PREDICTION OF FUTURE LAND USE LAND COVER (LULC) AND ASSESSMENT OF ITS IMPACT ON THE WATER SUPPLY AVAILABILITY OF BUTUAN CITY-TAGUIBO RIVER WATERSHED AND FOREST RESERVE (TRWFR), PHILIPPINES

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ABSTRACT:

The Taguibo River Watershed and Forest Reserve (TRWFR) is the primary source of water supply in Butuan City. However, intermittent water supply became a problem for years now in Butuan especially in dry seasons. Hence, this study intended to assess the impacts of LULC change in the TRWFR by generating and predict temporal land covers and determine the impact of these land covers to the current and future water supply of the watershed. This study used Google Earth Engine (GEE) to generate LULC maps of TRWFR from year 2013-2021 which will be used as inputs for the LULC prediction. The QGIS MOLUSCE Plugin was used to predict a land cover for the year 2024. The generated and predicted LULC maps for the year 2021 and 2024, respectively, were then used to simulate streamflow using the Soil and Water Assessment Tool (SWAT) model. The analysis of the SWAT model of the watershed, with the generated temporal land covers from 2013-2024, showcased increase streamflow from 3225.53 liter per second (lps) in 2013, 3267.10 lps in 2021 and 3239.73 lps in 2024. With the results of the hydrologic modeling, there is an increase in the water flow from 2013 to 2021 which might be due to the increase in vegetation but there is a probable decrease in the year 2024. The results show that the change in vegetation has an effect in the water flow in a watershed and this could be assessed through hydrologic modeling.

1. INTRODUCTION

Water is one of the most significant essential needs of people. With the constant developments and urbanization, water resources are critical for ensuring a sufficient food supply and a healthy environment for all living species. Water also plays a vital role in the socio-economic growth and development requiring considerable measures to secure water resources and control the utilization of the supply (Kilic, 2020).

Watersheds are significant source of supply of water in most communities but there are those that are under strain due to the increasing demand of water. There are also other several problems of watershed management such as the change in land use/land cover (LULC) caused by anthropogenic activities. Changes in land use, such as from forest to farmland or farmland to urban settlements, reduce a watershed's capacity to execute its ecological function. Watershed conversion and alteration have progressed to a large extent (Amarille and Rebancos, 2015).

The primary source of water supply in Butuan City for industrial, commercial, and irrigation is only the Taguibo River Watershed Forest Reserve (TRWFR), located at Taguibo, Anticala, Butuan City, Philippines (Serviano et al., 2017). The TRWFR provides water to National Irrigation Administration (NIA) irrigation dams serving large areas of rice farms and a source of income for watershed dwellers.

The water resource of Butuan City is divided between competing urban, agricultural, and ecological uses. However, with the rapid growth of the economy and population of the City, the demand of water for domestic and commercial uses is increasing. But in contrast, the city water supply seemingly been decreasing as there are several instances of water supply shortage. Due to anthropogenic exploitation upstream, the forest cover of this watershed is declining. Changes in land use and land cover (LULC) are one of the primary factors responsible for changing the hydrology of a watershed.

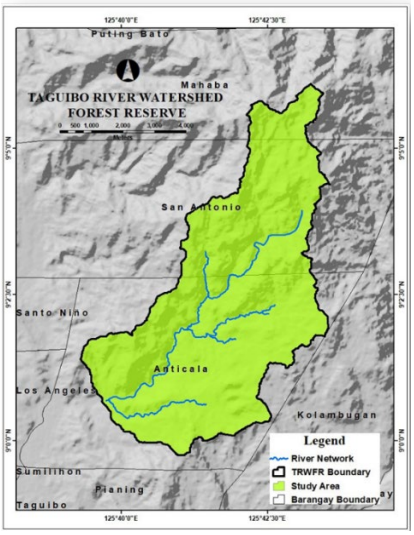

Figure 1. Map of Study Area – TRWFR Map

The study is focused on the prediction of Land Use/Land Cover (LULC) and assessing of its impact on water source of Butuan City. This aims to assess the impact on the water supply availability of Butuan City-Taguibo River Watershed Forest Reserve (TRWFR), Butuan City. The selected sampling site for the study is the upstream of the Taguibo Aquatic Solutions Corporation (TASC) reservoir.

Modern tools and technology such as hydrologic models, remote sensing, and GIS software will help play an essential role in influencing decisions and policymaking related to watershed management. Unfortunately, these advanced technologies are not yet well introduced in the local water management settings. In this research study, Google Earth Engine (GEE) was utilized to process land image classifications using Landsat images for the years 2013, 2015, 2018 and 2021 and predict 2024 LULC map using MOLUSCE.

2. METHODOLOGY

In generating a base LULC for LULCC simulation, integrated multispectral satellite imageries, including the study area's present scene, will be subjected to pre-processing techniques such as radiometric and atmospheric corrections to yield accurate image classification results. Support Vector Machine (SVM) will be utilized to generate the LULC map for 2013, 2015, 2018, and 2021. The researchers will propose predictions to the land cover from the acquired LULC map of 2021 to simulate future LULC and then evaluate the resulting LULC from the MOLUSCE plugin in QGIS. The researchers will then perform an intensive analysis of the predicted LULC's impact on the water supply availability in the study area to determine how it will influence events in the future. Figure 2 shows the general workflow of the methods used in the study.

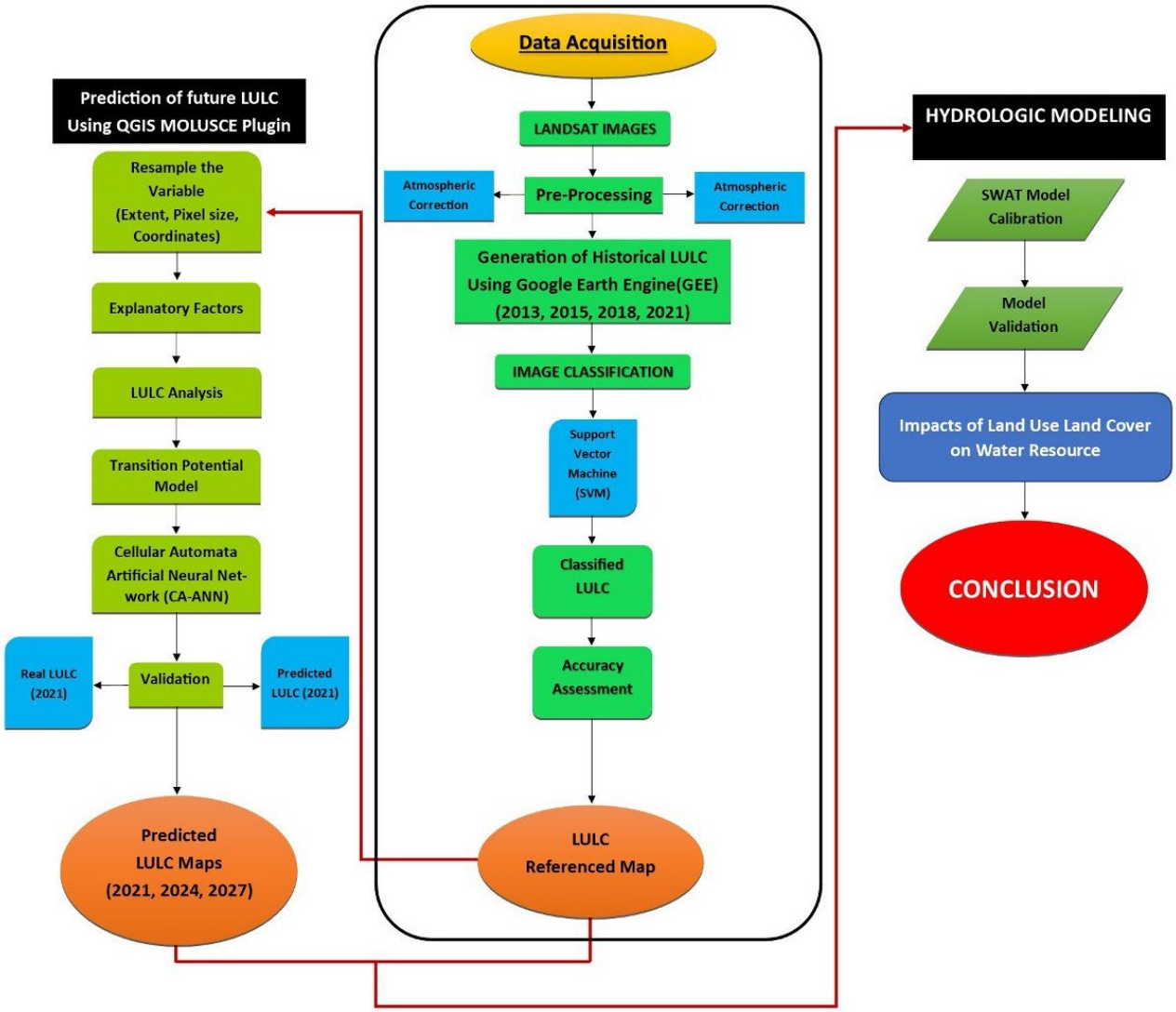

Figure 2. Methodological Flowchart of the Study

2.1 Data Collection

Landsat 8 OLI satellite images from years 2013, 2015, 2018 and 2021 were used for generating the temporal land covers of TRWFR. The spatial variable elements such as DEM, slope map, distance from roads and rivers, and buildings were used together with the generated land covers for the land cover prediction. Table 1 provides a summary of the datasets that were used.

Datasets	Source
Digital elevation model (DEM) Discharge Data	CSU-CReATe (Center Resource Assessment-analytics and Engineering Technologies)
Landsat Images	USGS Earth Explorer
Soil Map	CSU-CReATe (Center Resource Assessment-analytics and Engineering Technologies)
Road and River Network, and Building Footprint	Open Street Map
2013 Daily Discharge Data	Butuan City Water District

Table 1. Datasets Used in the Study

2.2 Land Cover Classification using GEE

The current research satellite data available on Google Earth Engine (GEE) includes fields operations data as well as historical LULC and aerial photograph datasets. The GEE provides easy online access to archived satellite images such as Landsat data as a collection produced United States Geological Survey, which means that there is no need to download the satellite images (Feizizadeh et al., 2021).

In this study, the classification scheme was defined as vegetative (agricultural area, palm, shrubs, grassland, forest), nonvegetative (built-up areas), barren and water. Ground truth samples were collected with the help of Google Earth historical imageries, exploring the true and false color composites of Landsat data, and expert knowledge. The most commonly used machine learning classification, Support Vector Machine (SVM), was used to classify the LULCs (Medina et al., 2019) in GEE. A recursive process was employed in the SVM-based approach to producing prior probability estimates for known and unknown classes. The system was validated using synthetic data and data from two optical sensors, validating its accuracy, especially when ground-referenced data was insufficient (Mountrakis et al., 2010). The validation points collection was aided with the use of Google Earth satellite images as well and expert knowledge in the area. The researchers were not able to go in the upstream areas because of security reasons. Confusion Matrix was used to assess the accuracy of the generated LULCs.

2.3 2024 Land Use Land Cover Prediction and Change Detection Analysis using MOLUSCE Plugin

The MOLUSCE Plugin was utilized to quantify the changes between the research intervals (2013-2015, 2015-2018), generate LULC maps, and establish the trend of changes for the study area between 2013, 2015, 2018 and 2021 and was used also to predict the 2024 LULC. MOLUSCE stands for Methods of Land Use Change Evaluation and this tool supports land use land cover change analysis and prediction (Muhammad, 2022). The initial (2018) and last generated (2021) LULC maps, and the geographical factors such as slope, road, aspect, and wadies, were utilized for the spatial variables of the prediction. A predicted 2021 LULC was generated first to compare and assess its accuracy using the generated 2021 LULC.

2.4 Hydrologic Modelling using SWAT

Hydrological models allow for the study and measurement of hydrological processes as they are influenced by rainfall and watershed variables (Arnold et al., 1998). This may be used to calculate the impact of changes in LULC in the flow and quantity of water in an area or watershed (Näschen et al., 2019). Soil and Water Assessment Tool (SWAT) was utilized for analysing the impact of LULC to the water flow in the Taguibo River Watershed Forest Reserve in particular (TRWFR) since it has shown relevance in hydrologic modelling for several research.

A Soil and Water Assessment Tool (SWAT) model will be utilized to simulate the hydrological process of the TRWFR to determine the stream flow water availability of the watershed at the sampling site TASC. Available daily water discharge data from the Butuan City Water District (BCWD) from year 2013 were used to generate and calibrate a SWAT model for the watershed. The calibrated model was used to generate the models for 2021 and 2024.

3. RESULTS AND DISCUSSIONS

3.1 Generated Land Use Land Cover Maps

Using Landsat 8 images LULC maps of Taguibo River Watershed Forest Reserve (TRWFR) for the years 2013, 2015, 2018 and 2021 were generated as shown in Figure 3. Based on the conducted accuracy assessment, the land cover classification results had an overall accuracy of 97.5% for the base year 2013. In the year 2015, the land cover classification had an overall accuracy of 90% shown in. In 2018, the land cover classification had an overall accuracy of 97.6% shown in. Lastly, in the year 2021 the land cover classification had an overall accuracy of 96.6%.

Eight classes were Annual Cropland (sage dust), Built-up (mars red), Open Forest (leaf green), Shrubs (light apple), Barren (cocoa brown), Grassland (lemongrass), Perennial Cropland (dark olivenite), and Water (big sky blue) for all the maps from 2013-2021. Among the eight classes in the LULC for the year 2013, the land class that had the largest coverage was Forest with 2482 ha, followed by Shrubs and Agricultural area with 1433.22 ha and 240.79 ha, respectively. These three large classes were also conveniently recognized due to its dispersion as being well-grouped and was evident on the pixels matching in the classified raster data. For the year 2015 land cover, the land class that had the largest coverage was Forest with 3039.9 ha, followed by Grassland and Shrubs with 651.80 ha and 487.56 ha, respectively. In 2018, the land class that had the largest coverage was Forest with 3144.32 ha, followed by Grassland and Shrubs with 5256.01 ha and 393.45 ha, respectively. Also, in the year 2021, the land class that had the largest coverage was Forest with 3659.57 ha, followed by Palm and Shrubs with 355.1 ha and 257.91, respectively. The small classes were also more scattered and have less-grouped pixels. A graph shown in Figure 4, is the area percentages of the change detection analysis from 2013, 2015, 2018 and 2021.

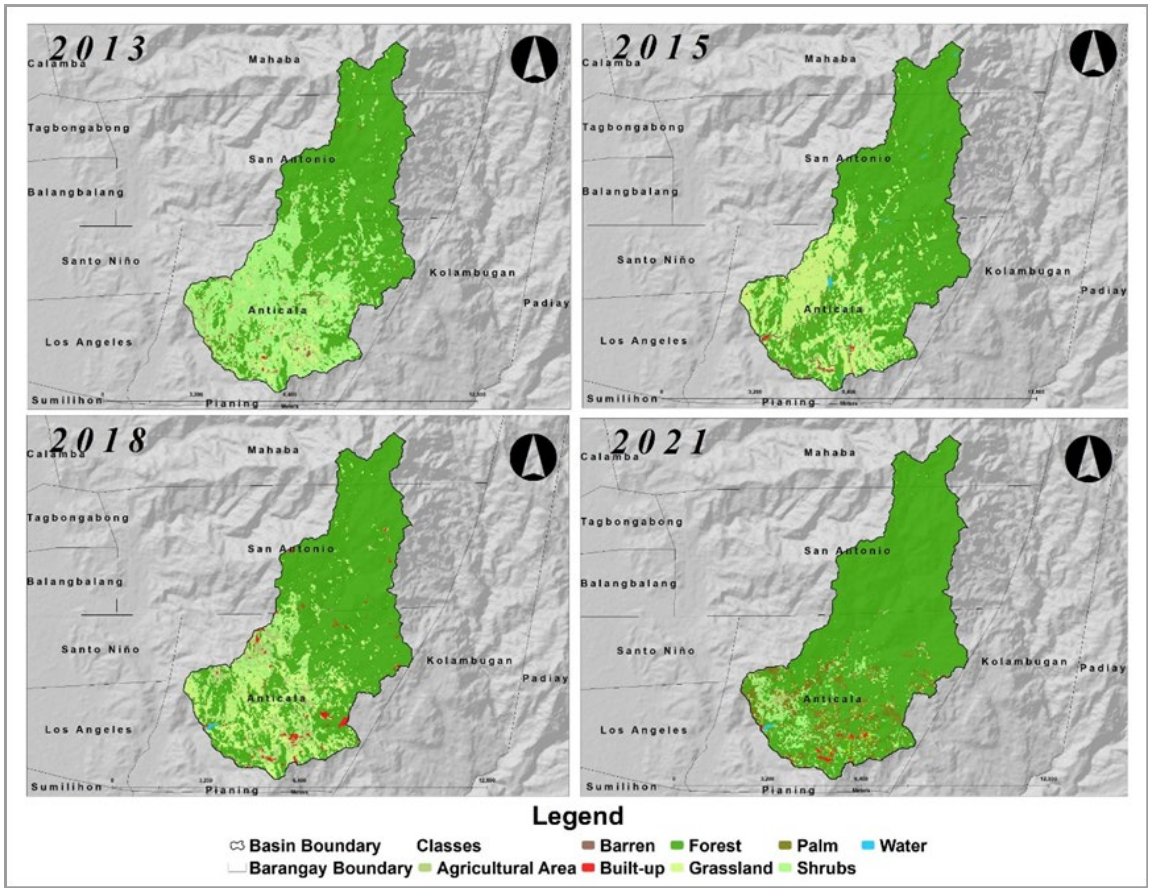

Figure 3. TRWFR Land Cover Map for years 2013, 2015, 2018 and 2021

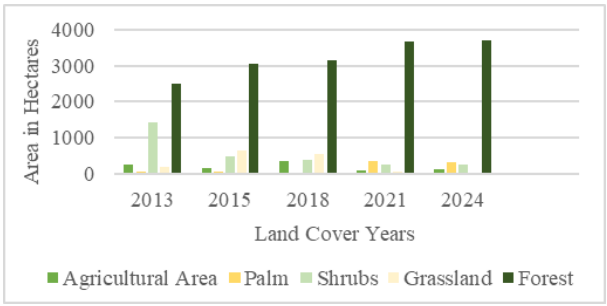

Figure 4. LULC Map Classes Area Percentages from years 2013-2021

3.2 Predicted Land Use Land Cover Maps

Predicted LULC map for year 2021 based on the land cover maps from 2015 and 2018 which was also subjected to the validation with 93.29% overall accuracy as shown in Table 2. The generated and predicted LULC maps of 2021 are shown in Figure 5.

%Correctness	93.29%
Kappa (Overall)	0.90

Table 2. Accuracy results of 2021 predicted LULC map

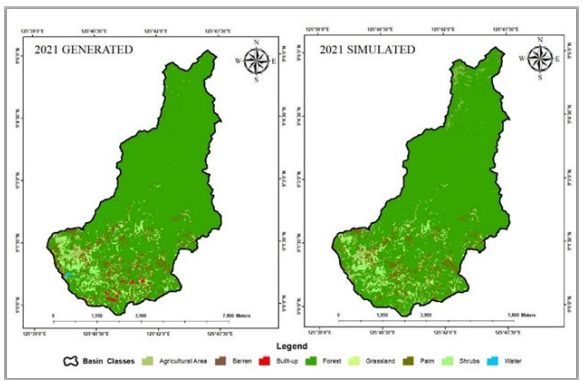

Figure 5. TRWFR Generated and Predicted 2021 LULC maps for MOLUSCE Result Evaluation

The predicted LULC map for the year 2024 (see Figure 6) was simulated and predicted along with the transition maps from 2015-2018, 2018-2021, and 2021-2024. Change detection analysis was done to see the trends of the LULC changes in the watershed especially in the vegetation. The area changes were shown in Figure 7. From the chart, there was increasing quantity of the forest area from 2013-2021 with minimal growth in the year 2015-2021. However, using the temporal LULCs, it was predicted that there will be a decreasing trend of the forest cover from 2021-2024. This could be noted as, in reality, there was really a minimal change in the forest cover due to the anthropogenic influence in the upstream portion of the watershed.

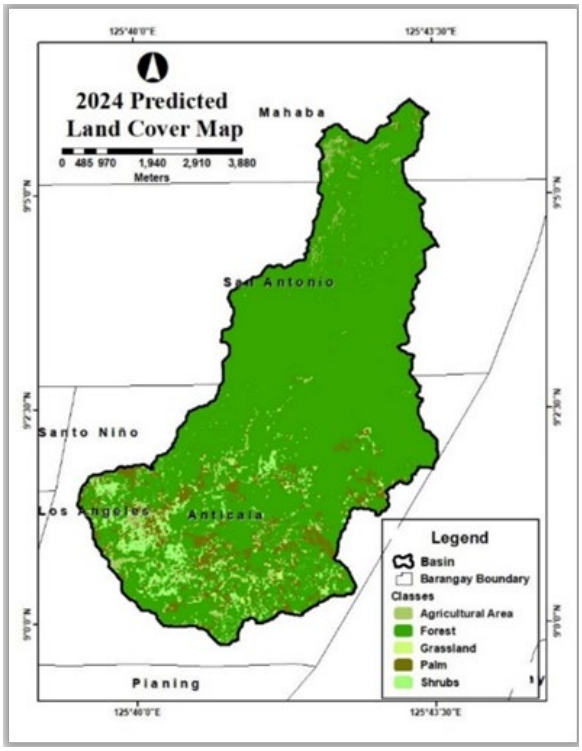

Figure 6. 2024 Predicted LULC Map

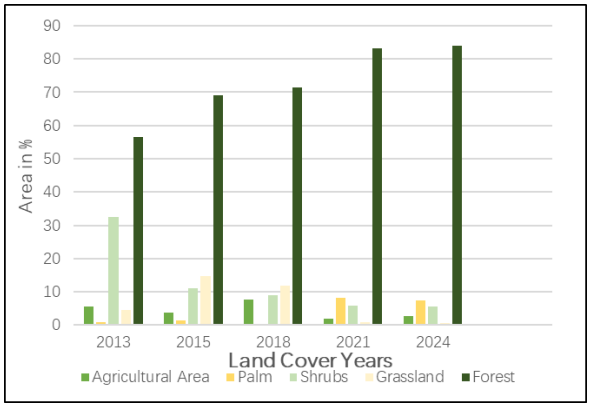

Figure 7. 2013- 2024 LULC Classes Area changes in Percentage

3.3 Prediction of Runoff Volume

To assess the future prediction of water availability in the study area, the generated Land covers from the years 2013, 2021 and 2024 were used as input in ArcSWAT to simulate the stream flow in and stream flow out. A “fixing-changing method” was applied in this study where LULC maps were interchanged, while keeping other inputs (i.e., rainfall data, soil, DEM) constant when simulating runoff using the SWAT model. Figure 8 shows the simulated streamflow in litre per second.

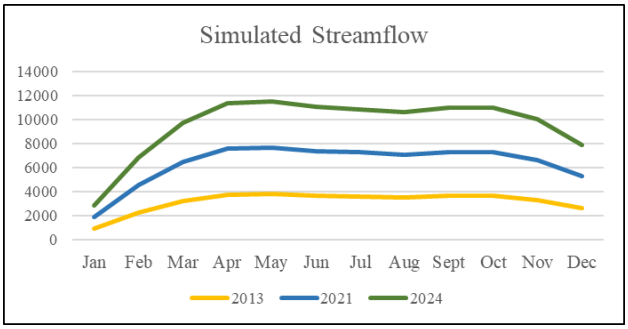

Figure 8. Simulated streamflow for year 2013, 2021, and 2024

As shown in Figure 9, it could be observed that though the increasing forest cover compliments also to the increasing streamflow from 3225.53 liter per second (lps) in 2013 to 3267.10 lps in 2021.However, the model output results revealed that areas that generates high streamflow increased from year 2482.27 hectares(ha) in 2013 to 3690.5 ha during the year 2021 and 2024 simulation LULC’s condition. The simulated and calculated streamflow in 2024, using the predicted LULC with a forest cover lesser than that of the year 2018, is 3239.73 lps which is lower than the streamflow in 2018.

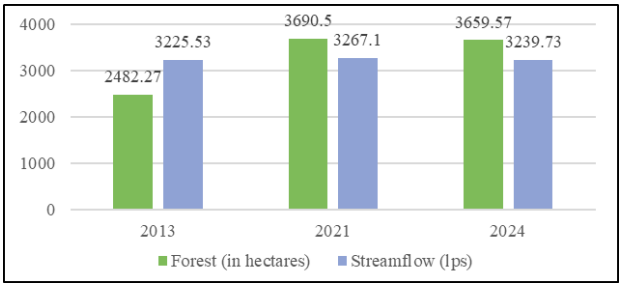

Figure 9. Comparison between forest cover change and change in streamflow for the years 2013, 2021, and 2024

4. CONCLUSIONS AND RECOMMENDATIONS

In this paper, the effects of changes in the land cover through time on flow simulations were investigated using a physically based hydrological model called the Soil and Water Assessment Tool (SWAT). Most hydrological models assume that land cover remains constant during the simulation periods. In this study, the researchers simulated the impacts of LULC on the hydrologic response of the Taguibo River Watershed Forest Reserve (TRWFR). Butuan City's main supply of water is from the study area, in the TASC sampling site. Using Google Earth Engine, the researchers generate historical land cover maps from the year 2013-2021 with not less than 90 percent overall accuracy, which were then utilized as inputs in predicting LULC for the year 2021 for model validation and predicting the 2024 LULC map. It indicates a considerable increase in forest cover from 2013 to 2021 and a minor reduction from 2021 to 2024, which aligns with the simulated and calculated watershed's streamflow. Hence, with the direct relationship shown by the changes in the forest cover and streamflow, the results implies that the change in vegetation has a significant influence on the water flow in a watershed. Changes in the forest cover in the TRWFR would have a significant impact to the watershed’s water supply provisions in Butuan City.

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