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MARIA CELIA CLAVE-CABASAL

GIS-BASED SPATIO-TEMPORAL ANALYSIS OF LAND COVER CHANGES IN BARANGAY MONTE CALVARIO WITHIN THE BUHI-BARIT WATERSHED, BUHI, CAMARINES SUR (2015-2024)

Special Problem Adviser:

KARL ABELARD EDBERTO L. VILLEGAS, JR.
Faculty of Management and Development Studies

01 August 2025

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Maria Celia Clave-Cabasal and 01 August 2025
Signature over Student Name and Date

Acceptance Page

This Special Problem of **MARIA CELIA CLAVE-CABASAL** titled **"GIS-BASED SPATIO-TEMPORAL ANALYSIS OF LANDCOVER CHANGES IN BARANGAY MONTE CALVARIO WITHIN THE BUHI-BARIT WATERSHED, BUHI, CAMARINES SUR (2015-2024)"** is hereby accepted by the Faculty of Management and Development Studies, U.P. Open University, in partial fulfillment of the requirements for the **Masters of Environment and Natural Resources Management**.

KARL ABELARD EDBERTO L. VILLEGAS JR. Faculty-in-charge, ENRM 290 (Special Problem)	**Date**

KARL ABELARD EDBERTO L. VILLEGAS JR. Program Chair	**Date**

FINAFLOR F. TAYLAN, DPROFST
Dean
Faculty of Management and Development Studies

Date

DECLARATION

This is to certify that:

I. The special problem comprises only my original work towards the MENRM except where indicated in the Preface.

II. Due acknowledgement has been made in the text to all other material used.

III. The special problem is fewer than 25,000 words in length, exclusive of tables, maps, bibliographies and appendices.

Maria Celia Clave-Cabasal

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Abstract

This study titled “GIS-Based Spatio-Temporal Analysis of Land Cover Changes in Barangay Monte Calvario within the Buhi-Barit Watershed, Buhi, Camarines Sur (2015– 2024)” examined the spatial and temporal patterns of land cover transformation and their implications for watershed health and sustainability. Using Geographic Information Systems (GIS), Sentinel-2 satellite data, and National Power Corporation (NAPOCOR) land cover maps, the research analyzed environmental dynamics over a nine-year period. The findings revealed a dominant tree cover that expanded from 83% in 2017 to nearly 90% in 2024, reflecting ecological regeneration and reforestation efforts. However, concurrent increases in built-up areas and transitions in cropland and rangeland underscore continuing anthropogenic pressures from agriculture and settlement expansion.

The integration of ground truthing proved vital to the accuracy of this study, as field validation uncovered misclassified features such as informal housing, mixed cropping systems, and degraded lands inaccurately represented in satellite imagery. These findings highlighted the limitations of remote sensing alone in heterogeneous rural landscapes and reinforced the need for a hybrid approach that combines geospatial analysis with on-site verification. Recommendations emphasize adopting a hybrid monitoring framework that institutionalizes regular ground truthing alongside satellite- based classification to improve land use mapping, policy planning, and watershed governance. Such integration ensures data accuracy, supports participatory management, and strengthens adaptive, community-based environmental strategies.

Ultimately, the study contributes to developing sustainable and climate-resilient land use policies that balance ecological preservation and local development within the Buhi-Barit Watershed system.

Keywords: Land Cover Changes; Spatial; Temporal Patterns; Geographics Information Systems (GIS); Environmental Dynamics

I. INTRODUCTION

Watersheds are vital for preserving natural balance and delivering basic services like disaster relief, biodiversity preservation, and water supply. Watersheds are essential to maintaining hydropower production, agricultural operations, and the availability of drinking water in the Philippines. On the other hand, growing human activities like urbanization, agricultural growth, and deforestation have resulted in substantial changes in land cover that affect the dynamics of watersheds. Assessing and tracking land cover transitions over time is crucial since these changeshave an impact on soil stability, hydrologicalprocesses, and the general health of ecosystems (Lasco & Pulhin,2019). Geographic Information Systems (GIS) and remote sensing haveemerged as usefulinstrumentsfor assessingspatiotemporal changesin landcover, offering the insights required for sustainable watershed management in light of these difficulties (Ming et al., 2021).

Changes in land cover have an impact on runoff, sediment transport, and water infiltration, among other watershed processes. Research conducted shows that urbanization and deforestation have exacerbated soil erosion and flood risks by increasing surface runoff and decreasing groundwater recharge (Cruz et al., 2020). For example, studies conducted in the Pampanga River Basin found that changes in land cover from 1996 to 2016 were linked to more frequent floods and worsened soil conditions (David et al., 2019). Similar to this, research by Rodriguez and Palma-Torres (2023) emphasized the necessity of proactive land use planning by highlighting the detrimental consequences of agricultural growth on watershed resilience. These results highlight how important it is to track changes in land cover in order to reduce environmental hazards and guarantee the long-term viability of watersheds. The Buhi-

Barit Watershed, Buhi, Camarines Sur, is a vital ecological zone that supports both natural and human systems in the Rinconada region. It is a sub - watershed of the larger Rinconada Watershed and encompasses key features such as Mt. Malinao, Lake Buhi, and the Barit River. This watershed plays a critical role in providing irrigation, domestic water supply, and hydropower through the National Power Corporation’s (NAPOCOR) hydropower facilities. It supports multiple land cover types including forests, croplands, rangelands, and built-up areas, which are essential to the economic and ecological functions of the area.

Recent studies have highlighted the challenges facing Philippine watersheds, including the Buhi-Barit, such as deforestation, agricultural expansion, and urbanization, which contribute to biodiversity loss and increased vulnerability to disasters (Lasco et al., 2010). The integration of Geographic Information Systems (GIS) and remote sensing has become indispensable for assessing spatio-temporal changes in land cover, supporting better land use planning and watershed management (Estoque & Murayama, 2010). Ensuring the sustainable management of the Buhi-Barit Watershed is crucial for securing water resources, preserving ecological integrity, and enhancing climate resilience in the region.

Land cover transition analysis and detection have been successfully accomplished with GIS and remote sensing. Researchers can categorize land cover types, identify changes over time, and evaluate their effects on watershed health by using high-resolution satellite imagery (Pérez- Vega et al., 2020). Guillermo and Makinano-Santillan (2022) used remote sensing techniques to analyze the Marikina sub-watershed and found increases in urbanization and deforestation. This information is crucial for watershed management strategies.

A different study conducted in Bohol used GIS-based morphometric analysis to describe the characteristics of watersheds, providing important information about how land cover and watershed resilience are related (Salvador et al., 2021). Located on the slopes of Mount Malinao in Buhi, Camarines Sur, Barangay Monte Calvario is an ecologically significant location that has seen considerable changes in land cover in recent decades. Mount Malinao provides essential water for nearby villages, meeting their home and agricultural needs. Watershed stability is challenged by growing land use pressures, especially those resulting from deforestation and agricultural growth (Narisma et al., 2018). Developing conservation plans and sustainable land management policies requires an understanding of the magnitude and effects of these changes.

The purpose of this study is to analyse the land cover changes in Barangay Monte Calvario from 2015 to 2024 using a GIS-based spatiotemporal approach. In particular, it aims to categorize different forms of land cover, spot trends in change, assess how they affect the resilience of watersheds, and offer policy suggestions for sustainable management. Detailed land cover maps for 2015 and 2024, an examination of change detection trends, and an evaluation of the effect of land cover transitions on watershed resilience are among the anticipated results of this study. The study also intends to offer policy suggestions to improve watershed management techniques and aid regional conservation efforts.

Located on the slopes of Mount Malinao in Buhi, Camarines Sur, Barangay Monte Calvario is an ecologically significant location that has seen considerable changes in land cover in recent decades. Mount Malinao provides essential water for nearby villages, meeting their home and agricultural needs. Watershed stability is challenged by growing land use pressures, especially those resulting from deforestation and agricultural growth (Narisma et al., 2018). Developing conservation plans and sustainable land management policies requires an understanding of the magnitude and effects of these changes.

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II. REVIEW OF RELATED LITERATURE

Land Cover Change and Its Implications. Changes in land cover, such as deforestation, urbanization, and agricultural growth, have a substantial effect on watershed ecological and hydrological processes. These changes can impact water quality and availability for downstream ecosystems and human communities by increasing surface runoff, decreasing groundwater recharge, and increasing soil erosion.

According to a study, between 1995 and 2017, the Philippines' Agusan River Basin had a rise in agricultural lands from 12.2% to 15.5% and a decline in forest cover from 67.7% to 62.8%. Higher discharge rates, deeper floods, and wider flood extents were the outcomes of these land cover changes, suggesting detrimental effects on the hydrologic and hydraulic behaviors of the basin (Santos et al., 2023).

Land degradation has spread to 15 million square kilometers, an area larger than Antarctica, at a startling rate of 1 million square kilometers every year. This deterioration jeopardizes attempts to maintain sustainable food supply, conserve biodiversity, and moderate the climate. In the last ten years, unsustainable farming methods have decreased the land's ability to absorb carbon dioxide by 20%, contributing to 80% of the loss of forests and accelerating climate change (The Guardian, 2024).

Furthermore, evaluations of biodiversity's sensitivity to climate change heavily depend on change in land use and land cover. According to a comprehensive assessment, by changing habitats and ecosystem services. These alterations may make species more vulnerable to climate change. Developing successful conservation strategies requires integrating land cover dynamics into vulnerability assessments

(Zhang et al, 2022).

These results highlight the need for integrated policy measures and sustainable land management techniques to lessen the negative impacts of shifting land cover on watershed dynamics and overall environmental health.

Ecological changes in watershed areas are largely caused by changes in land cover. According to Borelli et al. (2020), the natural equilibrium of water absorption and runoff is disrupted when land use shifts from forest to agricultural or urban. Research indicates that forested watersheds exhibit reduced runoff levels and higher infiltration rates in contrast to regions that have been transformed into agricultural or populated areas (Huang et al., 2020). This change immediately affects downstream water bodies and nearby towns by raising the danger of flooding, decreasing groundwater recharge, and increasing soil erosion.

According to a study by Liu et al. (2022), deforestation worsens soil stability, which raises runoff and decreases water retention. According to Pérez-Maqueo et al. (2021), increased agricultural production decreases groundwater recharge and degrades soil, which impacts the availability of water downstream. Comparable trends have been noted in tropical watersheds, where long-term water security is at risk due to unregulated land use changes.

Recent research further highlights how important land use planning is for reducing adverse effects. According to Abell et al. (2022), afforestation and sustainable agricultural practices can enhance watershed resilience and lessen soil erosion. Similarly, community-managed forestlands have lower rates of deforestation than privately held lands, according to a study by Qi et al. (2023) that looked at how land tenure regimes affect land degradation rates.

The effects of changing land cover are made worse by climate change. Increased temperatures and changed precipitation patterns hasten soil deterioration, increasing the susceptibility of deforested watersheds to extreme weather events (Chawla et al., 2022). Weldegiorgis et al.'s research from 2023 emphasizes the necessity of adaptive watershed management strategies to mitigate these compounding effects.

Remote Sensing and GIS in Land Cover Analysis. Monitoring changes in land use over time is now much easier because to developments in geospatial technology. Researchers can accurately define and assess different forms of land cover when they use remote sensing in conjunction with GIS (Chowdhury & Maith ani, 2020). Studies by Liu et al. (2020) and Gashaw et al. (2018) show how satellite imaging may identify changes in agricultural land use, urbanization, and deforestation patterns. By enabling predictive modeling, these methods assist policymakers in foreseeing upcoming changes in land cover and the ecological effects they may have. In a recent study conducted in the Philippines, Santos et al. (2023) used high-resolution images to evaluate changes in land cover in highland watersheds and found a direct link between higher sedimentation rates and plant loss. The accuracy of identifying small changes in the landscape has increased further with the incorporation of machine learning into land cover classification (Zhang et al., 2022).

Detecting changes in land cover is made possible by remote sensing, particularly in areas where field research is not feasible because of difficult terrain and accessibility problems (Roy et al., 2021). The identification of urban sprawl, deforestation trends, and vegetation changes has been enhanced by the use of multispectral and hyperspectral satellite imagery (Sun et al., 2020). Changes in vegetation health and land use patterns over time can be effectively identified by combining Sentinel-2 and Landsat data with GIS analysis (Kouadio et al., 2021).

Machine learning techniques for classifying land cover using remote sensing data have been the subject of recent research (Mahdavi et al., 2022). Deep learning methods like Convolutional Neural Networks (CNNs), Random Forest (RF), and Support Vector Machines (SVM) have greatly increased classification accuracy in identifying minute changes in land cover. High-resolution photography and machine learning techniques provide real-time monitoring capabilities for identifying urbanization, water body loss, and deforestation (Gomez et al., 2021).

Additionally, the accuracy of land cover analysis has increased with the use of Unmanned Aerial Vehicles (UAVs) in distant sensing applications. When detecting small-scale land use changes, UAVs fitted with LiDAR and multispectral sensors offer high-resolution data that is superior to standard satellite photography (Wallace et al., 2021). These developments have been used in watershed monitoring to monitor changes in water bodies, soil erosion patterns, and vegetation health.

Climate Change and Watershed Resilience. Watershed vulnerability is further exacerbated by climate variability. In deforested watersheds, greater rainfall unpredictability exacerbates erosion and sedimentation, lowering water storage capacity and raising the danger of flooding. Typhoons and other extreme rainfall events brought on by climate change exacerbate watershed degradation in tropical areas like the Philippines, underscoring the necessity of sustainable land management techniques.

The Mananga River Watershed Reserve in Metro Cebu, Philippines, was the subject of a study that examined the spatiotemporal changes in land cover and land use from 2010 to 2020 and projected how these changes will affect flooding dynamics until 2050. According to the study, growing built-up regions increased the likelihood of flooding and surface runoff, highlighting the need for proactive land management to reduce flood risks in the future.

Dynamic ecosystems, watersheds are vital for maintaining biodiversity, controlling hydrological processes, and delivering vital ecosystem services. Nonetheless, precipitation patterns, water availability, erosion rates, and general watershed stability have all been altered by climate change, which has had a substantial impact on watershed resilience (IPCC, 2021). Temperature variations, extreme weather, and changing land use patterns all interact with natural watershed processes, frequently making the hazards of flooding, sedimentation, and water scarcity worse. With an emphasis on contemporary peer- reviewed research that investigates hydrological shifts, adaptive watershed management, and methods for improving watershed sustainability, this review looks at how climate change affects watershed resilience.

Watershed Vulnerability to Climate Extremes. Watershed resilience is seriously threatened by extreme weather phenomena like hurricanes, typhoons, and protracted droughts. These incidents worsen land degradation and upset the water distribution's natural equilibrium (Tomer et al., 2021). Climate-driven floods have increased sediment transport and deposition in rivers, decreasing reservoir storage capacities and increasing floodplain flooding, according to a review by Fan et al. (2020).

Climate change is also speeding up glacier melt in high -altitude watersheds, which impacts downstream river flow and the availability of water for urban and agricultural areas (Panday et al., 2018). Watershed stability is further weakened in tropical watersheds by increasing storm surges and high rainfall events that cause landslides and flash floods (Zhang et al., 2022).

Land Cover Change and Watershed Degradation Under Climate Stress. Watershed stability is greatly impacted by the interaction of land cover changes and climate change. Urbanization, agricultural growth, and deforestation change the natural infiltration and runoff processes, making watersheds more vulnerable to climate change (Pérez-Maqueo et al., 2021). The loss of tree cover makes watersheds more vulnerable to erosion and flash floods, while forested watersheds normally control water flow by improving infiltration and decreasing surface runoff (Liu et al., 2022).

Recent research emphasizes how changes in land cover exacerbate watershed degradation brought on by climate change. According to a research by Bonan et al. (2021), which used remote sensing data to examine how deforestation affects watershed hydrology, forest loss causes rivers to become more sedimented and soil moisture levels to drop. Water quality and ecosystem health are at risk in agricultural watersheds due to nutrient leaching and groundwater depletion caused by intensive farming methods and unpredictable rainfall patterns (Gashaw et al., 2018).

The growth of monoculture plantations in the Philippines has changed the way natural watersheds work, impacting the amount and quality of water (Hernandez et al., 2024). According to research, extensive deforestation in the watersheds that supply large river basins has accelerated siltation, reduced the effectiveness of hydroelectric dams, and resulted in urban water shortages.

Adaptive Watershed Management in the Context of Climate Change. Participatory watershed governance has been shown to improve climate resilience in an increasing amount of research. Degraded watersheds have been successfully restored through community-led watershed preservation programs, such as reforestation and sustainable land management projects (Ostrom et al., 2019). According to a case study conducted in India by Sharma et al. (2021), watershed stability and water availability in climate-vulnerable areas were greatly enhanced by combining conventional water conservation techniques with contemporary hydrological modeling.

Payment for Ecosystem Services (PES) programs have encouraged local people in the Philippines to participate in watershed conservation initiatives (Hernandez et al., 2024). By offering monetary compensation for ecosystem services that benefit water users downstream, these programs incentivize landowners to implement reforestation and soil protection measures

Future Research Directions and Policy Implications. Even while recent studies have provided light on climate change and watershed resilience, there are still a lot of unanswered questions about how hydrological changes, land cover changes, and socioeconomic factors interact over the long run. High -resolution climate models and watershed simulations should be integrated as a top priority in future research to enhance forecasts of future watershed responses under various climate scenarios (Kumar et al., 2021).

It is crucial from a policy standpoint to reinforce climate-resilient watershed management techniques. To stop watershed deterioration, governments need to invest in green infrastructure, enforce sustainable farming methods, and strengthen land-user rules. According to Panday et al. (2018), areas where rivers and water sources cross several political borders will also require collaborative climate adaption efforts, making transboundary watershed governance crucial.

Policy and Sustainable Watershed Management. In order to mitigate land degradation, community-based conservation initiatives and government policies are essential. Numerous areas have effectively adopted integrated watershed management strategies that incorporate land use planning, soil protection, and afforestation. Watershed health has been demonstrated to benefit from policies that encourage reforestation and sustainable farming methods.

The importance of participatory techniques in resource management was emphasized in a study on watershed governance in the Philippines. Reversing degradation trends and increasing water retention capacity have been accomplished through community-led projects including agroforestry and watershed preservation programs. Payment for ecosystem services (PES) programs have also encouraged landowners to embrace conservation -friendly techniques.

Policy Frameworks for Watershed Management. In order to develop sustainable watershed management techniques, policymaking is essential. Land use, water distribution, pollution management, and conservation activities are influenced by policies, which offer directives, regulatory tools, and incentives (Armitage et al., 2019). Multi-level governance systems that involve national, regional, and local stakeholders are incorporated into watershed management strategies in many nations.

Decentralized vs. Centralized Approaches. In watershed management, there are two types of governance structures: decentralized and centralized.

Centralized governance ensures consistency in implementation by having national or state authority enforce laws and regulations. However, a lack of community involvement makes top-down policies difficult to implement when dealing with local watershed issues (Bakker et al., 2019).

On the other hand, decentralized watershed governance gives local governments, NGOs, and communities the ability to take part in decision -making. Community-led watershed governance is more successful in implementing conservation plans and adjusting to local environmental conditions, according to a 2019 study by Ostrom. Decentralized watershed programs in India have effectively involved rural communities in water collection, afforestation, and soil conservation projects (Sharma et al., 2021).

Climate Change Adaptation Policies. Due to its effects on hydrological cycles, increased risk of drought and floods, and acceleration of land degradation, climate change presents serious difficulties to watershed management (IPCC, 2021). In order to mitigate these effects, policies that include climate resilience techniques in watershed governance are necessary.

Wetland restoration and agroforestry are two examples of nature-based solutions that effectively increase watershed resilience to climate change, according to a study by Xiao et al. (2022). Climate models have been integrated into adaptive watershed plans in Canada to inform decisions about water distribution, guaranteeing sustainable water use even during dry spells (Moudrak et al., 2020).

However, many nations do not have climate-focused watershed regulations, which exposes vulnerable communities to escalating dangers associated with water. For long-term watershed sustainability, it is imperative to strengthen climate adaptation strategies through data-driven decision-making and international collaboration.

Strengthening Community-Based Watershed Governance. Community-led methods to watershed management should be emphasized in future policy changes. According to Lebel et al. (2020), participatory governance guarantees that conservation plans are in line with social and economic interests, promotes local ownership, and improves the execution of policies. Promoting inclusive governance will need fortifying legal frameworks to acknowledge traditional watershed management techniques and indigenous water rights.

Leveraging Technology in Policy Implementation. New possibilities for developing watershed policies are presented by developments in artificial intelligence, geographic information systems (GIS), and remote sensing. According to Thompson et al. (2021), these technologies have the potential to improve monitoring, aid in decision-making, and strengthen the implementation of watershed conservation regulations. In order to enhance data collecting, climate modeling, and real-time water resource management, future policies should incorporate technology advancements.

Theoretical and Conceptual Framework for Policy and Sustainable Watershed Management in the Philippines. Watershed management is essential for water security, biodiversity preservation, and climate resilience in the Philippines, an archipelagic nation with 18 major watersheds and 421 important river basins. However, the sustainability of watersheds is threatened by fast deforestation, urbanization, agricultural growth, and climate change. Addressing these issues requires community involvement, institutional frameworks, and government policies. In the Philippines, government laws like the Integrated Water Resources Management (IWRM) framework, Executive Order No. 318 (Promoting Sustainable Forest Management), and the Philippine Clean Water Act of 2004 (Republic Act No. 9275) serve as guidelines for sustainable watershed management. Effective implementation of these programs is hampered by sociopolitical tensions, governance inadequacies, and lax enforcement. This section presents a theoretical framework that explains the policy mechanism shaping watershed management and a conceptual framework that identifies the key variables influencing watershed sustainability in the Philippine context.

Theoretical Framework

Institutional Theory and Multi-Level Governance. Watershed governance in the Philippines is shaped by both formal institutions (laws, policies, and agencies) and informal institutions (community norms and traditional resource management techniques), as explained by institutional theory. A multi-level governance structure governs the nation's watershed management. National agencies, including the Department of Agriculture (DA), the National Water Resources Board (NWRB), and the Department of Environment and Natural Resources (DENR), are in charge of formulating policies, while local government units (LGUs) and community-based organizations (CBOs) are in charge of carrying them out.

Water quality monitoring and pollution control are required by the Philippine Clean Water Act, but enforcement is lax because of disjointed governance and a lack of funds (Molle & Floch, 2021). Furthermore, watershed management is made more difficult by Indigenous Peoples' (IPs') ancestral domain claims under the Indigenous Peoples Rights Act (IPRA) of 1997, since legal frameworks frequently clash with traditional resource use (Rola et al., 2018). According to institutional theory, increased institutional coordination and the incorporation of community-based strategies into official governance frameworks enhance the efficacy of policies.

Adaptive Governance and Climate-Resilient Watershed Management. With an increase in typhoons, floods, and droughts that impact watersheds, the Philippines is extremely vulnerable to climate change. The necessity of adaptable, scientifically grounded, and participatory watershed management policies is emphasized by adaptive governance theory. According to studies, community-based watershed management initiatives have proven more successful than top-down government interventions. Examples of these initiatives include the Upper Marikina Watershed and the La Mesa Watershed in Metro Manila (Lasco et al., 2019)

The significance of adaptable policies is demonstrated by the example of the Ipo Watershed, which provides water to Metro Manila. Deforestation brought about by Illegal logging and encroachment has prompted multi-stakeholder partnerships in conservation and replanting initiatives, including the participation of Manila Water, Maynilad, DENR, and Indigenous Dumagat-Remontado groups. This is consistent with the adaptive governance tenets of Elinor Ostrom (2015), which emphasize decentralized administration and group decision -making.

Socioeconomic Disagreements and Political Ecology in Watershed Management. The socioeconomic and political factors that influence watershed policies are examined by political ecology theory. Degradation of watersheds in the Philippines is frequently associated with disputes between commercial interests and conservation efforts. For instance, commercial agriculture, charcoal manufacturing, and kaingin (slash -and-burn farming) are the main causes of deforestation in Nueva Ecija's Pantabangan-Carranglan Watershed (Rola & Pulhin, 2018).

Additionally, problems between businesses, indigenous groups, and environmental activists have arisen as a result of large-scale mining projects in watershed areas like Tampakan in Mindanao and Didipio in Nueva Vizcaya. Policy contradictions are shown by the Mining Act of 1995 (Republic Act No. 7942), which places a higher priority on mining extraction than watershed protection. According to Political Ecology Theory, in order to prevent environmental restrictions from uprooting underprivileged people, sustainable watershed policies must strike a balance between conservation and socioeconomic fairness.

Market-Based Conservation and Ecosystem Services Payment (PES). In order to encourage watershed conservation, the Payment for Ecosystem Services (PES) paradigm suggests financial incentives. Private sector involvement in reforestation is encouraged in the Philippines by the National Greening Program (NGP) and regional PES programs. For example, corporate sponsors are financing tree-planting efforts to offset carbon emissions as part of the Upper Marikina Watershed conservation initiative. However, research shows that PES programs work best when payments are made directly to local people, as is the case with Benguet's Bakun Indigenous Forest Guardians program (Bennagen & Javier, 2020).

Conceptual Framework

A dynamic process driven by both natural and man-made influences, land cover change has a big impact on the resilience and health of watersheds. Barangay Monte Calvario, Buhi, Camarines Sur's land cover variations over time and space are investigated in this study using remote sensing and Geographic Information Systems (GIS) from 2015 to 2024. The conceptual framework combines spatiotemporal analysis techniques, and drivers of land cover change to create a systematic understanding of how these components interact.

Changes in land cover are caused by both man-made and natural forces. Typhoons and protracted droughts are examples of extreme weather events that contribute to vegetation loss, soil degradation, and changes in water retention capacity. Climate variability, rainfall distribution, topography, and hydrological processes all influence the dynamics of land cover (Peng et al., 2020). However, human-caused elements like deforestation, increased agricultural production, infrastructural development, and unchecked land-use changes hasten land cover shifts. Watershed instability, erosion, and runoff are all exacerbated by unsustainable farming methods and rapid settlement growth (Chen et al., 2019). Decisions about land use have an impact on the sustainability of watersheds and the resilience of the environment because of these interrelated processes.

GIS-based spatiotemporal analysis is a crucial method for mapping and classification in order to methodically examine changes in land cover. Deforestation rates, urbanization patterns, and vegetation loss can all be evaluated using remote sensing methods, such as satellite imagery from Sentinel and Landsat (Müller et al., 2015). Land cover changes throughout time may be precisely quantified thanks to advanced classification techniques as supervised and unsupervised classification, normalized difference vegetation index (NDVI), and change detection algorithms (Roy et al., 2020). Additionally, hydrological modeling, soil erosion analysis, and terrain mapping are some of the watershed assessment methods that aid in assessing how land cover change affects watershed resilience.

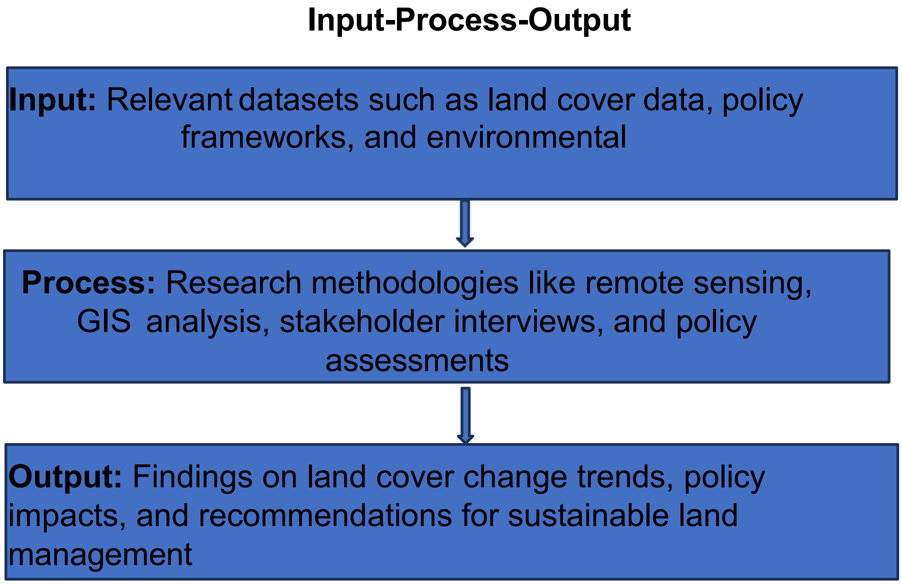
Barangay Monte Calvario's changing land cover has a direct impact on watershed dynamics, influencing runoff production, water infiltration, and sediment transport (Fan et al., 2021). In addition to causing soil erosion and sedimentation in water bodies, increased deforestation and agricultural land conversion lower

groundwater recharge capacity. These modifications impact the Buhi-Barit watershed water availability and hydrological routes. Furthermore, the growth of populated regions results in more impermeable surfaces, which lowers water infiltration and raises the risk of flooding. The watershed's general stability is jeopardized by these cumulative consequences, which also present difficulties for the sustainable management of water resources (Gashaw et al., 2018).

Policy proposals are essential for advancing sustainable land management in light of the noted changes in land cover. The goal of this research is to provide solutions that enhance long- term watershed resilience and lessen adverse environmental effects. Conservation-based land-use planning, zoning laws, and reforestation initiatives will be the main topics of the recommendations (Chowdhury & Maiti, 2021). Furthermore, using community-based resource management techniques will support watershed governance that is climate resilient, guaranteeing local people' ecological and financial survival.

This conceptual framework demonstrates how watershed dynamics, spatiotemporal analysis, and drivers of land cover change are interconnected. The study will use remote sensing and GIS techniques to empirically demonstrate changes in land cover and how they affect the health of Mount Malinao's watersheds. Evidence-based policy recommendations that aim to improve watershed resilience and sustainable land management will be based on the findings. Land cover change and its wider environmental impacts will be better-understood thanks to this study's scientific, data-driven methodology.

Figure 2.1. Research Paradigm.



Input-Process-Output

Input: Relevant datasets such as land cover data, policy frameworks, and environmental

Process: Research methodologies like remote sensing, GIS analysis, stakeholder interviews, and policy assessments

Output: Findings on land cover change trends, policy impacts, and recommendations for sustainable land management

III. STATEMENT OF THE STUDY

Changes in land cover have a major impact on watershed dynamics, affecting ecosystem stability, erosion, and water retention. The surrounding watershed, especially Mount Malinao, has probably been impacted by changes in land cover over the last ten years in Barangay Monte Calvario, Buhi, Camarines Sur. Planning for sustainable land use and conserving watersheds depend on an understanding of these spatiotemporal shifts. However, little study has been done utilizing Geographic Information Systems (GIS) and remote sensing methods to systematically investigate the extent, trends, and drivers of land cover change in this region.

Statement of the Problem

There is a need to understand how land cover in Barangay Monte Calvario, located within the Buhi-Barit Watershed, has changed over space and time from 2015 to 2024.

This study addresses this gap by analyzing spatio-temporal land cover changes during this period to inform land use planning and watershed management.

Specifically, the study seeks to:

1. What are the major land cover changes in Barangay Monte Calvario within Buhi-Barit Watershed from 2015 to 2024 based on GIS and remote sensing analysis?
2. What are the key drivers of these land cover changes, including natural and anthropogenic factors?
3. What policy or land management recommendations can be

proposed based on the observed trends in land cover change and watershed conditions?

IV. OBJECTIVES OF THE STUDY

The primary objective of this study is to conduct a GIS-based spatio-temporal analysis of land cover change in Barangay Monte Calvario, Buhi, Camarines Sur, within the Buhi-Barit Watershed from 2015 to 2024. This study aims to generate data-driven insights that can contribute to sustainable land use planning and watershed management. within the Buhi-Barit WatershesMount Malinao from 2015 to 2024. This study aims to generate data-driven insights that can contribute to sustainable land use planning and watershed management.

Specifically, the study seeks to:

1. What are the major land cover changes in Barangay Monte Calvario within Buhi Barit Watershed from 2015 to 2024 based on GIS and remote sensing analysis?
2. Identify and assess key drivers (natural and anthropogenic) influencing land cover transformations in the study area.
3. Evaluate existing land use policies and management practices in relation to observed land cover changes and watershed conditions.
4. Provide recommendations for sustainable land use and watershed conservation strategies based on the study’s findings.

V. RATIONALE

Watersheds are essential natural systems that maintain biodiversity, control hydrological cycles, and boost local economies by supplying water for domestic, industrial, and agricultural uses. However, the quick changes in land cover brought about by infrastructural development, agricultural growth, and deforestation have drastically changed the dynamics of watersheds and their capacity to deliver vital ecosystem services (Giri et al., 2021). Since watersheds are essential freshwater resources and help prevent climate-related calamities like droughts and floods, these environmental changes are especially worrisome in the Philippines (Lasco et al., 2019). In order to guarantee sustainable management techniques, the relationship between changes in land cover and watershed health requires ongoing monitoring and assessment.

This study focuses on Barangay Monte Calvario, Buhi, Camarines Sur, a key location within Buhi-Barit Watershed. The area has seen significant changes in land cover over time as a result of logging, agricultural intensification, and growing populations, all of which may have had an impact on soil stability, water retention, and overall watershed resilience. Using a GIS-based spatiotemporal analysis, this work attempts to close this research gap by mapping and quantifying changes in land cover from 2015 to 2024.

The significance of this study extends across multiple domains, particularly in environmental management and conservation. By analyzing land cover changes over time, the study will generate evidence-based findings that can guide policymakers, environmental agencies, and local government units in implementing effective watershed conservation strategies. For instance, identifying areas with high deforestation rates can help authorities prioritize reforestation initiatives and establish buffer zones to minimize environmental degradation. Likewise, understanding the impact of land cover modifications on hydrological patterns can inform the development of sustainable land use policies that balance economic activities with ecological preservation.

Furthermore, disaster risk reduction and climate adaptation can benefit from this research. Flood vulnerability, soil erosion, and the availability of water resources are all directly impacted by changes in land cover, such as deforestation and urbanization (Pradhan et al., 2020). The work will aid in climate resilience planning by evaluating these patterns, identifying regions at risk from environmental hazards, and suggesting risk-reduction tactics. The watershed system of Mount Malinao, which provides for towns below that can be vulnerable to water scarcity, sedimentation, or heightened flooding as a result of land degradation in the upland regions, is especially pertinent in this regard.

The results of this study will also help local stakeholders that rely on watershed resources for their livelihoods, such as farmers, indigenous people, and land managers, from a socioeconomic standpoint. These groups will benefit from the study's spatial data on land use trends, which will help them implement sustainable farming methods, enhance their water management plans, and promote laws that protect their access to natural resources. Furthermore, the study will encourage increased stakeholder participation in watershed conservation projects by supporting community-based environmental activities.

By combining geospatial analysis with policy evaluation, this study will scholarly add to the expanding knowledge on land cover change and watershed management in the Philippines. This study offers a localized, high -resolution analysis that gives a more thorough knowledge of environmental transitions in Barangay Monte Calvario, whereas earlier research has looked at land cover shifts at larger regional scales. The study will be a useful resource for scholars, environmental planners, and legislators working on watershed management and sustainable development initiatives since it connects the analysis of geographical data with real-world policy applications.

For Barangay Monte Calvario and the neighboring watershed areas, the ultimate goal of this study is to offer data-driven, scientifically supported insights that can promote long-term environmental sustainability. The results will support larger initiatives in disaster relief, climate resilience, and sustainable land use planning, guaranteeing that the watershed system of Buhi-Barit maintains its ecological integrity for coming generations.

VI. SCOPE AND LIMITATIONS

Scope

This study focused on the spatio-temporal analysis of land cover change in Barangay Monte Calvario within Buhi-Barit Watershed, Buhi, Camarines Sur, with a specific emphasis on the period 2015–2024. Using Geographic Information Systems (GIS) and remote sensing techniques, the research will map, quantify, and analyze changes in land cover over the selected years.

The study utilized satellite imagery from sources such as Landsat, Sentinel, and other publicly available geospatial datasets. Additionally, secondary data from government agencies, academic institutions, and environmental organizations will be incorporated to enhance the analysis. Interviews or surveys with key stakeholders such as local government units (LGUs), farmers, and conservation organizations may be conducted to gain insights into land use policies and watershed management practices.

The research explored the policy implications of land cover changes by assessing the effectiveness of existing environmental regulations, such as the Philippine Clean Water Act, the National Greening Program (NGP), and local watershed conservation initiatives. The study aimed to generate spatio-temporal maps, identify key drivers of land cover change, and provide recommendations for sustainable land use and watershed management.

Limitations

Despite its comprehensive scope, the study has several limitations that may affect the depth of analysis and the generalizability of findings:

1. Data Availability and Quality – The study relied on publicly accessible satellite imagery and government datasets. However, gaps in historical data, variations in spatial resolution, and cloud cover in satellite images may affect the accuracy of land cover classification.

2. Limited Field Validation – Due to logistical challenges and time constraints, the study may conduct only limited ground truthing activities to verify land cover classifications. Although Google Earth imagery, historical maps, and secondary reports were used to enhance validation, the accuracy of some land cover classifications may still be affected by seasonal variations and image resolution.

3. Time Constraints – Given that the research must be completed within a semester roughly three months, and extended period of 2 months for ground truthing. The analysis be limited periods of from year 2015 to year 2024. This time-bound approach ensures feasibility while still capturing significant changes over the study period. The year 2016 is not available.

VII. DESCRIPTION OF THE STUDY AREA

Location

Barangay Monte Calvario is situated in the Bicol Region (Region V) in Buhi, Camarines Sur, Philippines. Situated at roughly 13°27' North latitude and 123°30' East longitude, it is a component of the Buhi-Barit watershed system, which is essential to Mount Malinao's ecological and hydrological processes. The barangay contributes to the changing dynamics of land cover by including a varied panorama of agricultural fields, forested grounds, and growing human populations. Sustainable land use planning and efficient watershed management depend on an understanding of these changes (Cruz et al., 2019). The research region can be delineated by the use of Geographic Information System (GIS)-based spatial analysis, which also offers important insights into changes in land cover between 2015 and 2024.

Figure 7.1. Map of Buhi, Camarines Sur.

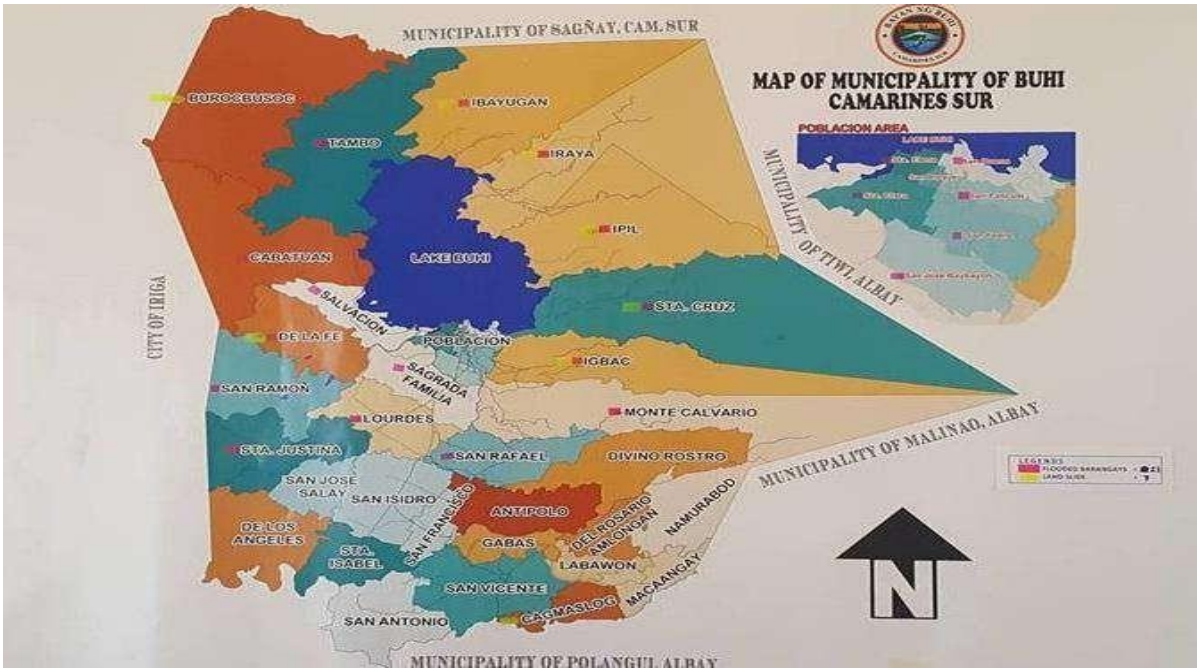


Figure 7.2. Google Earth Image of Barangay Monte Calvario and Land Cover Map Buhi-Barit Watershed Reservation.

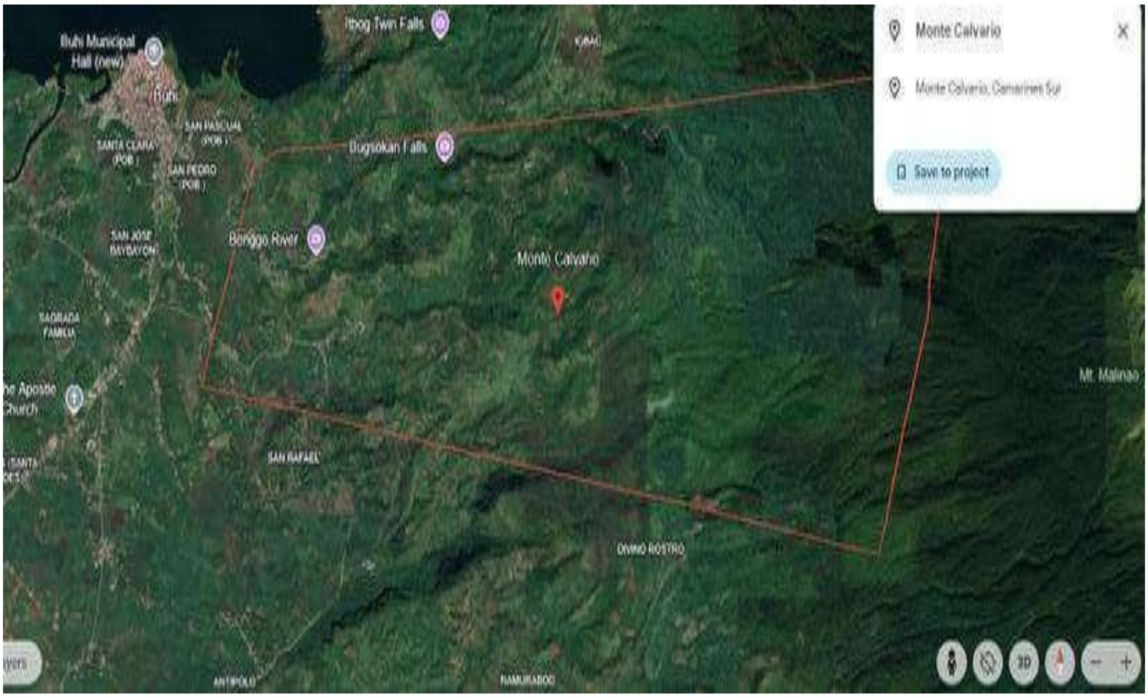
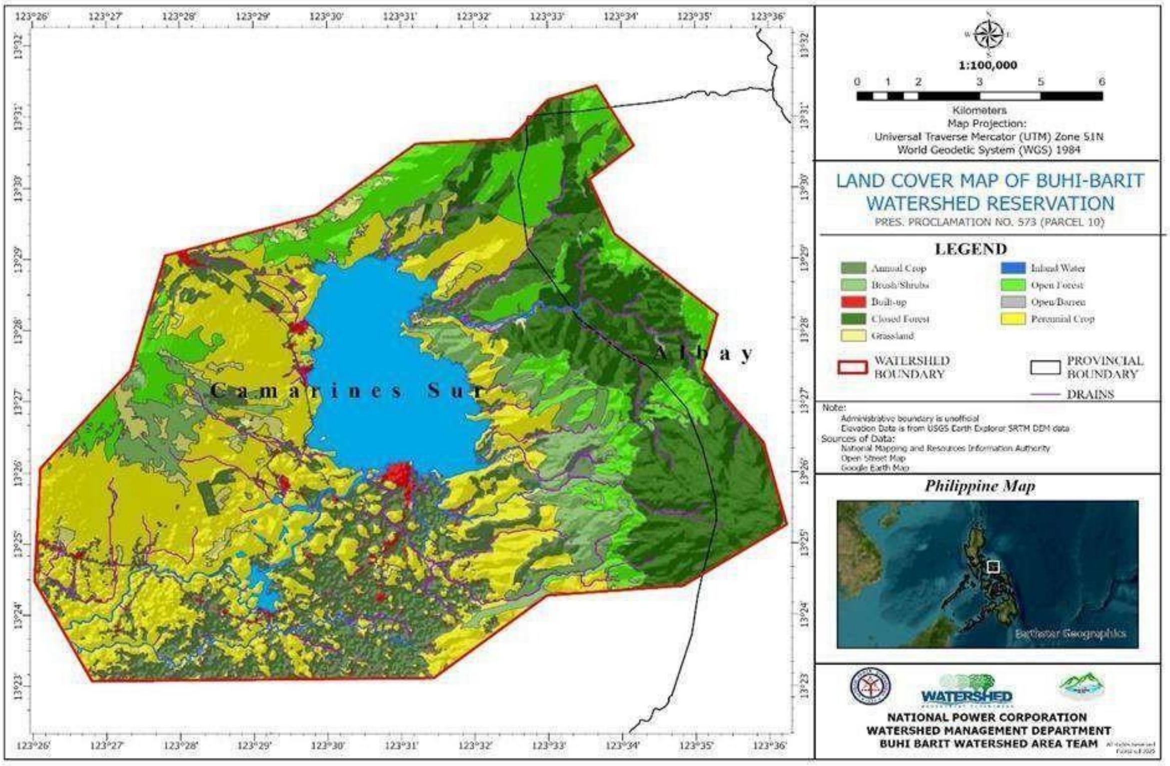


Figure 7.3. Land Cover Map Buhi-Barit Watershed Reservation.



Topography

Barangay Monte Calvario’s terrain is very diverse, with unique geographical features that affect environmental stability and land use patterns. The barangay is made up of steep upland parts that are vulnerable to soil erosion and deforestation, moderately sloping areas that support agroforestry and secondary vegetation, and lowland agricultural plains that are mainly used for rice farming and mixed cropping. Elevations vary from 100 to 800 meters above sea level, and higher elevations have a major impact on sedimentation, runoff, and the watershed’s ability to recharge. The region’s hydrological flow and geomorphology are significantly influenced by the existence of Mount Malinao, an inactive stratovolcano (David et al., 2018). Previous studies have shown that volcanic landscapes can have a significant impact on groundwater recharge and sediment transport, affecting watershed stability and resilience (Ocampo et al., 2020).

Climate

Barangay Monte Calvario is classified by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) as having a Type II climate. This group is defined by high annual rainfall, between 2,000 and 3,000 mm, with the southwest monsoon (Habagat) causing peak precipitation between June and November. The northeast monsoon, on the other hand, moderates the dry months of December through May (Amihan). Typhoons are also very common in the area, which increases the risk of flooding, soil erosion, and disturbances of land cover. These weather patterns have a direct effect on land use dynamics, vegetation regeneration, and watershed stability (Lasco et al., 2019). Studies indicate that extreme weather events and seasonal variations influence deforestation rates, agricultural expansion, and soil retention capacities, which are critical factors in watershed health assessment (Briones et al., 2020).

Description

As an essential catchment area that feeds into Lake Buhi, Barangay Monte Calvario is a component of the Buhi watershed. Because it sustains a variety of aquatic ecosystems and supplies water resources to nearby populations, this freshwater body is important both environmentally and economically. Rainfall patterns, changes in land use, and soil properties all affect the watershed's hydrological cycle, which determines the quantity and quality of water resources available to both biological systems and human settlements. Recent studies have shown that changes in land cover, including urbanization, agricultural land expansion, and deforestation, are changing the watershed's hydrological balance (Molina et al., 2021). The reduction of natural forest cover has been linked to decreased water retention capacity, increased surface runoff, and higher sediment loads in downstream areas.

Over the last ten years, there have been notable changes in the land cover in the Buhi watershed. Patterns of vegetation loss, the growth of built-up regions, and changing land use practices have been identified by remote sensing and GIS-based spatiotemporal studies. Deforestation for agricultural development, the conversion of secondary woods and grasslands into residential and commercial zones, and the use of agroforestry techniques to reduce land degradation are the main causes of these changes. Uncontrolled land use practices still contribute to soil instability and watershed vulnerability, even if agroforestry has been acknowledged as a sustainable land management strategy (Kafy et al., 2022). Understanding the long-term effects of land cover changes on watershed resilience is crucial for environmental preservation and sustainable resource management.

Barangay Monte Calvario is essential to preserving the ecological integrity of Mount Malinao and the Buhi watershed because of its advantageous location. However, the sustainability of water resources, biodiversity preservation, and the efficacy of policy interventions for watershed governance are all called into question by the observed changes in land cover. The sustainability of watersheds is threatened by increased sedimentation, modified hydrological pathways, and habitat fragmentation, all of which have been connected to changes in land use and land cover. In order to improve watershed resilience and lessen anthropogenic stresses, comprehensive environmental policies and land management techniques must be put into place (Dargantes & Torres, 2017).

Barangay Monte Calvario's changing land cover dynamics call for a policy-driven, evidence-based approach to watershed management. In order to support well-informed decision- making in land use planning and environmental sustainability initiatives, this study attempts to provide empirical data on spatiotemporal land cover changes and their effects on watershed health. A more accurate evaluation of land cover changes over time will be possible through the integration of remote sensing technology and GIS-based analysis, which will make it easier to establish adaptive management methods that will improve ecological stability and watershed resilience (Lee et al., 2021). This research will aid in the development of science-based policies targeted at sustainable watershed management and environmental conservation by elucidating the interactions among land use changes, climatic fluctuations, and watershed hydrology.

VIII. METHODOLOGY

This study employed secondary data obtained from two reliable sources: the Esri Sentinel- 2 Land Cover Explorer and the National Power Corporation (NAPOCOR) land cover maps. The Esri Sentinel-2 platform is renowned for providing high-resolution satellite imagery with a 10 to 60-meter spatial resolution, which enables detailed observation of land cover changes over time. The Sentinel-2 data serves as a critical tool for monitoring shifts in vegetation, urban development, water bodies, and other land cover types in the study area of Monte Calvario, Buhi, Camarines Sur, spanning from 2015 to 2024.

In conjunction with Sentinel-2 data, the NAPOCOR land cover maps, which offered insights into various land cover categories such as annual crops, forest types, and grasslands, provide further granularity and context for the analysis. These maps, based on satellite-based information, have been essential in understanding the historical and ongoing trends in land use and land cover changes within the region. By combining these two datasets, this study aims to identify significant spatio-temporal changes and their potential impacts on local ecosystems, agricultural practices, and urbanization.

Collection of satellite images

The collection of satellite images for this study is a crucial aspect of monitoring land cover changes in Monte Calvario, Buhi, Camarines Sur. Satellite imagery provides an efficient and non- invasive means of capturing large-scale, high-resolution data that can be used to track land cover changes over time. For this study, images were primarily sourced from the Esri Sentinel-2 Land Cover Explorer, which offers free access to satellite imagery from the European Space Agency's Sentinel-2 satellites.

To analyze the spatial and temporal changes in land cover within the study area, land cover data from 2017 to 2024 was obtained from the ESRI Sentinel imagery repository, which provides satellite-derived datasets at a 100-meter spatial resolution. These data layers were selected for their consistent annual coverage and compatibility with ArcGIS 10.5, the primary software used for spatial processing and cartographic output. The datasets, originally in raster format, were imported into ArcGIS 10.5 and preprocessed to align with the study's coordinate reference system. The clip tool was then used to extract only the portion of each yearly raster that corresponded with the designated study area boundary, ensuring that the analysis remained geographically consistent and restricted to the relevant extent.

Once clipped, the raster datasets were classified into distinct land cover categories, such as Water, Trees, Crops, Built-up Areas, Clouds and Rangelands. Each category was assigned a unique color for easy visual interpretation. The classification was consistent across all years, allowing for comparison over time.

Subsequently, a summary analysis was performed by land cover class using the "Summarize" function, which aggregated the total area (in hectares) per class. This step enabled the construction of a comparative temporal dataset that revealed land cover transitions and trends over the 2017–2024 period.

Each yearly map was then designed and laid out using ArcMap's Layout View. The layout included standard map elements such as a legend, scale bar, north arrow, and coordinate grid (latitude and longitude). This ensured that the maps were not only analytically accurate but also cartographically clear and ready for presentation or publication. The resulting outputs provide a consistent and data-driven visualization of land use patterns and changes across multiple years, serving as a valuable reference for environmental monitoring, land planning, and local governance decision -making.

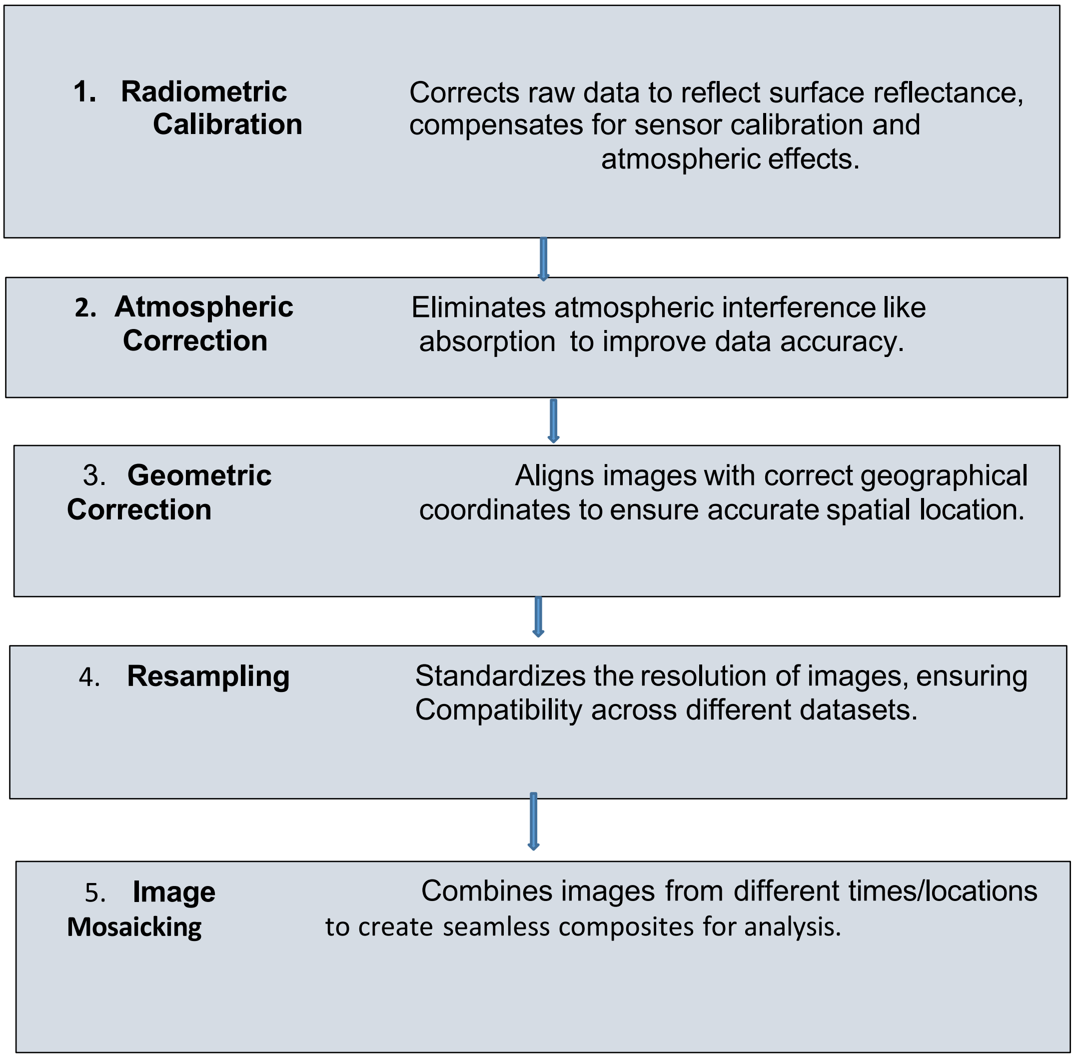
To complement the Sentinel-2 data, NAPOCOR maps, which also contain land cover information, were used for further validation. The available GIS records from NAPOCOR records covers the years 2015 and 2020, derived from officially released land cover data from National Mapping and Resource Information Authority (NAMRIA). These datasets have been validated on the ground by Buhi-Barit Watershed Area Team (BBWAT) to ensure accuracy and applicability in watershed monitoring and planning. While this data does not fully align with the requested time frame, it provided the corresponding maps focused on Barangay Monte Calvario. Together, these datasets offer a comprehensive and detailed view of land cover dynamics in the study area.

Pre-processing of satellite images

Pre-processing of satellite images is a vital step in ensuring the accuracy and reliability of the land cover analysis. This phase involves several key operations designed to improve the quality of raw satellite data and prepare it for detailed interpretation. For this study, the Sentinel-2 imagery, acquired through the Esri Land Cover Explorer, underwent various pre-processing steps to ensure consistency and suitability for land cover classification (Phiri et al, 2020).

The first step in pre-processing is radiometric calibration, which corrects the raw digital numbers of the satellite images to reflect actual surface reflectance. This step compensates for atmospheric interference, sensor calibration, and other distortions, ensuring that the data reflects true ground conditions. Atmospheric correction is also applied to eliminate atmospheric effects like scattering and absorption that can distort the spectral values of surface features. This step improves the quality of the imagery, especially in terms of vegetation and water body analysis. Next, geometric correction is performed to align the satellite images with the correct geographical coordinates. This step ensures that each pixel in the image accurately corresponds to its location on the Earth's surface, facilitating reliable spatial analysis. Images are then resampled to a uniform resolution, ensuring that all datasets from different years are compatible. Finally, image mosaicking is conducted when images from different satellites or different time periods are stitched together, creating seamless composites for the entire study area. This comprehensive pre- processing ensures that the satellite images are accurate, aligned, and ready for further analysis (Phiri et al 2020).

Figure 8.1. Pre-processing of satellite images (Phiri et al 2020).



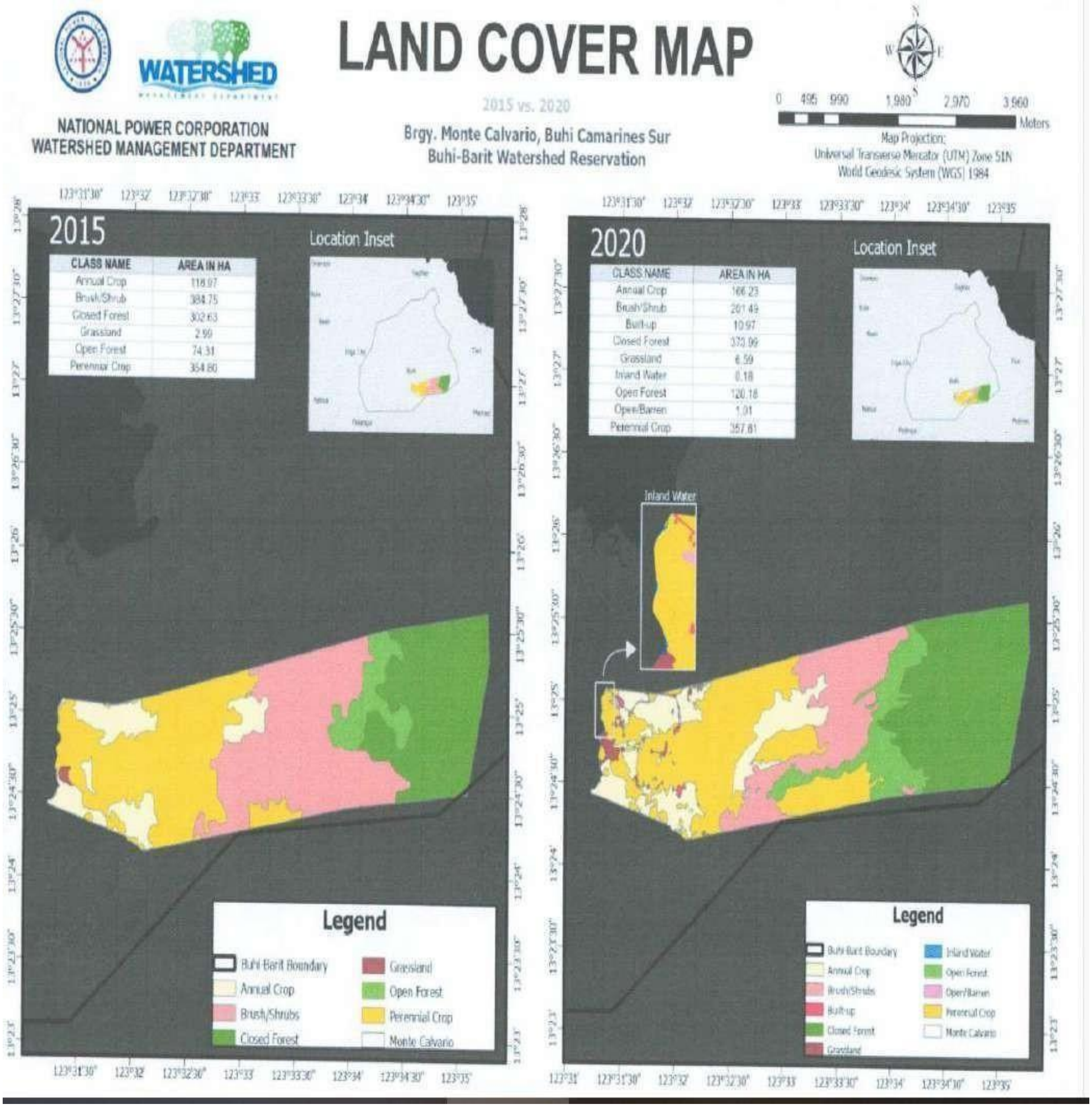
Land Cover Classification Identification

Land cover classification identification is a fundamental step in remote sensing and geographic information systems (GIS), aimed at categorizing surface features captured in satellite imagery into distinct land cover types such as forests, water bodies, croplands, urban areas, and bare lands. This process enables researchers and planners to monitor landscape changes, evaluate environmental conditions, and inform land use decisions. Classification methods are generally divided into two categories: supervised and unsupervised. In supervised classification, the analyst selects representative sample areas (training sites) for each land cover class based on prior knowledge or field data, and an algorithm assigns classes to the entire image accordingly. Common algorithms include Maximum Likelihood Classification, Support Vector Machines (SVM), and Random Forests. Conversely, unsupervised classification relies on the software to identify statistically significant clusters in the imagery without prior input, which are then labeled by the analyst post hoc (Basheer et al, 2022).

In this study, land cover classification was performed using high -resolution Sentinel-2 imagery through the Esri Land Cover Explorer, which applies advanced machine learning and cloud computing techniques to distinguish cover types. The output maps were validated against NAPOCOR data to improve accuracy. Identifying accurate land cover types is essential for analyzing trends in deforestation, urban sprawl, and agricultural transformation within Monte Calvario.

IX. RESULTS

Figure 9.1. Land Cover Map Monte Calvario (2015) based on NAPOCOR.



2015

CLASS NAME	AREA IN HA
Annual Crop	118.97
Brush/Shrub	384.75
Closed Forest	302.63
Grassland	2.99
Open Forest	74.31
Perennial Crop	354.80

2020

CLASS NAME	AREA IN HA
Annual Crop	166.23
Brush/Shrub	201.49
Built-up	10.97
Closed Forest	373.99
Grassland	6.59
Inland Water	0.18
Open Forest	120.18
Open/Barren	1.01
Perennial Crop	357.81

Table 9.1

Land Cover Monte Calvario (2015) based on NAPOCOR

Land Cover Monte Calvario (2015) based on NAPOCOR	Area in HA	Percentage (%)
Annual Crop	118.97	9.6

Brush/Shrub	384.75	31.07
Closed Forest	302.63	24.44
Grassland	2.99	0.24
Open Forest	74.31	6.00
Perennial Crop	354.80	28.65
Total	**1238.45**	**100**

In 2015, based on NAPOCOR data, Monte Calvario was characterized by a dominantly vegetated landscape. Brush and shrublands covered the largest area at 384.75 hectares, indicating early successional or regenerating vegetation. Closed forest followed with 302.63 hectares, suggesting well-preserved natural forest ecosystems. Perennial crops, likely including fruit- bearing or long-term agricultural plantations, accounted for 354.80 hectares, underscoring the importance of agriculture in the region. Annual crops occupied 118.97 hectares, supporting seasonal farming activities. Open forest (74.31 ha) and grassland (2.99 ha) were present in smaller patches, indicating limited land degradation. There is no Built-up area in this Landcover from NAPOCOR, but the Philippine Atlas population status for year 2015 reflected a total of 3,090.

Table 9.2

Land Cover Monte Calvario (2020) based on NAPOCOR

Land Cover Monte Calvario (2020) based on NAPOCOR	**Area in HA**	**Percentage (%)**
Annual Crop	166.23	13.42
Brush/Shrub	201.49	16.27

Built up	10.97	0.89
Closed Forest	373.99	30.2
Grassland	6.59	0.53
Inland Water	0.18	0.014
Open Forest	120.18	9.70
Open Barren	1.01	0.08
Perennial Crop	357.81	28.90
Total	1238.45	100

In 2020, Monte Calvario’s land cover showed noticeable shifts compared to 2015, based on NAPOCOR data. Closed forest expanded significantly to 373.99 hectares, reflecting strong forest regeneration or improved conservation. Open forest also increased to 120.18 hectares, suggesting secondary growth or partial canopy recovery. However, brush/shrub areas declined sharply from 384.75 ha to 201.49 ha, likely due to succession into forest or conversion into farmland. Annual crop areas increased to 166.23 ha, showing intensified seasonal agriculture, while perennial crop areas slightly grew to 357.81 ha. Built-up areas emerged at 10.97 ha, indicating new urban development. Grassland, open barren land, and inland water covered minimal areas, reflecting stable but slightly altered ecological conditions

The comparative land cover maps of Brgy. Monte Calvario, Buhi, Camarines Sur for 2015 and 2020 reveal significant landscape changes that reflect both environmental processes and human activities within the Buhi-Barit Watershed Reservation. The closed forest area notably increased from 302.63 hectares in 2015 to 373.99 hectares in 2020, suggesting the success of reforestation efforts, natural forest regeneration, or effective forest protection policies. Similarly, open forest coverage expanded from 74.31 ha to 120.18 ha, indicating secondary growth or the recovery of degraded lands.

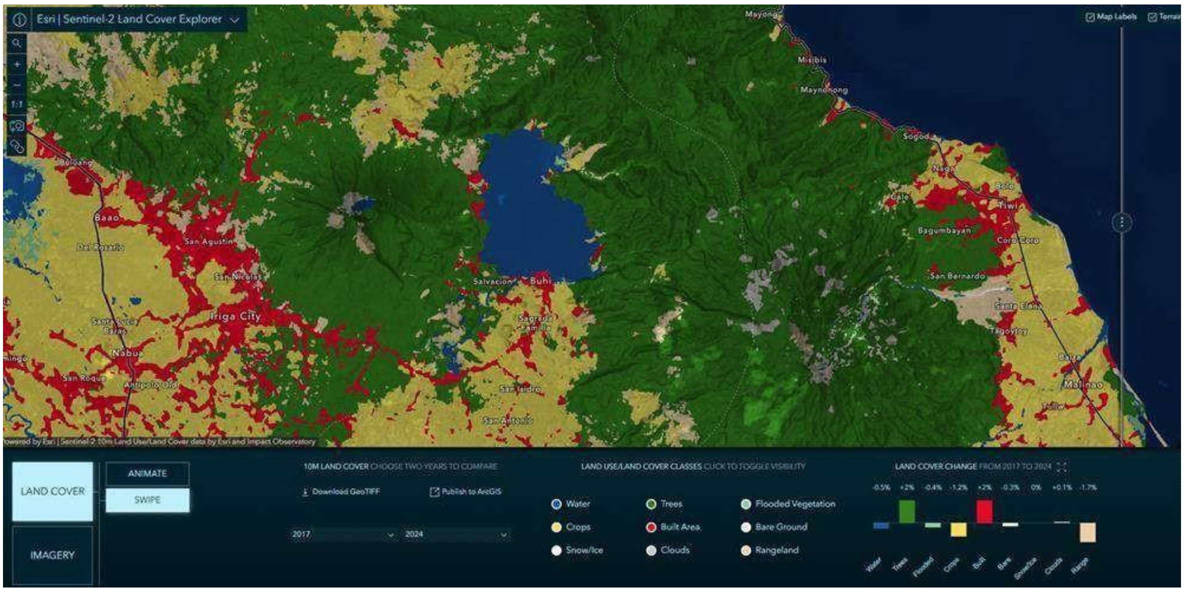
In contrast, brush/shrub cover declined markedly from 384.75 ha to 201.49 ha, potentially due to land conversion for agriculture, forest succession, or deliberate clearing. Annual crop areas also increased, from 118.97 ha to 166.23 ha, pointing to a rise in agricultural activity, possibly driven by growing livelihood needs. The perennial crop areas remained largely stable, changing only slightly from 354.80 ha to 357.81 ha, which may reflect consistent farming practices for long - term crops.

Figure 9.2. Buhi-Barit Watershed from Esri | Sentinel-2 Land Cover Explorer Swipe 2017.

From 2015 to 2020, land cover in Brgy. Monte Calvario within the Buhi-Barit Watershed showed signs of ecological restoration, with closed forest expanding by 71.36 hectares and open forest increasing by 45.87 hectares (National Power Corporation, 2020). This was accompanied by a decline in brush/shrub areas by 183.26 ha, suggesting possible reforestation or forest succession. Agricultural land, particularly annual crops, also grew, indicating intensified land use, while perennial crops remained stable.

Comparing this with the 2017–2024 regional Sentinel-2 land cover map, it can be observed a similar and complementary trends. The region around Buhi and Iriga City experienced a +2% increase in tree cover, reinforcing local forest expansion trends seen in Monte Calvario. Simultaneously, there was a -1.2% reduction in crop cover and a +2% increase in built-up areas, notably around Iriga, Nabua, and Tiwi. These shifts suggest a transition from agriculture to urban use in some zones, even as forest recovery con tinues in others. Furthermore, rangeland declined by -1.7% across the region, possibly reflecting either reforestation or urban encroachment. Minimal changes in water and bare ground areas indicate general stability in surface water bodies and undeveloped land. Together, these findings portray a dual dynamic: while urban expansion is accelerating, particularly near urban centers, upland and protected areas like Monte Calvario are witnessing forest regeneration and vegetation recovery. These trends underscore the importance of land use planning that balances development needs with ecological conservation.

Figure 9.3. Buhi-Barit Watershed from Esri | Sentinel-2 Land Cover Explorer Swipe 2024.



The Sentinel-2 land cover data between 2017 and 2024 reveals notable landscape transformations around Lake Buhi and surrounding municipalities. Most prominently, the green tree cover expanded by approximately 2%, a positive indicator of reforestation or natural forest regeneration, particularly visible around the northeastern and southeastern peripheries of Lake Buhi and the mountainous regions eastward. This aligns with local efforts in upland protection and possible reforestation campaigns.

Conversely, the crop areas declined by 1.2%, especially in lower elevation agricultural zones such as San Antonio, Nabua, and Tiwi. This reduction may reflect land conversion into urban spaces or fallow practices. Supporting this, built-up areas surged by 2%, particularly dense in the urban corridors of Iriga City, Nabua, and along the east coast of Camarines Sur, signifying growing urbanization and infrastructure development.

Notably, rangeland decreased significantly by 1.7%, which could be attributed either to reforestation or land conversion to agriculture or settlements. A slight 0.5% decrease in water bodies was observed, which may indicate seasonal fluctuations, sedimentation, or slight surface water loss—possibly related to climate or watershed degradation. In contrast, land cover classes such as bare ground, flooded vegetation, and snow/ice showed minimal or negligible changes, indicating relative ecosystem stability in those specific classes. The spread of urban expansion and loss of agricultural land mirrors national trends in rural-urban migration and the pressure of development. Taken together, the data illustrate a dual pattern: forest recovery in upland zones coupled with urban encroachment and agricultural land conversion in the lowlands. This underscores the urgent need for balanced land use policies and Integrated watershed management planning to sustain both ecological integrity and socio-economic development in Buhi and surrounding regions.

Table 9.3

Definition of Land Cover Classifications of Esri Sentinel

Name	Description
Water	Areas where water was predominantly present throughout the year; may not cover areas with sporadic or ephemeral water; contains little to no sparse vegetation, no rock outcrop nor built up features like docks; examples: rivers, ponds, lakes, oceans, flooded salt plains.
Trees	Any significant clustering of tall (~15 feet or higher) dense vegetation, typically with a closed or dense canopy; examples: wooded vegetation, clusters of dense tall vegetation within savannas, plantations, swamp

	or mangroves (dense/tall vegetation with ephemeral water or canopy too thick to detect water underneath).
Crops	Human planted/plotted cereals, grasses, and crops not at tree height; examples: corn, wheat, soy, fallow plots of structured land.
Built Area	Human made structures; major road and rail networks; large homogenous impervious surfaces including parking structures, office buildings and residential housing; examples: houses, dense villages / towns / cities, paved roads, asphalt.
Clouds	No land cover information due to persistent cloud cover.
Rangeland	Open areas covered in homogenous grasses with little to no taller vegetation; wild cereals and grasses with no obvious human plotting examples: natural meadows and fields with sparse to no tree cover, open savanna with few to no trees, parks/golf courses/lawns, pastures. Mix of small clusters of plants or single plants dispersed on a landscape that shows exposed soil or rock; scrub-filled clearings within dense forests that are clearly not taller than trees; examples: moderate to sparse cover of bushes, shrubs and tufts of grass, savannas with very sparse grasses, trees or other plants.

Figure 9.4. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2017.

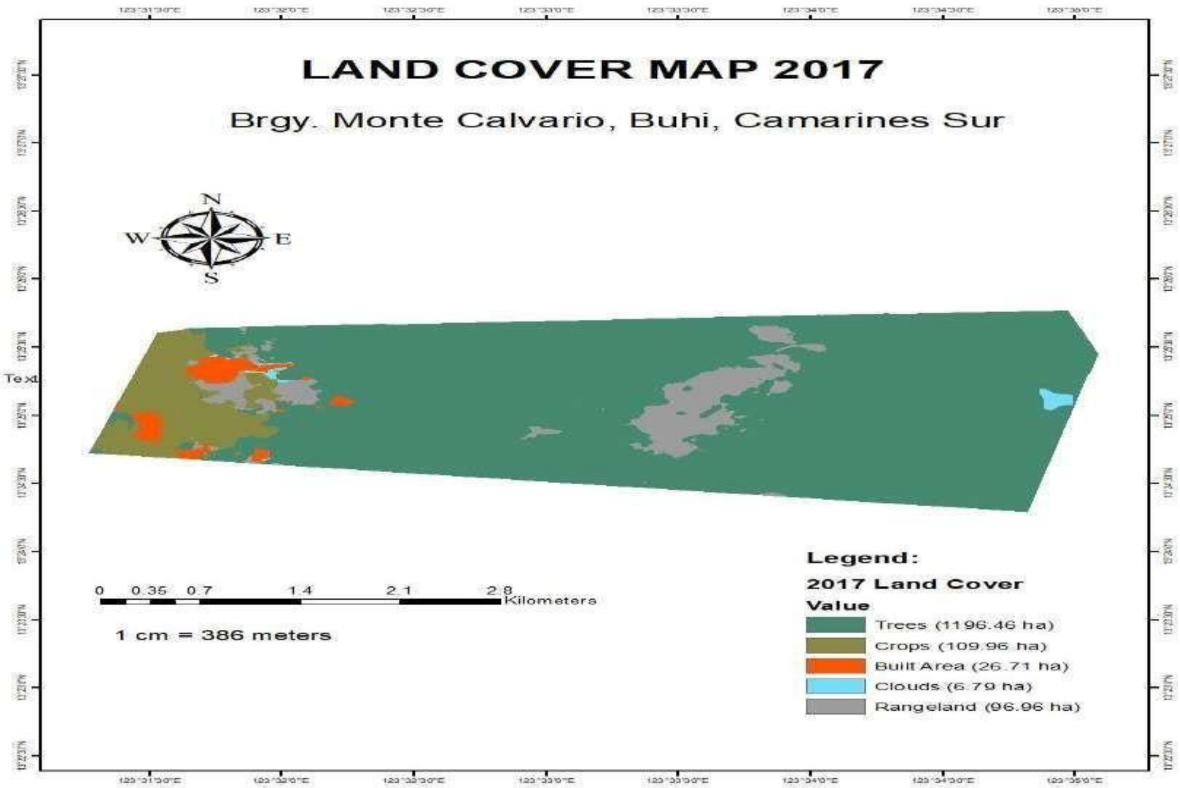


Table 9.4

Percentage Land Cover Monte Calvario (2017)

Land Cover Monte Calvario (2017) **Areas in Ha Percentage (%)**	**Areas in Ha**	**Percentage (%)**
Trees	1196.46	83.27
Built Area	26.71	1.86
Rangeland	96.96	6.75
Crops	109.96	7.65
Water	0	0
Cloud	6.79	0.47
Total	1436.88	100

Table 9.4 presents the year 2017 land cover profile of Brgy. Monte Calvario with tree cover reaching 1,196.46 hectares, approximately 83.3% of the total 1,436.88 hectares. However, this year also shows the highest recorded extent of rangeland at

96.96 hectares (6.7%), indicating potential forest degradation, overgrazing, or shifting cultivation practices—a concern previously noted in other upland areas like the Upper Pulangui Watershed (Ong & Dizon, 2021).

Cropland accounted for 109.96 hectares (7.6%), suggesting moderate agricultural. Meanwhile, built-up areas were limited to 26.71 hectares (1.9%), reflecting minimal urban or infrastructure intrusion at that time. Notably, cloud cover interference was relatively high at 6.79 hectares, which may have introduced some uncertainty in land classification results, especially for smaller or mixed-use patches.

Figure 9.5. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2018.

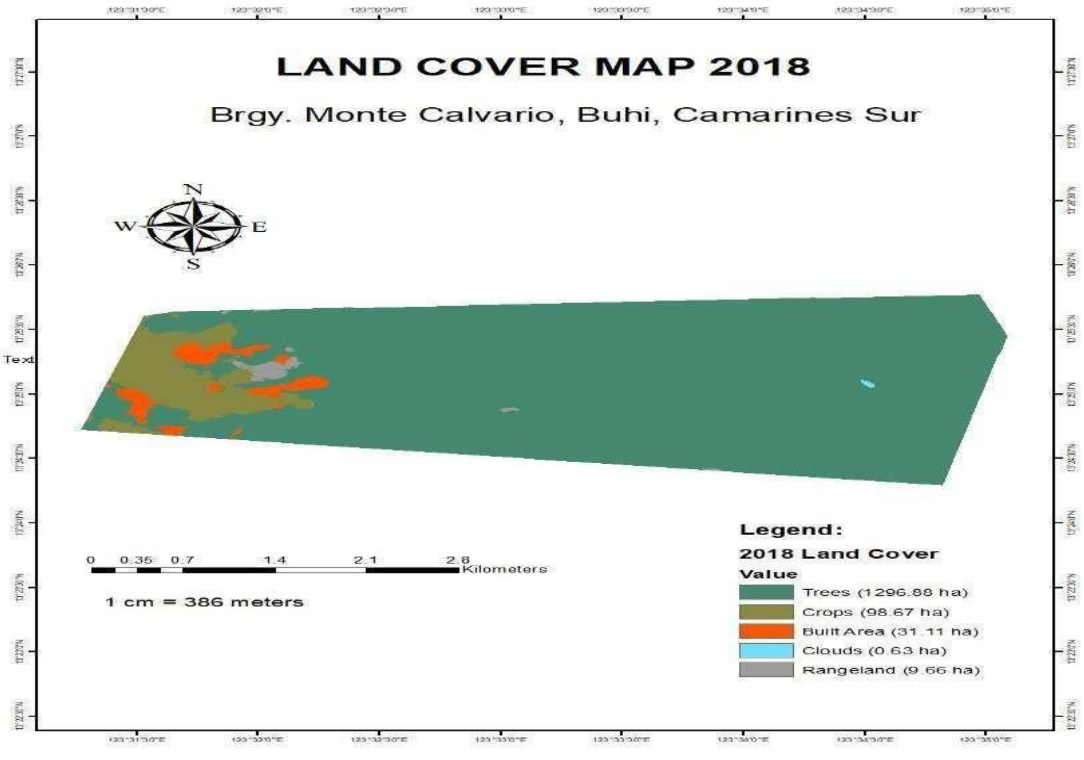


Table 9.5

Percentage Land Cover Monte Calvario (2018)

Land Cover Monte Calvario (2018)	Areas in Ha	Percentage (%)
Trees	1296.88	90.38
Built Area	31.11	2.17
Rangeland	9.66	0.67
Crops	96.67	6.74
Water	0	0
Clouds	0.63	0.04
Total	1434.95	100

The 2018 land cover distribution of Brgy. Monte Calvario reflects a period of ecological recovery and stabilization, with tree cover reaching 1,296.88 hectares, the highest recorded during the multi-year monitoring period. This accounts for approximately 90.3% of the total area. The significant forest cover supports erosion control, microclimate regulation, and hydrological functions vital for watershed management, particularly in upstream zones like Monte Calvario (Lasco et al., 2015). Built-up areas remained relatively low at 31.11 hectares (around 2.2%), suggesting limited urban expansion, possibly confined to essential infrastructure or residential development. Meanwhile, cropland declined slightly to 96.67 hectares (6.7%), which may reflect a temporary shift from cultivation to reforestation, land fallowing, or reclassification. The most notable change is the sharp drop in rangeland, from 96.96 ha in 2017 to just 9.66 hectares in 2018, suggesting significant land rehabilitation or vegetation succession, potentially aided by soil conservation efforts or reduced grazing pressure, as observed in other Philippine watersheds under reforestation programs (Dano et al., 2022). Cloud cover interference was minimal at 0.63 hectares, allowing for a high-confidence interpretation of satellite data.

Figure 9.6. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2019.

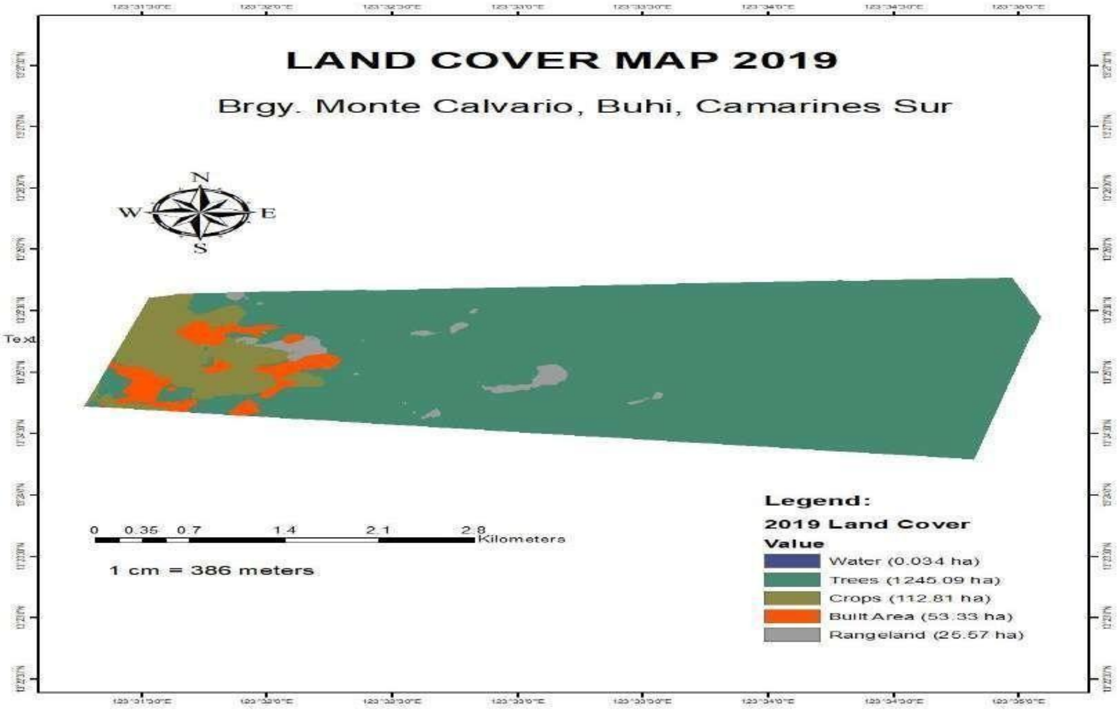


Table 9.6

Percentage Land Cover Monte Calvario (2019)

Land Cover Monte Calvario (2019)	Areas in Ha	Percentage (%)
Trees	1245.09	86.66
Built Area	53.33	3.72
Rangeland	25.57	1.78
Crops	112.81	7.85
Water	0.034	0.002
Clouds	0	0
Total	1436.83	100

Table 9.6 represents year 2019, the land cover of Brgy. Monte Calvario indicated a mixed- use landscape with both ecological strength and signs of increasing anthropogenic activity. Tree cover remained dominant at 1,245.09 hectares, accounting for approximately 86.7% of the total areas. Although slightly lower than in 2018, this still suggests a strong forest presence, essential for the protection of upstream watersheds, erosion prevention, and biodiversity conservation (Lasco et al., 2015). However, the built-up area rose significantly to 53.33 hectares (3.7%), reflecting a marked increase in infrastructure development or settlement expansion, possibly tied to population growth or road construction. This level of development pressure, if unmanaged, can lead to increased runoff, sedimentation, and watershed degradation, as observed in similar upland communities (Gonzales & Lasco, 2020).

Cropland also increased to 112.81 hectares, indicating intensified agricultural activity, which may support local livelihoods but also signals a potential encroachment Into forest or grassland zones. Rangeland, at 25.57 hectares, represents areas of low vegetation cover that could be under transitional use, such as shifting cultivation or degraded pastures.

Interestingly, 2019 was the only year where surface water was detected a minimal of 0.034 hectare suggesting either a temporary exposure of water features or seasonal variation captured in the satellite imagery. Cloud cover was absent, allowing for highly accurate classification across all categories.

Figure 9.7. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2020.

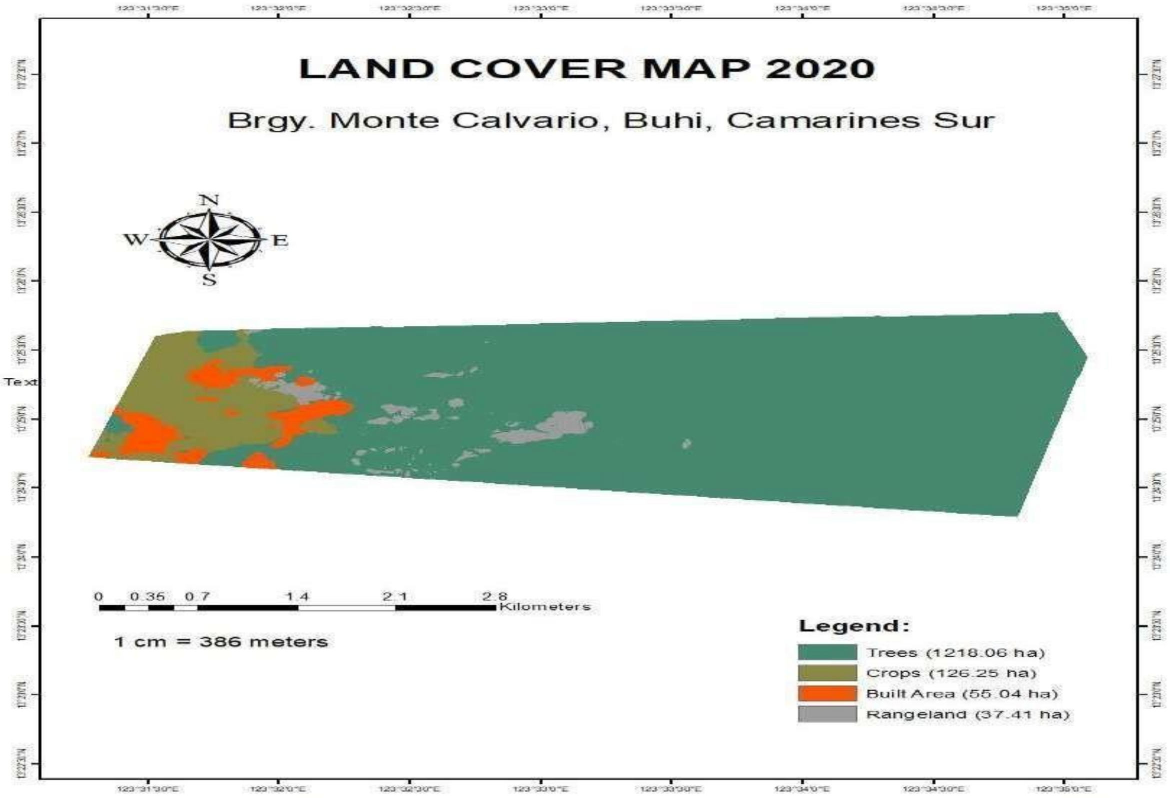


Table 9.7

Percentage Land Cover Monte Calvario (2020)

Land Cover Monte Calvario (2020)	Areas in Ha	Percentage (%)
Trees	1216.06	84.76
Built Area	55.04	3.84
Rangeland	37.41	2.61
Crops	126.25	8.80
Water	0	0
Clouds	0	0
Total	1434.76	100

The 2020 land cover data for Brgy. Monte Calvario reveals a landscape under increasing anthropogenic pressure, despite the continued dominance of forested areas. Tree cover totaled 1,216.06 hectares, comprising approximately 84.7% of the total areas. While still substantial, this represen ts a decline compared to previous years, possibly due to forest clearing for agriculture or settlements. Simultaneously, built-up areas reached their highest level in the recorded period at 55.04 hectares (3.8%), signaling a peak in urban expansion or infrastructure development, a trend that mirrors upland conversion observed in other watersheds such as the Upper Marikina (Lasco et al., 2015). This shift raises concerns about increasing impervious surfaces and their impact on runoff, flooding, and water quality. Cropland expanded to 126.25 hectares, indicating strong agricultural activity. Rangeland also rose sharply to 37.41 hectares, the highest since 2017, suggesting land degradation, shifting cultivation, or reduced forest recovery in certain zones. The combination of increased rangeland and cropland highlights potential pressures on marginal lands and points to the need for agroforestry integration or erosion control strategies to prevent further watershed decline (Dano et al., 2022). No surface water or cloud cover was recorded.

Figure 9.8. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2021.

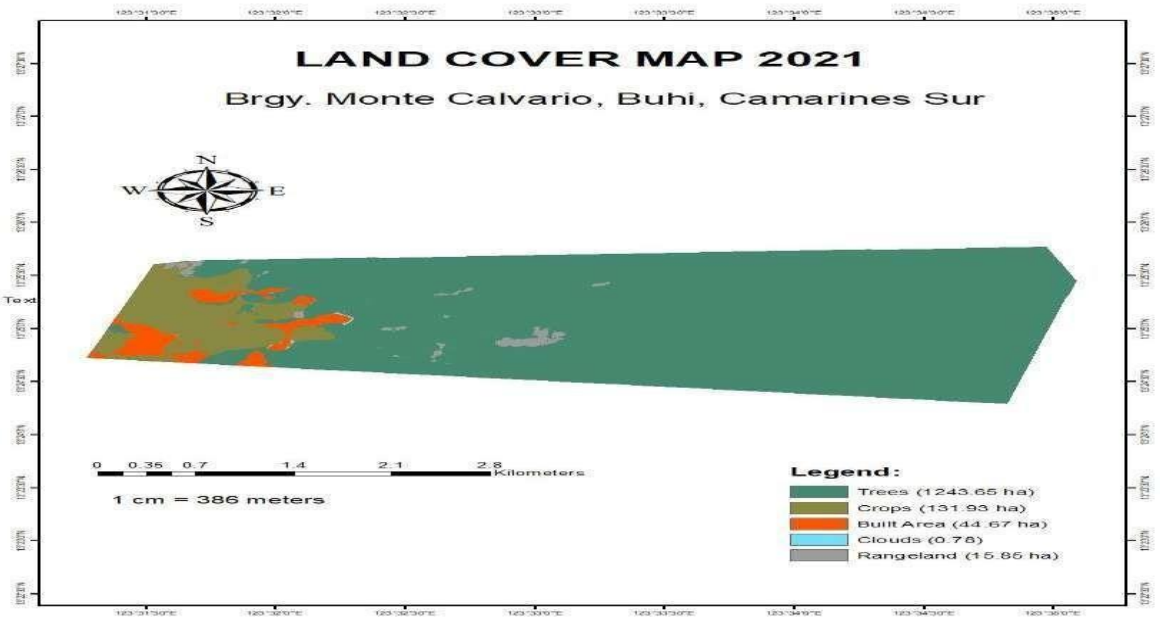


Table 9.8

Percentage Land Cover Monte Calvario (2021)

Land Cover Monte Calvario (2021)	Areas in Ha	Percentage (%)
Trees	1243.65	86.55
Built Area	44.67	3.11
Rangeland	15.85	1.10
Crops	131.93	9.18
Water	0	0
Cloud	0.78	0.054
Total	1436.88	100

In 2021, the land cover composition of Brgy. Monte Calvario reflected a partial recovery in forest cover, with trees accounting for 1,243.65 hectares, or approximately 86.6% of the total 1,436.88 hectares. This increase from the previous year suggests effective reforestation, natural regeneration, or reduced disturbance, aligning with community-based greening efforts and local ordinances promoting hillside stabilization and watershed protection (DENR, 2022). At the same time, cropland expanded to 131.93 hectares, its highest level in the recorded period, representing 9.2% of the land area. This expansion likely reflects heightened agricultural productivity and land conversion for food or income-generating purposes, which, while essential for local livelihoods, could increase risks of soil erosion and sedimentation if not managed sustainably.

Built-up areas declined to 44.67 hectares, following a peak in 2020, suggesting a slowdown in development pressure, possibly due to land saturation, zoning enforcement, or socioeconomic shifts during the COVID-19 pandemic. Rangeland significantly decreased to 15.85 hectares, supporting the hypothesis that some previously degraded or open lands may have transitioned back into cropland or secondary forest, echoing patterns seen in community-rehabilitated zones like Layawan Watershed (Dano et al., 2022).

Although cloud cover slightly increased to 0.78 hectares, it remained negligible in terms of classification reliability. No open water bodies were detected, consistent with earlier observations in the area.

Figure 9.9. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2022.

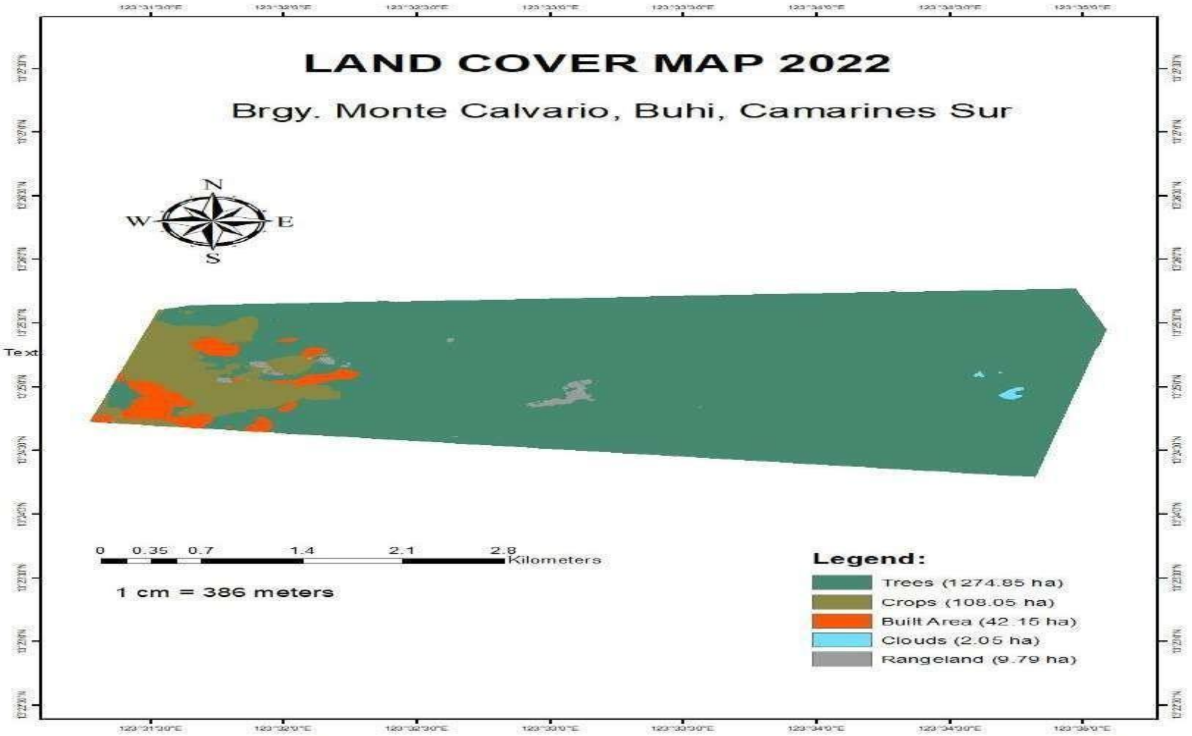


Table 9.9

Percentage Land Cover Monte Calvario (2022)

Land Cover Monte Calvario (2022)	Areas in Ha	Percentage (%)
Trees	1274.85	88.72
Built Area	42.15	2.93
Rangeland	9.79	0.68
Crops	108.05	7.52
Water	0	0
Clouds	2.05	0.143
Total	**1436.89**	**100**

The 2022 land cover data for Brgy. Monte Calvario demonstrates a continued trend toward ecological stabilization, with tree cover reaching 1,274.85 hectares, making up approximately 88.7% of the total 1,436.89 hectares. This growth from the previous year reflects effective forest recovery, potentially supported by local reforestation activities and hillside protection policies. The dense forest presence contributes significantly to watershed regulation, soil stabilization, and carbon sequestration—core functions critical for upstream ecosystems (Lasco et al., 2015; DENR, 2022).

Built-up areas slightly declined to 42.15 hectares (2.9%), suggesting a moderation in infrastructure growth, possibly due to land use controls or spatial limits in upland development. At the same time, cropland decreased to 108.05 hectares from its peak in 2021, indicating either a shift to agroforestry systems, land abandonment, or reduced farming activity. Rangeland further shrank to 9.79 hectares, the lowest since 2018, which may point to successful vegetation recovery in previously degraded areas or land use reclassification.

Figure 9.10. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2023.

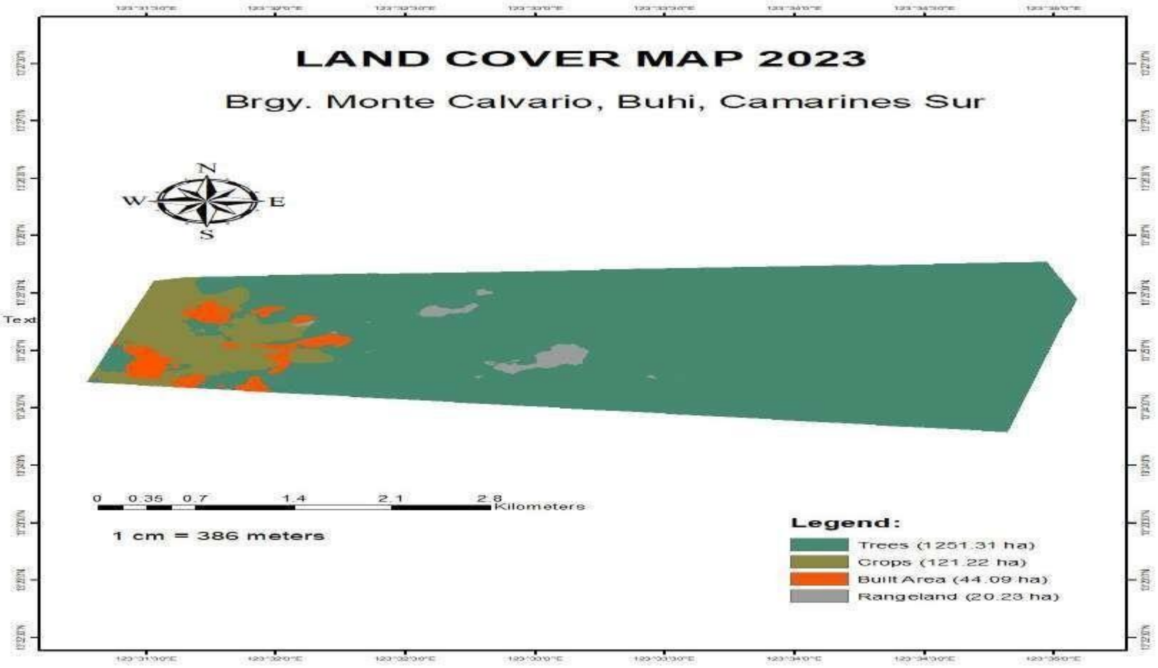


Table 9.10

Percentage Land Cover Monte Calvario (2023)

Land Cover Monte Calvario (2023)	Areas in Ha	Percentage (%)
Trees	1251.31	87.09
Built Area	44.09	3.07
Rangeland	20.23	1.41
Crops	121.22	8.44
Water	0	0
Clouds	0	0
Total	1436.85	100

The 2023 land cover data for Brgy. Monte Calvario shows a landscape largely dominated by tree cover, which spans 1,251.31 hectares, accounting for approximately 87.1% of the total land area (1,436.85 hectares). Built-up areas cover 44.09 hectares (around 3.1%), representing localized infrastructure development and possibly residential or institutional expansion. Meanwhile, cropland extends to 121.22 hectares, making up 8.4% of the land use. This figure indicates active agricultural use, which is likely essential for local livelihoods.

Rangeland is recorded at 20.23 hectares (1.4%), which may represent areas of low vegetation or mixed-use zones transitioning between agriculture and forest. No open water bodies or cloud cover were detected in the 2023 dataset.

Figure 9.11. Monte Calvario from Esri | Sentinel-2 Land Cover Explorer 2024

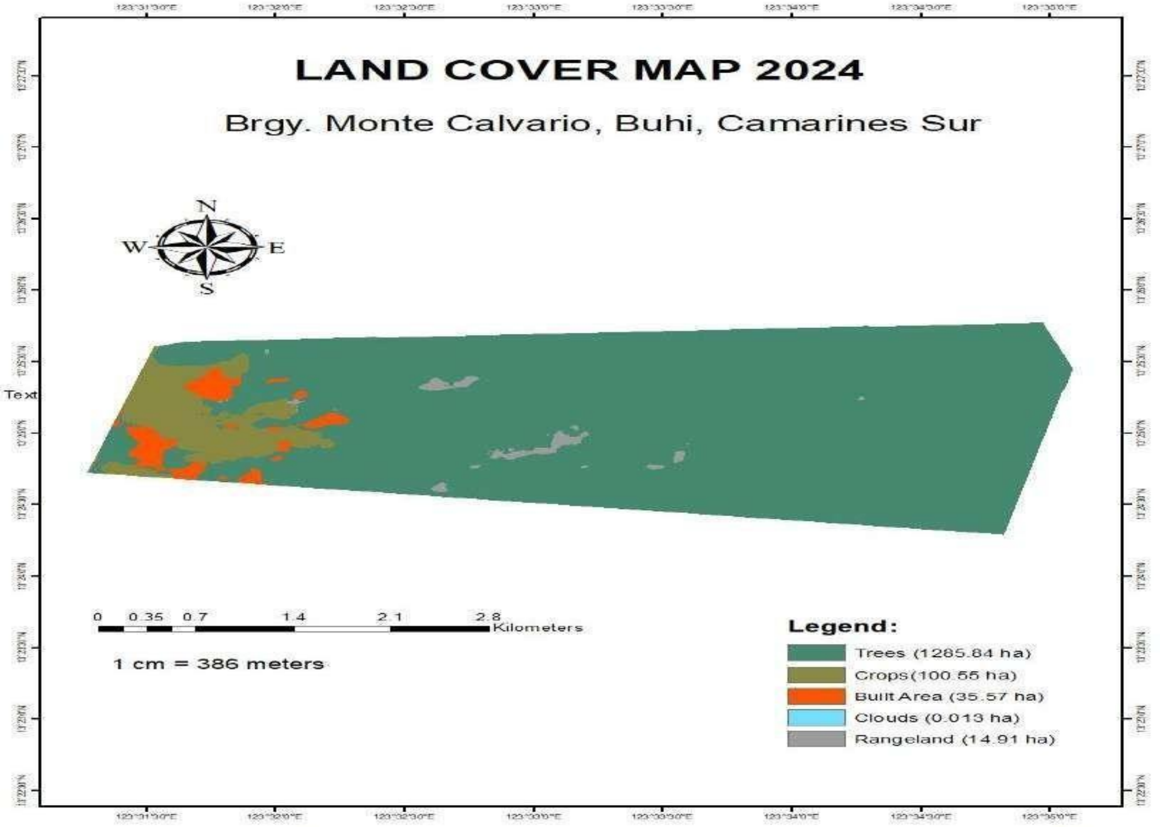


Table 9.11

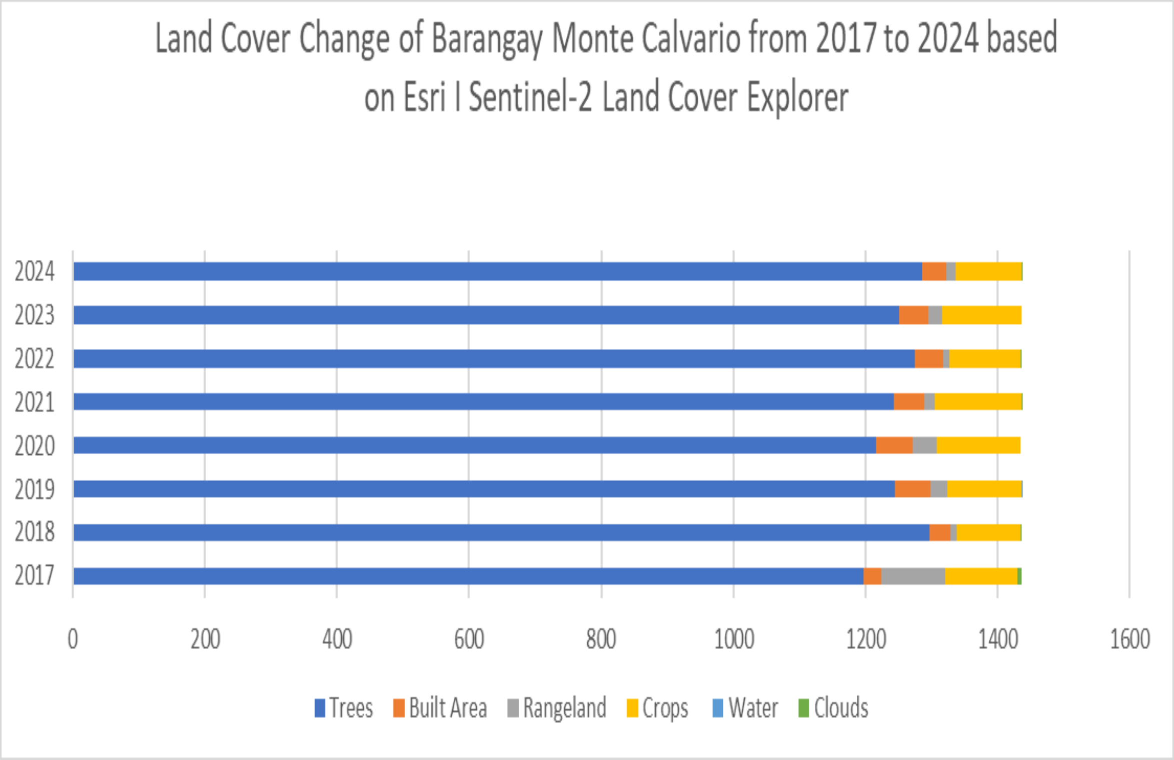
Percentage Land Cover Monte Calvario (2024)

Land Cover Monte Calvario (2024)	Areas in Ha	Percentage (%)
Trees	1285.84	89.49
Built Area	35.57	2.48
Rangeland	14.91	1.04
Crops	100.55	7.00
Water	0	0
Clouds	0.013	0.001
Total	1436.88	100

Table 9.11 shows that in year 2024 land cover distribution in Brgy. Monte Calvario, Buhi- Barit Watershed, reveals a predominantly forested landscape. Tree cover accounts for 1,285.84 hectares, or approximately 89.5% of the total 1,436.88 hectares mapped. The relatively low extent of built-up areas (35.57 ha), just about 2.5% of the total. It suggests controlled urban expansion, which is critical for maintaining watershed integrity and preventing slope destabilization and erosion (Lasco et al., 2015).

Rangeland (14.91 ha) and cropland (100.55 ha) combined represent less than 9% of the land cover, indicating limited agricultural pressure compared to earlier years. This may reflect a shift toward forest-based land use or stabilization of farming activities. The absence of open water bodies and minimal cloud cover interference (0.013 ha) in the imagery suggests optimal satellite image conditions and increased accuracy in classification for 2024.

Figure 9.12. Land Cover Changes of Monte Calvario from Year 2017 to Year 2024.



Finally, in 2024, the area appeared to enter a phase of relative ecological recovery. Tree cover increased significantly to 1,285.84 hectares, approaching 2018 levels and indicating successful vegetation regrowth or continued conservation interventions. Cropland declined to 100.55 hectares, while built-up areas fell further to 35.57 hectares. Rangeland was reduced to 14.91 hectares, and cloud cover was virtually eliminated, enhancing the accuracy of satellite-based assessments. These patterns suggest that the enhanced National Greening Program (ENGP), reforestation policies, and community- based watershed management programs may be yielding positive results in Monte Calvario (DENR, 2022).

Table 9.12

Areas in HA of Land Cover Monte Calvario from Year 2017 to Year 2024

Year	Trees	Built Area	Range land	Crops	Water	Clouds
2017	1196.46	26.71	96.96	109.96	0	6.79
2018	1296.88	31.11	9.66	96.67	0	0.63
2019	1245.09	53.33	25.57	112.81	0.034	0
2020	1216.06	55.04	37.41	126.25	0	0
2021	1243.65	44.67	15.85	131.93	0	0.78
2022	1274.85	42.15	9.79	108.05	0	2.05
2023	1251.31	44.09	20.23	121.22	0	0
2024	1285.84	35.57	14.91	100.55	0	0.013

Table 9.12 shows the land cover change of Brgy. Monte Calvario within the Buhi-Barit Watershed from 2017 to 2024. Tree cover remained dominant, consistently above 1,190 hectares, peaking in 2018 (1,296.88 ha) and recovering again in 2024 (1,285.84 ha). In contrast, built-up areas expanded rapidly from 26.71 ha in 2017 to 55.04 ha by 2020, before gradually declining to 35.57 ha by 2024, suggesting early

urban growth followed by possible regulatory intervention or land saturation, a trend similarly observed in watersheds like Laguna de Bay (Gonzales & Lasco, 2020).

Croplands increased steadily, peaking in 2021 at 131.93 ha before dropping to 100.55 ha in 2024, possibly due to land abandonment or reforestation, echoing findings in Layawan and Marikina watersheds where agroforestry and conservation influenced land transitions (Dano et al., 2022; Lasco et al., 2015). Rangeland showed sharp fluctuations, starting high in 2017 (96.96 ha), falling in 2018, then peaking again in 2020, suggesting cyclical land degradation or shifting cultivation. Water surfaces were minimal, detected only in 2019, likely due to limitations in satellite resolution. Meanwhile, cloud cover interference was highest in 2017 but declined significantly by 2024, enhancing classification accuracy in later years.

Figure 9.13. Yearly Tree Data and Annual Differences.

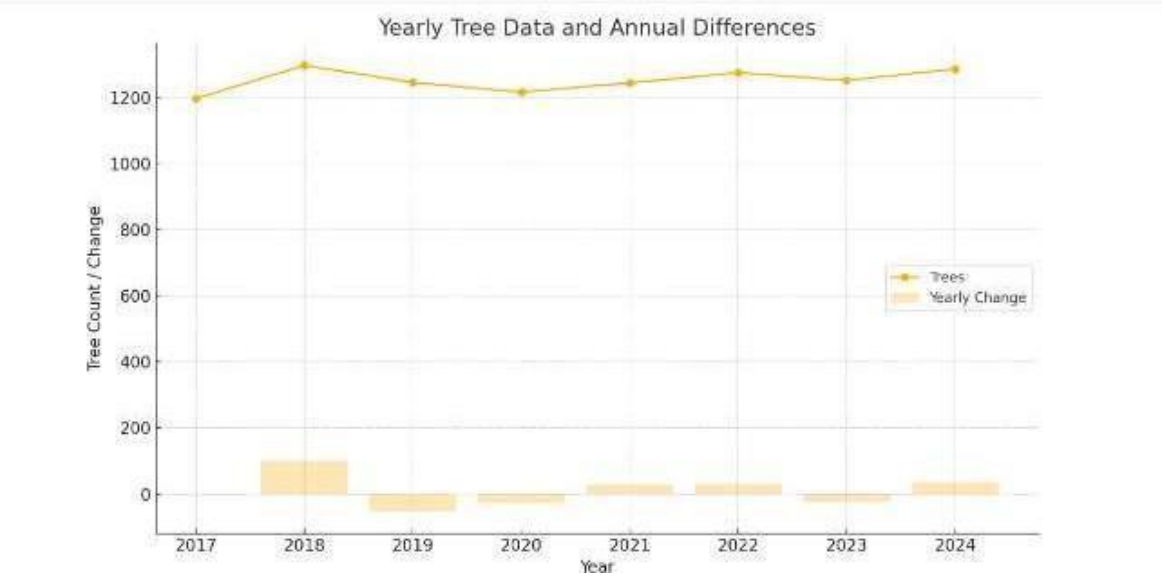


Table 9.13

Annual Variations of Trees Classifications

Year	Trees (ha)	Annual Difference (ha)
2017	1196.46	–
2018	1296.88	+100.42
2019	1245.09	-51.79
2020	1216.06	-29.03
2021	1243.65	+27.59
2022	1274.85	+31.20
2023	1251.31	-23.54
2024	1285.84	+34.53

The Trees data from year 2017 to 2024 shows a general increasing trend with some fluctuations. In 2018, there was a notable increase of 100.42 Trees from the previous year, reaching 1,296.88. However, this was followed by two consecutive years of decline, with the Trees count dropping to 1,245.09 in 2019 and further to 1,216.06 in 2020. Recovery began in 2021 with a slight increase of 27.59, and continued in 2022 and 2024, with increases of 31.20 and 34.53 respectively. Although year 2023 saw a minor decrease of 23.54, the overall trend from 2021 onwards indicates steady growth. These changes may reflect natural environmental variations, conservation efforts, or land use practices within the area.

Figure 9.14. Yearly Built Up and Annual Differences.

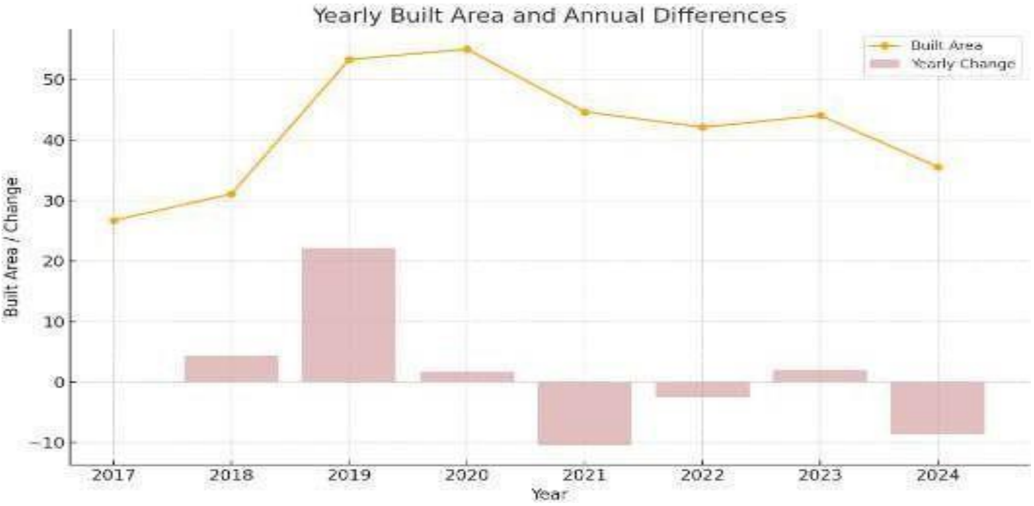


Table 9.14

Annual Variations of Built-Up Area

Year	Built-Up Area (ha)	Yearly Difference (ha)
2017	26.71	–
2018	31.11	+4.40
2019	53.33	+22.22
2020	55.04	+1.71
2021	44.67	–10.37
2022	42.15	–2.52
2023	44.09	+1.94
2024	35.57	–8.52

The Built-up area in Barangay Monte Calvario experienced noticeable changes between 2017 and 2024. Starting at 26.71 hectares in 2017, the area steadily increased to 31.11 hectares in 2018, followed by a significant rise in 2019 to 53.33

hectares, marking the largest annual increase of 22.22 hectares. The expansion continued in 2020 but at a slower rate, reaching 55.04 hectares. However, a decline was observed in 2021, dropping to 44.67 hectares, and this downward trend continued slightly in 2022 at 42.15 hectares. In year 2023, there was a small increase of 1.94 hectares, but by 2024, the Built-up area declined again to 35.57 hectares. These variations may be associated with factors such as urban development pressures, zoning policies, or natural constraints. The peak in 2020 suggests a period of rapid infrastructure growth, possibly linked to local development initiatives and this is the year of Covid 19 pandemic.

Table 9.15

Annual Variations Range Land Area

Year	Range Land Area (ha)	Yearly Difference (ha)
2017	96.96	–
2018	9.66	–87.30
2019	25.57	+15.91
2020	37.41	+11.84
2021	15.85	–21.56
2022	9.79	–6.06
2023	20.23	+10.44
2024	14.91	–5.32

The data on Range Land Area from 2017 to 2024 reveals significant fluctuations. In 2017, the range land covered a high of 96.96 hectares, but this sharply dropped in 2018 to only 9.66 hectares, a decrease of 87.30 hectares, marking the most drastic reduction during the period. Some recovery occurred in 2019 and 2020, with gains of 15.91 and 11.84 hectares respectively. However, in 2021, the area decreased again by 21.56 hectares, followed by a further drop in 2022. A brief increase was seen in 2023, with a gain of 10.44 hectares, but this was followed by another slight decrease in 2024.

These erratic trends suggest that range land is highly sensitive to changes in land use, possibly influenced by agricultural expansion, infrastructure development, or reclassification into other land cover types. The extreme decline from 2017 to 2018 might indicate a major shift in land management or conversion. The recurring reductions after short recoveries show an unstable pattern, emphasizing the need for land use regulation and monitoring to preserve remaining range land resources.

Table 9.16

Annual Variations of Cropland Areas

Year	Crop Area (ha)	Yearly Difference (ha)
2017	109.96	–
2018	96.67	–13.29
2019	112.81	+16.14
2020	126.25	+13.44
2021	131.93	+5.68
2022	108.05	–23.88
2023	121.22	+13.17
2024	100.55	–20.67

The Cropland area in Barangay Monte Calvario showed varying trends from

2017 to 2024. In 2017, the area devoted to crops was 109.96 hectares, but it declined by 13.29 hectares in 2018. A significant recovery occurred in the next three years, with consistent increases reaching a peak of 131.93 hectares in 2021. This upward trend suggests a period of agricultural expansion or intensified cultivation.

However, a notable decline of 23.88 hectares occurred in 2022, followed by a partial recovery in 2023 with a gain of 13.17 hectares. The year 2024 again saw a decrease of 20.67 hectares, bringing the cropland area down to 100.55 hectares. These fluctuations may reflect shifting land use priorities, climate variability, market factors, or competition with other land cover types such as built-up areas.

Overall, while crop areas increased steadily from 2019 to 2021, the general trend from 2022 to 2024 shows instability, pointing to potential pressures on agricultural land or changes in farming practices.

X. ANALYSIS AND DISCUSSIONS

Analysis of Land Cover Changes in Monte Calvario (2017–2024)

The land cover dynamics of Brgy. Monte Calvario, located within the ecologically vital Buhi-Barit Watershed in Camarines Sur, reveal meaningful trends between 2017 and 2024 that reflect both natural regrowth and human -driven land use changes. In 2017, the area recorded 1,196.46 hectares of tree cover, establishing a solid ecological baseline. However, this year also marked the highest extent of rangeland at 96.96 hectares—suggestive of either degraded land or areas used for grazing or shifting cultivation. Similar observations were noted in the Upper Pulangui Watershed, where expansive grasslands resulted from upland farming practices and forest loss (Ong & Dizon, 2021). Agricultural land (cropland) comprised 109.96 hectares, showing moderate use, while built-up areas were relatively minimal at 26.71 hectares. Notably, cloud cover interference was also at its peak this year, covering 6.79 hectares, which may have contributed to misclassification errors in remote sensing.

By 2018, forest regeneration was evident, with tree cover reaching its highest point during the eight-year span at 1,296.88 hectares. This increase may be attributed to either natural succession or reforestation programs, echoing successful forest protection efforts such as those implemented in the Mt. Makiling Forest Reserve (Lasco et al., 2015). In contrast, rangeland drastically declined to just 9.66 hectares, possibly due to land rehabilitation or reclassification into forest or cropland. Built-up areas expanded modestly to 31.11 hectares, and cropland slightly decreased to 96.67 hectares. This drop in agricultural area may signal a shift toward reforestation or reduced cultivation due to land degradation or economic factors.

In 2019, signs of increasing anthropogenic pressure became apparent. Built-up areas surged to 53.33 hectares, nearly doubling from the previous year. This could reflect infrastructure development, residential expansion, or economic shifts—a trend similarly observed in the Tagum- Libuganon Watershed where land development intensified in peri-urban zones (DENR-MGB, 2019). Concurrently, tree cover slightly decreased to 1,245.09 hectares, likely as a consequence of land conversion. Cropland rose to 112.81 hectares, while rangeland rebounded to 25.57 hectares. This suggests a complex pattern of land use intensification and possible rotational use of marginal lands, a scenario common in many upland agricultural communities.

The year 2020 marked the peak of urban expansion, with built-up areas reaching 55.04 hectares, the highest in the recorded period. This expansion corresponded with a further decrease in tree cover to 1,216.06 hectares. Agricultural land use also intensified, as cropland rose to 126.25 hectares. Meanwhile, rangeland expanded to 37.41 hectares, indicating possible forest clearing or abandonment of croplands. This land use pressure reflects trends documented in the Laguna Lake Basin, where forest edges were in creasingly fragmented due to population growth and economic development (Gonzales & Lasco, 2020).

In 2021, there was a modest ecological recovery. Tree cover increased to 1,243.65 hectares, while cropland peaked at 131.93 hectares—the highest level during the study period. Built-up areas declined to 44.67 hectares, suggesting a possible slowdown in infrastructure expansion or the implementation of local land use controls. The reduction of rangeland to 15.85 hectares may indicate reforestation efforts or more efficient land allocation. Such land use adjustments align with government-led integrated watershed management strategies and the implementation of agroforestry-based livelihood programs, such as those under the Department of

Agriculture’s NCIARMP project (DENR, 2022).

By 2022, tree cover continued its upward trend, reaching 1,274.85 hectares. Cropland, however, decreased to 108.05 hectares, and built-up areas slightly declined to 42.15 hectares. This year also saw a brief rise in cloud interference (2.05 hectares), which may have limited classification accuracy. Rangeland dropped again to 9.79 hectares, pointing toward possible stabilization or conversion into more permanent land cover types. This trend parallels the situation in Layawan Watershed in Oroquieta City, where strategic reforestation helped reclaim degraded areas and mitigate soil erosion (Dano et al., 2022).

In 2023, land cover distribution reflected moderate fluctuation. Tree cover dipped slightly to 1,251.31 hectares, while cropland rebounded to 121.22 hectares, indicating renewed agricultural activities. Built-up areas stabilized at 44.09 hectares, and rangeland increased to 20.23 hectares, possibly due to short-term land abandonment or shifts in cultivation cycles. These changes illustrate the dynamic nature of land use in the area, driven by both livelihood needs and environmental pressures.

Finally, in 2024, the area appeared to enter a phase of relative ecological recovery. Tree cover increased significantly to 1,285.84 hectares, approaching 2018 levels and indicating successful vegetation regrowth or continued conservation interventions. Cropland declined to 100.55 hectares, while built-up areas fell further to 35.57 hectares. Rangeland was reduced to 14.91 hectares, and cloud cover was virtually eliminated, enhancing the accuracy of satellite-based assessments. These patterns suggest that the enhanced National Greening Program (ENGP), reforestation policies, and community-based watershed management programs may be yielding positive results in Monte Calvario (DENR, 2022).

Table 10.1

Comparison of Year 2020 GIS-Map from NAPOCOR and Esri-Sentinel

Overview Two GIS Maps	**NAPOCOR GIS Land Cover Map (2020)**	**Esri Sentinel GIS Land Cover Map (2020)**	**Remarks**
Total Area	1238.45 HA	1434.76 HA	Actual Land Area: 900.9 HA (Based on Barangay Data)
Detailed Classifications	9 Classifications: Annual Crop, Perennial Crop, Closed Forest, Open Forest, Brush/Shrub,	6 Classifications: Trees, Crops, Rangeland, Built Area, Water, Clouds.	NAPOCOR GIS MAP focused on ecological Types and Agricultural categories Esri

	Built-up, Inland Water, Open Barren.		Sentinel GIS Map generalized categories based on Sentinel satellite Imaginary:
Classification Overlaps and Similarities	Closed Forest + Open Forest + Brush/Shrub + Perennial Cropv	Trees	Both refer to forested areas; NAPOCOR distinguishes canopy density while Esri generalizes it.
	Annual Crop	Crops	NAPOCOR separates crops by lifecycle; Esri combines all crop types.
	Grassland + Open Barren	Rangeland	These NAPOCOR types suggest degraded or transition zones; Esri groups them under a broad

		'Rangeland' category.
Built-up	Built Area	Direct equivalent, though Esri identifies a larger area.
Inland Water	Water	NAPOCOR detects a small amount; Esri records none in 2020.

A comparative analysis of the 2020 GIS-based land cover maps of Brgy. Monte Calvario highlights the fundamental differences in approach, scale, and classification detail between two mapping sources—NAPOCOR and Esri Sentinel. The NAPOCOR GIS map accounts for a total classified area of 1,238.45 hectares, while the Esri Sentinel map covers a larger area of 1,434.76 hectares. This variation suggests either a difference in boundary delineation or extent of coverage, with Esri likely encompassing adjacent transition zones or including a broader classification envelope based on its satellite data coverage.

In terms of classification structure, NAPOCOR adopts a detailed, ecological - based typology, utilizing nine land cover categories: Annual Crop, Perennial Crop, Closed Forest, Open Forest, Brush/Shrub, Grassland, Built-up, Inland Water, and Open Barren. This fine-scale differentiation reflects NAPOCOR’s institutional focus on hydrological and ecological resource management, offering a granular perspective of vegetation types, land degradation, and agricultural practices within the watershed. In contrast, the Esri Sentinel GIS map simplifies land use into six broad categories:

Trees, Crops, Rangeland, Built Area, Water, and Clouds. This generalization is derived from automated processing of Sentinel satellite imagery, favoring a more streamlined and scalable framework suitable for temporal monitoring and national-level assessments.

Despite differing schemes, there are notable overlaps and thematic equivalencies between the two datasets. NAPOCOR's Closed Forest and Open Forest align with Esri's broader Trees category, although the former distinguishes forest density more precisely. Similarly, NAPOCOR's Annual Crop and Perennial Crop are both classified under Crops in the Esri map, suggesting that Esri sacrifices agricultural specificity for simplicity. For transition zones, NAPOCOR provides separate classes such as Brush/Shrub, Grassland, and Open Barren, whereas Esri aggregates these into a generalized Rangeland classification. Built-up areas are comparable across both sources, although Esri records a significantly larger Built Area, likely due to broader classification thresholds or differing spatial resolution. Lastly, Inland Water appears only in NAPOCOR's dataset (0.18 ha), while Esri registers none, pointing to potential differences in image capture timing, spectral resolution, or classification sensitivity.

While NAPOCOR's land cover map provides ecological specificity ideal for site-level watershed rehabilitation, the Esri Sentinel map offers broader spatial coverage and operational efficiency for regional landscape assessments. When integrated, the two datasets can complement each other—NAPOCOR for ground-truth validation and forest/agricultural detail, and Esri for trend analysis and rapid monitoring. Such dual mapping perspectives are particularly useful in adaptive watershed management, where both precision and scalability are essential.

Table 10.2

Quantitative Comparison of NAPOCOR GIS Land Cover Map and Esri Sentinel GIS Land Cover Map Year 2020

Quantitative Comparison	NAPOCOR GIS Land Cover Map (2020)	Esri Sentinel GIS Land Cover Map (2020)	Difference	Remarks
Total Area	1238.45 HA	1434.76 HA	- 196.31	Actual land area based on Barangay data: 900.9 ha
Forests/Trees:	Closed Forest + Open Forest + Brush/Shrub + Perennial Crops: 1053.47 ha	Esri Sentinel (Trees): 1,216.06 ha	+162.29	Discrepancy likely due to classification boundaries or Esri's inclusion of tree crops and dense shrubs as forest canopy.
Crops:	(Annual Crops): 166.23 ha	(Crops): 126.25 ha	-39.98	NAPOCOR may more accurately distinguish planted areas using ground-truth data or finer classification;

				Esri may underdetect smaller or mixed-use crop zones.
Built Area	10.97 ha	55.04 ha	+44.07	Esri may overestimate built-up zones due to inclusion of paved roads or small structures
Rangeland Open Barren Grass	7.6 ha	37.41 ha	+29.81	NAPOCOR is more detailed in classifying semi-natural cover types
Water	0.18 ha	0	-0.18	NAPOCOR may use localized knowledge or better spectral resolution to identify small inland water bodies

Table 10.3

Quantitative Difference of NAPOCOR AND Esri Sentinel in Ha Year 2020

Land Cover Type	**NAPOCOR (ha)**	**Esri Sentinel (ha)**	**Difference (Esri - NAPOCOR)**
Forests/Trees	1,053.47	1,216.06	+162.59
Crops	166.23	126.25	–39.98
Built-Up Area	10.97	55.04	+44.07
Rangeland/Open Barren	7.6	37.41	+29.81
Water	0.18	0.00	–0.18
Total	1238.45	1434.76	-199.31

The comparative analysis of the NAPOCOR and Esri Sentinel GIS Land Cover Maps for 2020 reveals notable discrepancies in total land area and land cover classifications, which have implications for spatial accuracy and interpretation. The total area covered in both maps exceeds the actual barangay land area of 900.9 hectares, with NAPOCOR mapping 1,238.45 hectares and Esri Sentinel reporting an even larger area of 1,434.76 hectares. This overestimation in both datasets may stem from imprecise boundary delineation, generalized classification extents, or image overlap beyond barangay limits.

In the forest and tree cover category, Esri Sentinel reports 1,216.06 hectares, which is higher than NAPOCOR's 1,053.47 hectares that combines closed forest, open forest, brush/shrub, and perennial crops. The difference of 162.59 hectares is likely due to Esri's broader classification approach, potentially including dense shrubs, mixed vegetation, or tree crops under forest canopy. This highlights a common challenge in remote sensing, where high-canopy cover and spectral similarities can lead to category merging, unless validated with local knowledge.

In terms of cropland, NAPOCOR identifies 166.23 hectares of annual crops, while Esri Sentinel reports only 126.25 hectares. This suggests that NAPOCOR's classification may be more precise, possibly using ground validation or field surveys to distinguish cultivated areas. In contrast, Esri's satellite-derived classification may underestimate agricultural land, especially where crops are interspersed with other land uses or during off-season imagery acquisition.

A significant variation is observed in the built-up area, where Sentinel reports 55.04 hectares, much higher than NAPOCOR's 10.97 hectares. The 44.07-hectare discrepancy may result from Esri's inclusion of paved roads, small structures, or construction zones that produce reflectance similar to built environments. NAPOCOR's more conservative estimate may reflect reliance on official infrastructure data or stricter classification thresholds.

For rangeland, grassland, and open barren land, Esri Sentinel again shows a higher estimate of 37.41 hectares compared to 7.6 hectares in the NAPOCOR map. This suggests that Esri's classification may encompass a wider range of sparsely vegetated or degraded areas, while NAPOCOR may apply more refined distinctions, which is beneficial for monitoring vegetation health and land degradation.

Lastly, the classification of water bodies shows a minor presence of 0.18 hectares in the NAPOCOR map, while Sentinel records none. This may be due to NAPOCOR's use of high- resolution imagery or localized mapping experience that allows identification of small or seasonal inland water bodies, which can be easily missed by coarser satellite data or during dry periods. While both datasets provide valuable spatial insights, the discrepancies underline the importance of ground-truthing and boundary accuracy, especially when actual land area (900.9 ha) is significantly lower than what is captured in both maps. NAPOCOR appears to offer a more conservative and locally grounded classification, whereas Sentinel provides broader but potentially overgeneralized outputs. For reliable land cover assessments and planning in Barangay Monte Calvario, integrating both datasets with field validation is essential to enhance spatial accuracy and inform land management decisions.

Table 10.4

Total Areas Crops Planted for Year 2024

Crop	Q1 (ha)	Q2 (ha)	Total (2024)
Ampalaya	0.32	0.22	0.54
Upo	0.47	0.04	0.51
Eggplant	2.83	1.22	4.05
Hot Pepper	0.32	0.09	0.41
Ginger	7.83	0.00	7.83
Okra	0.26	0.12	0.38
Peanut	3.00	0.50	3.50
Petchay	2.78	0.32	3.10
Pole Sitao	0.22	0.14	0.36
Squash	1.25	0.53	1.78
Tomato	0.23	0.00	0.23
Sweet Potato	4.50	0.67	5.17
Taro Leaves	1.25	0.33	1.58

Taro Tuber	0.00	0.67	0.67
Cabbage	0.33	0.00	0.33
Mungbean	0.00	0.25	0.25
Cassava	30.00	0.00	30.00
Coconut	0.00	0.00	0.00
Banana	No record	No record	No record
Total	55.59	5.1	60.69

Seed provision funded by LGU through the Office for Agricultural Services (OAS); additional support from the Department of Agriculture Regional Field Office 5 (DA RFO5), including assorted vegetable seeds, vermicompost, foliar fertilizer, and agricultural tools such as garden tools.

Source: Department of Agriculture-Municipality of Buhi, Camarines Sur

In 2024, a total of 60.69 hectares of land in Monte Calvario were planted with various crops during the first and second quarters of the year. The crops were diverse, reflecting a mix of vegetables, root crops, legumes, and spices. Unlike 2025, where coconut planting dominated the land use, the 2024 crop distribution was more balanced, with no single crop occupying the majority of the area.

The largest areas planted were for cassava (30.00 ha), ginger (7.83 ha), and sweet potato (5.17 ha). These crops made up over two-thirds of the total planted area and are likely grown for both food and income purposes. Eggplant (4.05 ha) and peanut (3.50 ha) also occupied notable portions of land. Leafy vegetables such as petchay (3.10 ha) and okra (0.38 ha) were grown on smaller plots, possibly for home consumption or local market supply. Other crops like ampalaya, hot pepper, pole sitao, squash, tomato, taro leaves, taro tuber, cabbage, and mungbean were grown in even smaller areas, generally less than 1 hectare each, indicating small-scale or backyard farming. The crop diversity suggests that farmers in 2024 were engaged in mixed cropping practices, growing both cash crops and staple foods in moderate amounts.

The agricultural data for Monte Calvario in planted with various crops during the first and second quarters, excluding banana. In comparison, the land cover analysis for the same year classifies 100.55 hectares, or 7% of the barangay's total land area of 1,436.88 hectares, as cropland. This reveals a notable discrepancy of about 39.71 hectares between the land reported as actively cultivated and the area identified as "Crops" in the land cover classification. Several factors may account for this gap: portions of the cropland may have been left fallow, used for backyard or household farming not captured in municipal reports, utilized for crop rotation, or included under general classifications in satellite imagery without reflecting actual seasonal use.

Table 10.5

Total Areas Crops Planted Year 2025

Crop	Q1 (ha)	Q2 (ha)	Total (2025)
Ampalaya	0.93	0.66	**1.59**
Upo	1.83	0.22	**2.05**
Eggplant	1.87	1.70	**3.57**
Hot Pepper	0.17	0.61	**0.78**
Ginger	0.00	0.77	**0.77**
Okra	0.20	0.43	**0.63**
Peanut	0.00	0.82	**0.82**
Petchay	0.10	0.80	**0.90**
Pole Sitao	0.80	0.27	**1.07**
Squash	2.07	0.67	2.74

Tomato	0.00	0.17	0.17
Sweet Potato	2.83	1.28	4.11
Taro Leaves	0.00	0.52	0.52
Taro Tuber	0.00	0.08	0.08
Cabbage	0.20	0.00	0.20
Mungbean	0.00	0.17	0.17
Cassava	4.00	8.30	12.30
Coconut	252.15	199.00	451.15
Banana	No record	No record	No record
Total	267.15	216.47	483.62

Seed provision funded by LGU through the Office for Agricultural Services (OAS); additional support from the Department of Agriculture Regional Field Office 5 (DA RFO5), including assorted vegetable seeds, vermicompost, foliar fertilizer, and agricultural tools such as garden tools.

Source: Department of Agriculture-Municipality of Buhi, Camarines Sur

In 2025, Monte Calvario showed a big increase in the total area planted with crops, reaching 486.29 hectares, not including banana. This was mainly due to the large expansion of coconut planting, which covered 451.15 hectares, or more than 93% of the total planted land. This is a big change from the previous year and suggests that farmers are shifting to planting coconut, possibly for long-term income or due to support from government programs.

Other crops planted included cassava (12.30 ha), sweet potato (4.11 ha), eggplant (3.57 ha), and squash (2.74 ha). These crops continued from 2024 but in smaller areas. Vegetables like ampalaya, upo, pole sitao, and petchay were also grown, mostly in small plots, likely for home use or small-scale selling. Some crops such as mungbean, taro tuber, and cabbage had very limited planting.

The sudden rise in coconut planting has several important meanings. First, it shows that farmers may now be focusing on long-term crops instead of short-term vegetables, which could reduce food variety and limit crop rotation. Second, if coconut planting used land that was once forest or rangeland, this could lead to environmental problems, especially since Monte Calvario had high forest cover in 2024. Third, while many types of crops are still grown, most of them are planted in small areas, which could affect local food supply. Fourth, the appearance of coconut in the data may also mean that data collection improved in 2025.

Ground Truthing Activities

Ground truthing is a critical validation step in remote sensing and GIS-based land cover analysis, designed to confirm the accuracy of classified map features through direct observation on the ground. In the context of this study on the Buhi-Barit Watershed, specifically in Brgy. Monte Calvario, ground truthing activities were undertaken to verify spatial data interpretations, strengthen classification reliability, and align satellite-derived outputs with real-world conditions. These activities were organized systematically across identified land cover zones such as forested areas, agricultural fields, and built-up zones to ensure representative sampling and precise land use characterization.

The ground truthing process began with an initial courtesy call and orientation with barangay officials, facilitating local coordination, safety assurance, and cultural sensitivity was followed by a guided field validation of selected zones, allowing direct observation and cross- checking of land cover categories including closed and open forests, croplands, grasslands, and residential or built-up sites. Each site was geo-tagged and documented using GPS-enabled devices, providing spatially accurate reference points for map correction and refinement. When applicable, brief discussions with local residents were conducted to contextualize land use patterns and practices ensuring that informed consent and ethical research standards were observed throughout. All activities adhered to basic safety protocols and aimed to minimize disruption to the community and environment. This rigorous ground truthing phase plays a crucial role in enhancing the credibility and practical utility of the GIS maps, particularly in support of watershed planning and sustainable land management initiatives.

Figure 10.1. Initial courtesy call and orientation with barangay officials and Buhi-Barit Watershed Officers and Personnel.

Figure 10.2. Brief Discussions with Community Members When Needed, With Prior Consent (Barangay And BBWAT).

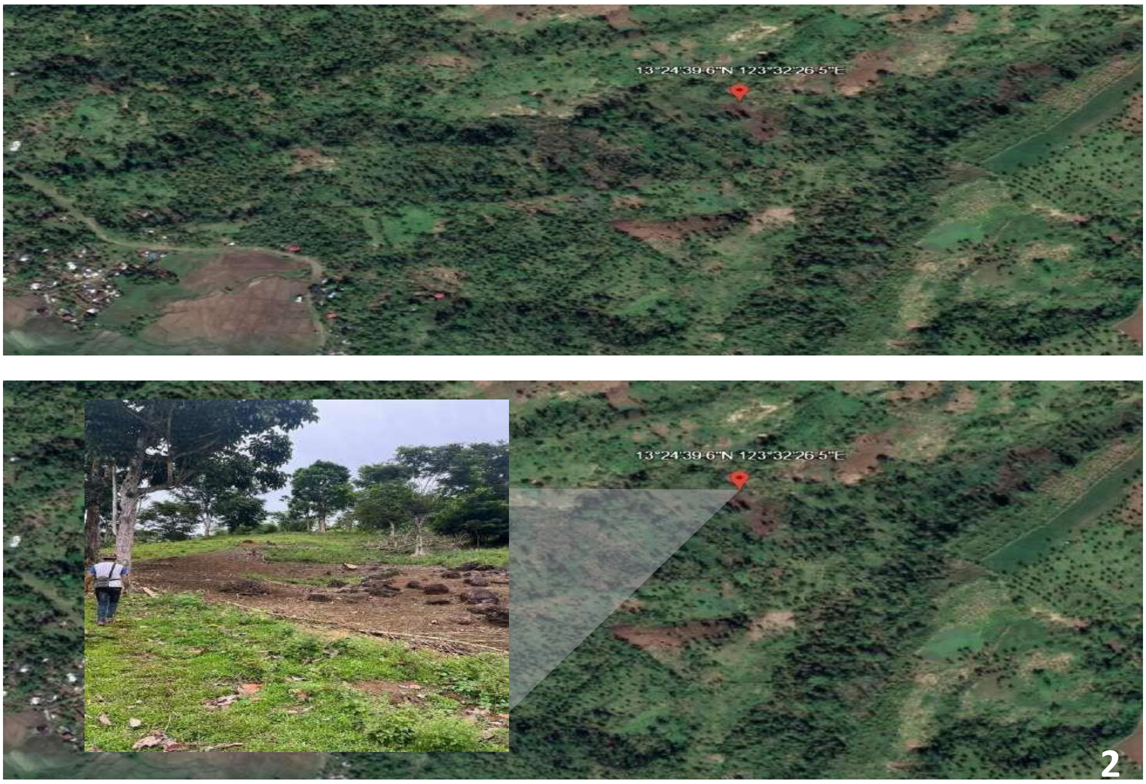
Figure 10.3. Brief discussions with community members when needed, with prior consent (tenants).

Figure 10.4. Brief discussions with community members when needed, with prior consent (community).

Figure 10.5. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24363°N and 123.31599°E.

The Barangay Monte Calvario Hall, located at coordinates 13.24363°N and 123.31599°E, served as the official starting point for the ground truthing activities. This site provided a strategic and accessible location for the initial courtesy call, orientation, and coordination with barangay officials, ensuring that fieldwork would be conducted with transparency and community support. As the central hub of local governance, the barangay hall played a crucial role in facilitating logistical arrangements, safety protocols, and field escorts when necessary. Establishing this point of reference also allowed the researcher to calibrate GPS devices, record the baseline spatial data, and plan the sequence of validation routes efficiently. Documenting the starting point strengthens the spatial integrity of the field activities and supports the structured implementation of the land cover verification process within the Monte Calvario portion of the Buhi-Barit Watershed.

Figure 10.6. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24396°N and 123.32265°E.



In this photo, taken at coordinates 13.24396°N and 123.32265°E, the ground validation revealed the presence of cut tree stumps and an unoccupied shanty structure, indicating a previously cleared or disturbed site. The absence of canopy cover and visible regrowth suggests that this area may have recently undergone tree removal or land clearing, possibly for informal settlement or agricultural conversion. Cross-referencing this location with satellite imagery from Google Maps confirms the ground observation: the area appears barren, with minimal to no vegetation, and lacks distinguishable tree cover. This field finding is significant in verifying the “Open/Barren” or “Brush/Shrub” classification in the NAPOCOR land cover map and could correspond to “Rangeland” or misclassified “Crops” in the Esri Sentinel data. Such discrepancies highlight the importance of ground truthing in detecting localized land use changes, especially in small-scale clearings that may be undetectable through automated satellite classification alone.

Figure 10.7. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24449°N and 123.32379°E.

At coordinates 13.24449°N and 123.32379°E, the ground observation revealed a landscape characterized predominantly by grassland vegetation interspersed with abaca and banana plants. These features indicate a semi-managed agro-ecological zone, where natural grass cover coexists with small-scale perennial crop cultivation. The dominance of grassy vegetation aligns with classifications such as Grassland in the NAPOCOR GIS map and may correspond to Rangeland or Crops in the Esri Sentinel dataset, depending on canopy density and spectral resolution.

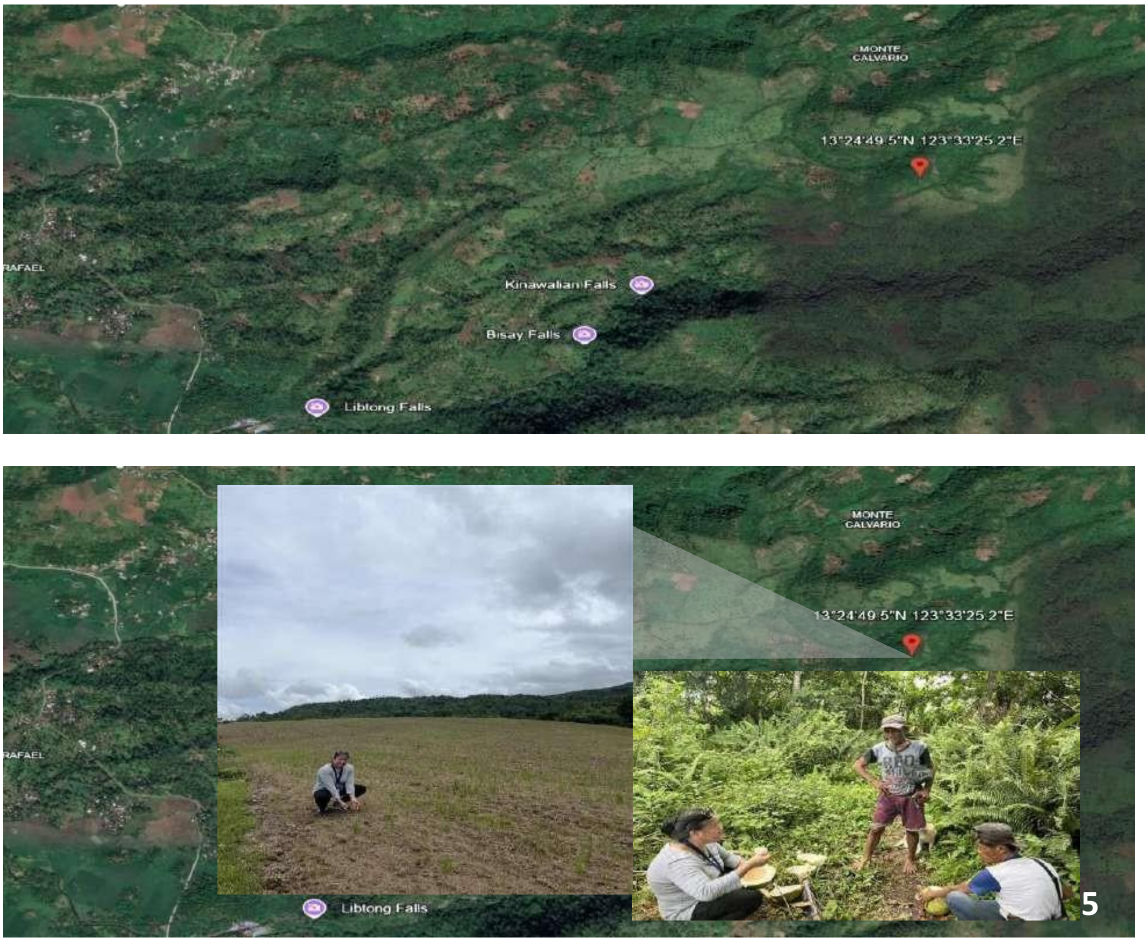
Satellite imagery from Google Maps further supports the field data, showing a lighter green hue, which commonly denotes sparse vegetation or shrub cover. The consistency between ground data and remote sensing interpretation enhances the reliability of the land cover classification in this area. However, the presence of perennial crops like abaca and banana also highlights the complexity of classifying mixed-use areas, where subsistence agriculture blends with natural vegetation. This observation emphasizes the importance of ground truthing in verifying and refining remotely sensed land cover data, especially in upland watershed zones with heterogeneous land uses.

Figure 10.8. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24538°N and 123.33025°E.

The site located at 13.24538°N and 123.33025°E was observed to be a vast expanse of grassland, actively used for pasture by carabaos and cows. The dominance of herbaceous cover and open terrain suggests that the area functions as a grazing zone, likely maintained through traditional or low-intensity livestock management practices. This land cover type aligns with the *Grassland* or *Brush/Shrub* classification in the NAPOCOR GIS map, and is consistent with the *Rangeland* category in the Esri Sentinel-based map, which broadly groups semi-natural and grazed landscapes.

Field evidence of livestock presence not only confirms the functional use of the land but also supports its role in local subsistence economies, especially in upland barangays where mixed- use agro-pastoral systems are common. Satellite imagery from Google Maps shows uniformly light green tones, reinforcing the classification of the site as open vegetated terrain with low canopy cover. This observation highlights the importance of ground truthing to distinguish between natural grasslands and areas used for livestock, which may share similar spectral characteristics but differ significantly in ecological impact and management needs.

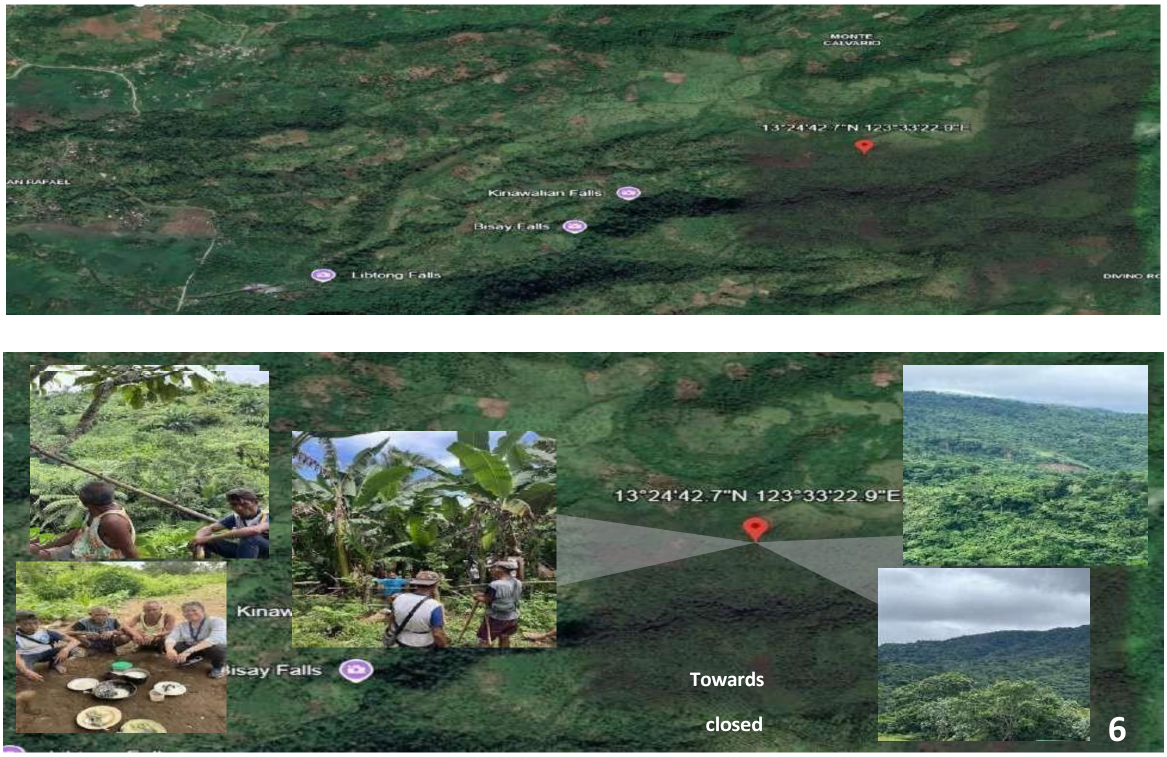
Figure 10.9. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24495°N and 123.33252°E.



At coordinates 13.24495°N and 123.33252°E, the field observation revealed a vast area of rice fields situated in an open upland terrain, adjacent to a closed forest zone. Unlike conventional irrigated lowland rice systems, this site supports a rainfed upland rice variety, which is uniquely adapted to thrive in environments with limited water availability. The absence of formal irrigation infrastructure confirms that the primary water source is direct rainfall, reflecting a traditional and climate -dependent farming practice common in upland regions of the Philippines. This type of land use fits into the Annual Crop category in the NAPOCOR GIS Land Cover Map, while it may be captured under the generalized Crops classification in the Esri Sentinel map.

Given the proximity to closed forest areas, the site may also serve as a buffer zone in the watershed, where agricultural expansion borders ecologically sensitive habitats. The distinction of this crop type is important for land cover classification, as rainfed upland rice fields often exhibit similar spectral signatures to grasslands or fallow land due to their irregular planting patterns and seasonal greenness. Therefore, ground truthing in this area was critical in ensuring the correct classification of agricultural land and understanding the adaptive strategies of local farmers managing marginal and sloped environments. Such findings contribute valuable insight into land use diversity, climate resilience, and sustainable watershed management planning.

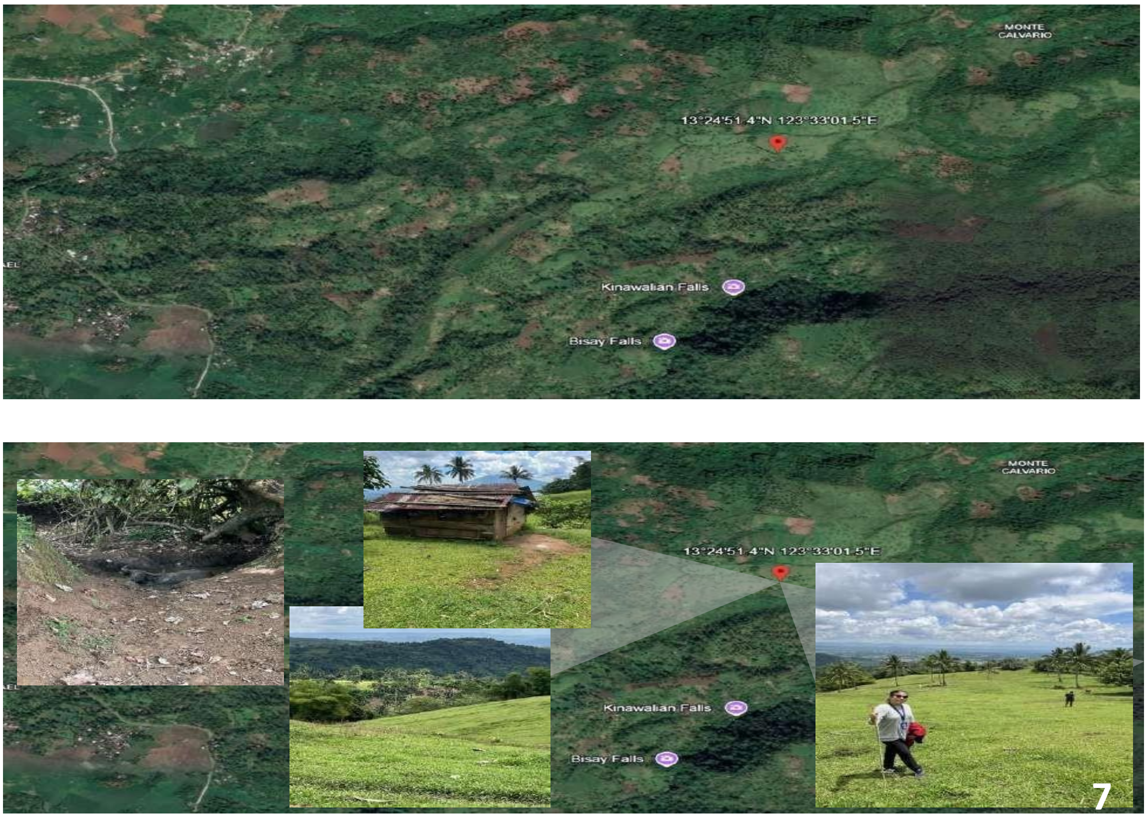
Figure 10.10. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24427°N and 123.33229°E.



At coordinates 13.24427°N and 123.33229°E, the site is located near a closed forest zone and is actively used by local tenant farmers for small -scale agricultural cultivation. The area hosts a diverse mix of subsistence crops, including *camote tops (sweet potato leaves)*, *abaca*, *banana trees*, and other upland varieties commonly suited to the hilly, rainfed terrain of Brgy. Monte Calvario. Despite its agricultural activity and human presence, the site remains undetected as a built-up area in satellite-based classifications, such as the Esri Sentinel map, likely due to the low structural footprint and dense vegetation cover surrounding the three small shanties constructed by the tenant families.

This observation illustrates the limitations of automated remote sensing in detecting scattered or informal structures, especially in vegetation -dominated settings, where rooftops may be obscured or too small to register under moderate spatial resolution imagery. In land cover classification, such areas might be mistakenly labeled as *Crops*, *Rangeland*, or even *Forest Edge*, highlighting the crucial role of ground truthing in refining spatial data accuracy. The presence of permanent cultivation and tenant dwellings also points to land tenure dynamics and human-environment interactions, which are often overlooked in purely spectral analyses. Incorporating this kind of on-the-ground evidence strengthens the interpretive value of land use maps and supports more inclusive and community-informed watershed management strategies.

Figure 10.11. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24514°N and 123.33015°E.



At coordinates 13.24514°N and 123.33015°E, the area is characterized by open grassland used as pastureland, with visible presence of grazing cows and carabaos, as well as mud pits commonly formed by wallowing carabaos. The site is predominantly covered with low grasses and herbaceous vegetation, with sparse tree cover, indicating a landscape more aligned with *grassland* or *rangeland* classifications rather than forested zones. A small, simple structure—likely used as a temporary shelter or resting area—was also noted on site, though it is not captured in satellite-derived land cover classifications, such as the Esri Sentinel map, which tends to miss isolated or minimally roofed dwellings in open areas.

This type of land use reflects a typical pastoral subsystem found in upland agricultural communities in the Philippines, where mixed-use landscapes support both subsistence farming and livestock grazing. In the NAPOCOR GIS land cover map, this location may fall under *Grassland*, *Open Barren*, or *Brush/Shrub*, depending on vegetation density. Meanwhile, in the Esri Sentinel map, it is likely classified broadly as *Rangeland*. Ground truthing this site was essential in distinguishing between natural grasslands and actively grazed pasture, as these categories may appear spectrally similar but serve different ecological functions and management priorities in watershed development. The combination of open terrain, animal presence, and minor habitation highlights the need for fine-scale land use analysis, particularly in planning for sustainable livestock integration, erosion control, and forest edge protection in the Buhi-Barit watershed.

Figure 10.12. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24462°N and 123.32456°E.

At coordinates 13.24462°N and 123.32456°E, the site is a small upland community composed of four household dwellings, one of which also functions as a local sari-sari store. The area reflects a settlement-agriculture interface, where families are in the early stages of cultivating various crops on adjacent plots. In addition to crop establishment, the presence of livestock and domesticated animals—including chickens, dogs, cats, carabaos, cows, and goats—suggests a semi-subsistence rural livelihood system, where animal husbandry is integrated with household farming practices.

Despite clear signs of human habitation and productive land use, such areas are often underrepresented in remote sensing data, particularly when small structures are partially obscured by vegetation or constructed with materials that blend spectrally with the landscape. In the Esri Sentinel GIS map, this location may not appear as Built Area but instead could be misclassified as Crops or Rangeland. The NAPOCOR GIS map, with more detailed classification, may better detect the agricultural activity but may still underrepresent residential presence due to the scale and nature of satellite inputs.

This observation underscores the importance of ground truthing in detecting small-scale rural settlements and validating mixed land use in watershed contexts. It highlights how community-managed lands contribute to local food security and livestock management, which are critical in upland resource governance and planning.

Figure 10.13. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24372°N and 123.31584°E.

At coordinates 13.24372°N and 123.31584°E, the site is characterized by the presence of young or semi-mature trees, indicating either a naturally regenerating area or a site previously included in reforestation efforts such as the DENR's National Greening Program (NGP). This vegetative cover is interspersed with a concrete water tank, which, according to the accompanying field escort, is a key infrastructure supplying water to two lowland barangays. The presence of the tank highlights the strategic use of elevated terrain in upland areas for water storage and distribution, especially in regions where groundwater supply in downstream communities is insufficient.

From a land cover classification perspective, the tree cover may have been captured under Open Forest, Brush/Shrub, or Perennial Crop in the NAPOCOR GIS map, and under the generalized Trees category in the Esri Sentinel-based classification. However, the water tank structure is unlikely to be detected by satellite imagery alone due to its limited surface area and visual blending with the surrounding vegetation. This reinforces the importance of ground truthing in identifying critical infrastructure and subtle landscape features that remote sensing may overlook.

Figure 10.14. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.24373°N and 123.31584°E.

At coordinates 13.24373°N and 123.31584°E, the area is situated in a lowland community zone and features a combination of agricultural and built-up land uses. Prominently, a rice mill facility and associated storage structure are present, indicating post-harvest processing activities that serve local farmers and possibly nearby barangays. The surrounding landscape includes paved or gravel roads, standing trees, and active agricultural plots planted with rice and corn —both of which are staple crops in the region. This mix of infrastructure and cultivation reflects a multi- functional rural zone where economic activity and food production are closely integrated.

In terms of land cover classification, this area may appear in the NAPOCOR GIS map as a combination of Built-Up, Annual Crop, and Perennial Crop categories. In contrast, the Esri Sentinel map may generalize this area under Crops and Built Area, depending on the visibility of built structures and vegetation patterns at the time of image acquisition. The field validation confirms the presence of dense land use heterogeneity that is often underrepresented or oversimplified in remote sensing datasets, especially when facilities like rice mills blend visually with the surrounding landscape.

This site emphasizes the economic and logistical role of lowland agricultural centers within the larger Buhi-Barit Watershed system, functioning as a hub for crop production, storage, and distribution. The presence of permanent infrastructure also underscores the need to accurately classify mixed-use zones for better land use planning, flood risk assessment, and resource allocation in future watershed development strategies.

Figure 10.15. Geo-tagging and documentation using GPS-enabled devices and Guided field validation of identified coordinates 13.324119°N and 123.32148°E.

At coordinates 13.324119°N and 123.32148°E, the site is notably occupied by a resort facility, which, according to field informants, has been closed due to legal and regulatory concerns involving the Department of Environment and Natural Resources (DENR). This highlights the ongoing tension between tourism development and environmental compliance, especially within ecologically sensitive areas such as the Buhi-Barit Watershed. The location also features a few small houses built along the perimeter, suggesting informal or semi-permanent residential use in close proximity to the resort. During the field validation, it was reported that a landslide had recently occurred in the area—approximately a month earlier—burying one house and resulting in the loss of a carabao. This incident underscores the hazard vulnerability of upland settlements, particularly when construction is done on unstable slopes without proper geo-risk assessments or engineering interventions.

In terms of land cover classification, this area may be ambiguously represented in both the NAPOCOR and Esri Sentinel GIS maps, as resorts and informal dwellings are often not accurately captured due to limited spatial resolution or tree cover obscuring rooftops. The terrain instability observed here also stresses the importance of incorporating disaster risk indicators into land use planning, especially in watershed zones where deforestation, unregulated development, and extreme weather events compound landslide risks (Lasco et al., 2010; DENR, 2022).

This field observation not only validates the presence of built structures and altered land use but also demonstrates the critical need for integrated planning approaches that align land classification, environmental regulations, and risk reduction strategies in fragile upland environments.

Summary of Ground Truthing

The ground truthing activities conducted in Barangay Monte Calvario provided critical insights into the spatial accuracy, ecological patterns, and socio-economic dynamics shaping the land cover of the Buhi-Barit Watershed. Field validation revealed a mosaic of land uses, ranging from young regenerating forests, cultivated upland crops, pastoral grasslands, and mixed-use residential-agricultural areas, to critical infrastructure such as water tanks and rice mills. Several locations, such as rainfed upland rice fields and smallholder agroforestry plots, were misrepresented or generalized in satellite-based classifications, underscoring the importance of on - the-ground verification to supplement GIS land cover data. For instance, while Esri Sentinel-based maps categorized most vegetation under generalized “Trees” or “Crops,” ground truthing identified nuanced land uses like abaca plantations, seasonal rice paddies, and grassland pastures used for livestock. Additionally, invisible built-up features, such as informal shanties and community stores, were not detected due to their size or material composition, highlighting limitations in remote sensing resolution for rural upland communities.

The researcher also documented landslide-prone areas, like the closed resort site at 13.324119°N, 123.32148°E, where unregulated construction contributed to slope instability and destruction of property. This raises urgent concerns about the interaction between land use and geohazards, especially in a climate-sensitive watershed. The field validation process emphasized that socio-economic drivers—including subsistence farming, informal land occupation, and community-led crop diversification—play a significant role in shaping the land cover mosaic. Therefore, future research should incorporate in-depth socio-economic assessments to understand local decision -making, agricultural practices, and the pressures of urban expansion. This can be achieved through targeted interviews or household surveys, especially in areas undergoing transitions, such as the emergence of upland settlements and shifting cropping systems.

Moreover, as climate variability intensifies, there is a need to integrate climate risk analysis into land use assessments. Rainfall-dependent crop systems and increasing slope erosion highlight the vulnerability of the watershed to changing precipitation patterns and extreme weather events. Overlaying climate data with land cover change trajectories will allow stakeholders to anticipate ecological stress and enhance adaptation planning. From a governance perspective, the findings suggest gaps in policy enforcement, particularly concerning land development, forest protection, and disaster preparedness. Current policies must be reevaluated through a policy analysis lens to ensure they are adaptive, locally grounded, and supported by real-time environmental data.

The Hard Truth and Inconsistencies

The ground truthing activities revealed notable inconsistencies between the classified land cover maps particularly those derived from NAPOCOR and Esri Sentinel and the realities observed on the ground. One of the most recurring discrepancies was the underrepresentation of small built-up structures, such as shanties, sari-sari stores, and rural houses, which were present in multiple validated locations (13.24427°N and 123.33229°E; 13.24462°N and 123.32456°E), yet were not classified as ‘Built-Up’ in either of the GIS datasets. This suggests a limitation in spatial resolution and spectral confusion, particularly in areas where rooftops are obscured by vegetation or constructed from materials with low reflectance contrast (Foody & Ghoneim, 2014). Similarly, Esri’s generalized Trees classification appeared to overestimate forest cover, likely due to the inclusion of semi-mature or sparsely distributed vegetation, as seen in areas with grass- dominated pasturelands that also contain scattered trees and abaca (13.24538°N and 123.33025°E). These areas, classified as forest in the map, were in fact grassland with occasional tree growth, leading to overclassification of forest extent, which has implications for carbon stock estimation and reforestation monitoring (Lasco et al., 2004).

Conversely, the NAPOCOR map offered more detailed subcategories, such as Closed Forest, Open Forest, Grassland, and Brush/Shrub, which are valuable distinctions in ecological assessments. However, the ground data indicated that some categories may overlap or be misassigned due to spectral similarity or outdated satellite imagery. For example, sites undergoing active crop rotation or conversion from grassland to upland crops were often still classified as Brush/Shrub or Grassland, when in fact these areas had been cleared and planted (13.24495°N and 123.33252°E). Likewise, certain areas coded as Perennial Crop were found to contain young reforestation plots or mixed upland farms, which did not fully match the assumed category. In terms of water classification, NAPOCOR detected a small inland water body (0.18 ha), while Esri's Sentinel map recorded no water presence, despite the existence of a communal water tank (13.24372°N, 123.31584°E), revealing the limitation of satellite imagery in detecting man-made infrastructure with minimal surface area.

These inconsistencies underscore the importance of integrating ground truthing data into classification validation, especially in heterogeneous rural landscapes like Monte Calvario. They also reflect challenges in accurately classifying transitional or mixed-use land, which can appear differently depending on the sensor resolution, classification algorithms, and the timing of image capture (Giri et al., 2013). For watershed management, such misclassifications can result in inaccurate land use planning, flawed erosion risk models, or misguided reforestation targets. As such, combining high-resolution satellite imagery with community-based validation offers a more realistic and context-sensitive land cover assessment, essential for developing adaptive, locally appropriate watershed governance strategies.

The Success Story

Importantly, the success of watershed management initiatives hinges on community engagement. Ground truthing revealed that many households are already implementing sustainable practices, such as diversified agroforestry and seasonal crop rotation. These should be scaled through community-based conservation programs that harness local ecological knowledge and strengthen stewardship. For long-term sustainability, the report recommends the establishment of a continuous monitoring system using high-resolution remote sensing technologies, supported by local validation teams. This hybrid approach ensures the accuracy of land classification, enhances early warning systems, and fosters a participatory governance model capable of responding to both environmental and social challenges.

XI. RECOMMENDATION AND CONCLUSION

Conclusion

This study analyzed the spatio-temporal land cover changes in Barangay Monte Calvario within the Buhi-Barit Watershed from 2015 to 2024 using GIS-based tools, specifically the annual Esri Sentinel land cover maps and the 2020 NAPOCOR land classification map, supported by detailed ground truthing. The findings clearly reveal substantial changes in land cover over the years, particularly in the expansion and contraction of vegetative cover, shifting agricultural patterns, and the gradual increase of built-up areas. From 2015 to 2024, "Trees" remained the dominant land cover category, but exhibited annual fluctuations suggesting intermittent deforestation and regrowth, likely influenced by both climatic factors and human activities. Notably, the built-up area increased steadily between 2017 and 2020, reflecting rural expansion and land conversion, before slightly decreasing post-2021 possibly due to changes in classification resolution or settlement abandonment.

The major land cover changes identified include: (1) a net increase in tree cover in 2015-2024 reflected a natural regeneration and reforestation efforts like localized initiatives like the Buhi- Barit Tree Planting project; (2) the transition of previously cultivated areas into grasslands and rangelands due to shifting agricultural practices, and (3) the appearance of new built structures, especially in lowland and road-accessible zones. However, these trends were not fully captured by satellite data alone. Ground truthing revealed overlooked realities such as informal housing, mixed - use crops, upland water tanks, and small livestock operations that were misclassified or missed by remote sensing. For example, shanties used by upland farmers, active but non-irrigated rice fields, and degraded lands mistaken for “trees” or “rangelands” highlights the limitations of satellite-only analysis.

The key drivers of these land cover changes include both anthropogenic and natural factors. On the human side, rural development, informal settlement expansion, agricultural land use shifts like low-water rice varieties, abaca, and banana farming), and tourism-related activities like unregulated resort construction) have altered the landscape significantly. Natural drivers such as slope, soil type, and rainfall variability also shaped land use, with areas prone to landslides demonstrating the vulnerability of marginal land uses. Moreover, climate variability and the absence of irrigation infrastructure prompted shifts to climate-resilient crops, while social factors like land tenure uncertainty also influenced land abandonment or informal land use.

Given these observed trends and drivers, several policy and land management recommendations are warranted. First, there is a need for harmonizing GIS classification standards between agencies like NAPOCOR under Buhi-Barit Watershed Reservation and DENR to improve landscape monitoring and avoid conflicting interpretations of forest cover or agricultural land use. Second, a hybrid monitoring approach that integrates annual satellite-derived data with regular ground truthing can help local governments and watershed managers accurately track land changes and target interventions more effectively. Third, local zoning ordinances and comprehensive land use plans (CLUPs) must be updated to reflect actual land use realities, especially in areas where land cover categories are mixed, under transition, or ecologically vulnerable.

Furthermore, there is a clear need for participatory land management planning involving local communities. Many upland farmers operate outside formal systems but are key actors in shaping the watershed’s ecology. Supporting community-based conservation, agroforestry, and risk-sensitive settlement policies can promote land stewardship while reducing environmental pressure. Lastly, the findings call for improved policy enforcement on land conversion, ecotourism regulation, and disaster preparedness, particularly in zones with steep slopes, limited vegetative buffers, and high exposure to extreme weather.

In conclusion, the integration of spatio-temporal GIS analysis, satellite classification maps, and ground-level observations has enabled a more complete and context-rich understanding of land cover change in Barangay Monte Calvario. The study not only answers what and where changes have occurred but also reveals why they are happening and how they can be addressed through coordinated, evidence-based, and inclusive watershed governance.

Ground truthing activities were critical in bridging these gaps. They uncovered several inconsistencies in satellite-based classifications such as misidentified built-up areas, overestimation of forested zones, and underrepresentation of active agricultural plots, fallow grasslands, and community water infrastructure. For instance, the Sentinel map's general "trees" category often included sparsely vegetated or transitional lands, while small-scale shanties, rice paddies, and water tanks critical to local water distribution were absent from both datasets. These findings underscore the importance of localized field validation in interpreting land cover data and ensuring its relevance for decision -making in watershed governance.

Overall, this research reinforces the need for a harmonized and community-informed approach to land cover monitoring. The discrepancies and overlaps between the two GIS maps NAPOCOR's ecologically grounded single-year classification and Sentinel's simplified multi- year coverage suggest that neither source alone is sufficient. Instead, the integration of these maps, supported by regularly conducted field validation, can generate a more accurate, nuanced, and responsive representation of land use in the area. This has significant implications for zoning, environmental protection, climate change adaptation, and sustainable agriculture. Moreover, the evidence gathered supports the formulation of evidence-based policies on land use conversion, reforestation priorities, and risk mitigation in areas vulnerable to natural hazards such as landslides.

In conclusion, a multi-layered GIS-ground truthing framework offers a strong foundation for effective watershed management in Monte Calvario. Such a framework ensures that environmental policies are not only data-driven but also grounded in the lived realities and ecological conditions of the community. By adopting this integrated approach, local government units, national agencies, and stakeholders can work collaboratively toward protecting the integrity of the Buhi-Barit Watershed while promoting sustainable land use practices that benefit both the environment and local livelihoods.

Recommendation

The integration of NAPOCOR's 2020 GIS land cover data, the annual Esri Sentinel-based land cover maps from 2017 to 2024, and the results of on -site ground truthing in Monte Calvario revealed critical discrepancies that highlight the need for more accurate, participatory, and dynamic land cover monitoring systems. While the NAPOCOR map offered detailed ecological classifications such as closed and open forests, perennial and annual crops, and brush/shrubland useful for watershed -specific interventions, it was limited to a single year. In contrast, the Esri Sentinel maps provided a broader, time-series view but with generalized categories, such as trees and crops, that sometimes misrepresented the reality on the ground. For instance, small-scale built- up areas like shanties and isolated homes, observed during field validation in upland zones, were not identified in either map. Similarly, areas categorized as dense forests in the Sentinel map were often semi -open spaces with grass, young trees, or agroforestry crops, and did not represent mature, closed-canopy forests. These discrepancies can potentially lead to misinformed watershed management policies, especially in a community where land use transitions, slope stability, and climate variability significantly influence local environmental dynamics. In light of these findings, a hybrid mapping system is recommended to guide effective policy and watershed planning. The local government, in partnership with DENR, NAMRIA, and local academic institutions, should integrate both datasets into a unified classification matrix that captures the ecological detail of the NAPOCOR map with the temporal sensitivity of the Sentinel maps. This harmonized approach should be institutionalized within the Municipal Planning and Development Office through the creation of a local land cover observatory program. This observatory can conduct annual reviews of updated satellite data, validate them with barangay-led ground truthing activities, and revise official land use classifications and zoning plans accordingly. A community-based monitoring approach should be adopted by training barangay officials and selected youth volunteers in GPS mapping, geo-tagged documentation, and environmental observation to enhance spatial accuracy, especially in upland zones where data inconsisten cies are most pronounced.

Furthermore, zoning and development regulations must be updated to reflect these verified datasets. The incident of a recent landslide near a small resort built in a hazard-prone zone underscores the urgent need to enforce slope-based land use restrictions and conduct geohazard mapping prior to the approval of construction permits. Environmentally critical areas such as buffer zones between closed forests and cultivated lands should be designated as protected areas, and encroachments for tourism or settlement should be strictly regulated. Areas found through multi-year

Sentinel analysis to show fluctuating forest cover should be prioritized for reforestation under the Buhi-Barit Tree Planting Initiatives. In all reforestation and conservation efforts, the integration of local crops such as abaca and banana, observed during field validation, can serve both ecological and livelihood purposes, improving the program's long-term sustainability.

Additionally, agricultural planning must consider the shift toward less water-intensive crops, such as upland rice, seen in areas without irrigation. These practices, verified on-site, should be supported through climate-resilient agriculture programs and erosion-control strategies. To manage these landscapes efficiently, slope-based farming technologies like Sloping Agricultural Land Technology (SALT), which integrates nitrogen-fixing hedgerows along contour lines, are highly effective in reducing erosion and improving soil structure (Watson & Laquihon, 1985). Agroforestry trees such as bamboo, gmelina, and mahogany are effective for long-term slope rehabilitation and watershed protection.

Likewise, infrastructure such as the upland water tank serving two lowland barangays should be documented and protected as critical assets in the local water supply system. These features are often invisible in large-scale satellite classification but are vital for long-term watershed sustainability. Finally, a data-informed governance model should be adopted wherein policies regarding land conversion, building regulation, reforestation, and climate adaptation are directly based on annually validated geospatial data. This approach ensures that policies are grounded in both scientific evidence and the lived realities of communities managing the land. By combining advanced remote sensing tools with active, local ground truthing and inclusive community participation, the municipality can establish a resilient, adaptive, and evidence-based framework for watershed and land use management.

The spatio-temporal analysis of land cover changes in Barangay Monte Calvario, Buhi, Camarines Sur, between 2015 and 2024 highlights the complex interplay between urban expansion, environmental conservation, and watershed health within the Buhi-Barit Watershed. While there has been a modest increase in tree cover that suggests some ecological restoration efforts, this gain is overshadowed by significant encroachment of built-up areas into agricultural lands and rangelands. The resulting landscape transformation poses substantial risks to local food security, biodiversity, watershed integrity, and flood vulnerability, particularly given the intensifying impacts of climate change.

Urban growth around Lake Buhi and its tributaries exacerbates environmental stresses by increasing sedimentation, disrupting hydrological pathways, and degrading critical buffer zones. These trends underscore the urgency for integrated land use planning that harmonizes municipal development with ecosystem preservation. The effective use of satellite-based geospatial technologies and real-time monitoring is highly recommended.

Sustainable and adaptive watershed management calls for strengthened policy enforcement, multi-agency coordination, and active community participation. Combining science- based evidence from remote sensing with participatory governance will empower local stakeholders to balance development pressures with environmental protection. Ultimately, the preservation of agricultural lands, sustainable urbanization, and the enhancement of green infrastructure are critical to maintaining the long-term ecological stability and resilience of the Buhi-Barit Watershed. These measures will ensure that future generations benefit from a balanced relationship between human development and the natural environment.

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