observations & GIS in the Honghe River Watershed, China. PLOS ONE, 10(3), e0119130. https://doi.org/10.1371/journal.pone.0119130
17. Zhang, C., Sargent, I., Pan, X., Li, H., Gardiner, A., Hare, J., & Atkinson, P. M. (2019). Joint Deep Learning for land cover and land use classification. Remote Sensing of Environment, 221, 173–187. https://doi.org/10.1016/j.rse.2018.11.014