Geospatial assessment of land use dynamics and Built-Up Area (BUA) expansion as determinants of island development trajectories

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Abstract. This study aimed to analyze the rate of changes in Land Use Land Cover (LULC) and Built-Up Area (BUA). Geospatial and remote sensing approaches were applied to analyze the trends of LULC changes and BUA expansion from 2017-2024. Results of the accurate testing have shown 98.03 for 2017 and 97.81 in 2024 indicating accurate data sets averaging 2% pixels misclassified both acceptable based on the 85% thresholds for remotely sensed data. Data on changes of LULC have shown fluctuations in land allocation, with forest accounts the largest with 83.38 in (2019) and 89.05% (2023), with declined in 2024 at 84.61. Waterbodies gradually reduced from 1.82% in 2017 to 1.64% in 2024, barren recorded fluctuation of 2.40% and 3.39%. Moreover, BUA exhibits an increasing trend, which peaks in 2020 at 4.58% and records stabilization of 4.27% in 2024, Furthermore, agricultural lands demonstrate the highest recorded variability with a notable reduction in 2022 of 3.64% but recovered in 2024 with 7.08% suggesting dynamism in land conversion processes. Generally, the observed LULC change patterns underscores the continuing pressures on the remaining forest and agricultural land which was driven by the BUA expansion and land conversion.

1 Introduction

Urbanization remains the leading factor that contributes to global landscape transformation in recent history of urbanization. A relationship between changes in land use, urbanization, and landscape patterns has been determined [1]. Urban environment continues to expand over the past decades at an unprecedented rate as a response to accommodate the rapid increase in population and expanding economic horizon [2].

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The quantification of urban induced LULC changes is crucial for analyzing the influence of urban landscape patterns that merits spatio-temporal investigations on thermal variation on a long-term scale [3]. Currently, there is no current data yet on the trajectory of the LULC changes in the Province of Marinduque, Philippines which drives this study to analyze spatio-temporal change as reference for the direction of island development, and this serves as basis to accommodate a holistic provincial sustainable urban development planning and environmental management policies anchored on the island carrying capacity. This study aimed to assess the LULC changes and BUA expansion from years 2017-2024 in the Province of Marinduque and its implications to sustainable island development patterns and trajectories.

2 Methodologies

2.1 Research Design

This study used a descriptive quantitative-non-experimental design using a GIS-based approach involving the acquisition of satellite images and reference data from Landsat 8 pre-processed in QGIS. The pre-processed image undergone geometric correction, atmospheric adjustment, and layer stacking to ensure spatial accuracy prior to classification. The semi-automatic classification plugin (SCP) in QGIS was employed to perform supervised classification of land cover classes, particularly in identifying BUA and land use categories. An accuracy assessment was carried out using the SCP Plugin's validation functions by generating a confusion matrix and computing overall accuracy, user's accuracy, producer's accuracy, and the Kappa coefficient. Finally, a temporal analysis was conducted to assess BUA expansion and LULC transitions across multiple years, to ensure the identification of patterns and rates of change in various time periods. Shown in Fig. 1 is Province of Marinduque where the study site is located.

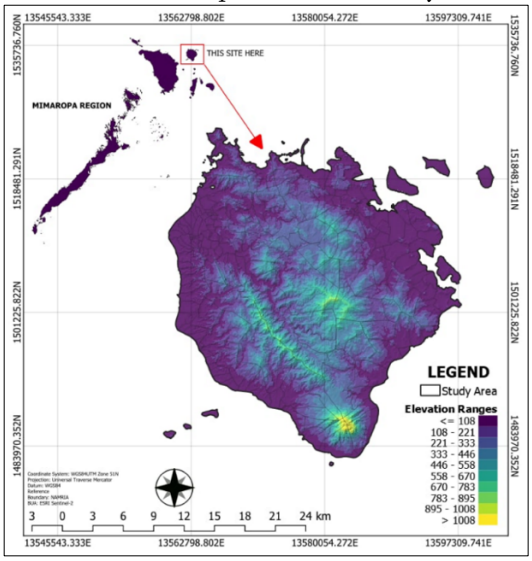

Fig. 1. Map showing the location of the study area

3 Results and discussion

Presented in Table 1 is the overall accuracy tests results; it shows a very high accuracy indicating that the process was reliable and consistent based on the computed PA of 98.03% in 2017 and 97.81% in 2024. This highlights the ability to capture strong actual land cover based on the analyzed land classes showing minimal misclassifications. Generally, between 2017 and 2024, the LULC classification remained highly accurate, averaging 98% emphasizing possible shifts of LULC linked with urbanization LULC changes. [4] cited that, classifying remotely sensed imageries remains challenging but the overall improvement of the classification accuracy in LULC maps provides significant potential for LULC modeling, indicating highly reliable classification with only minimal misclassifications.

Table 1. The area based-error matrix of LULC 2017 and 2024

Area Based Error Matrix (LULC 2017)							
	>Reference						
Classified	1	2	5	7	11	Area	Wi
1	0.0182	0.0000	0.0000	0.0000	0.0000	167697	0.0182
2	0.0185	0.8372	0.0000	0.0000	0.0000	7889638	0.8557
5	0.0000	0.0000	0.0278	0.0000	0.0000	255927	0.0278
7	0.0000	0.0000	0.0000	0.0306	0.0000	282569	0.0306
11	0.0012	0.0000	0.0000	0.0000	0.0665	623889	0.0677
Total	0.0379	0.83872	0.0278	0.0306	0.0665	921972	
Est. Area	34909135	771914657	25592700	28256900	61298609	921972000	
SE	0.0020	0.0020	0.0000	0.0000	0.0004		
SE Area	1843831	1808227	0	0	360591		
95% CI area	3613908	3544125	0	0	706759		
PA [%]	48.0381	100.0000	100.0000	100.0000	100.0000		
UA [%]	100.0000	97.8390	100.0000	100.0000	98.2524		
Overall Accuracy [%] = 98.03			CI = confidence interval				
Area unit = metre^2			PA = producer's accuracy				
SE = standard error			UA = user's accuracy				
Area Based Error Matrix (LULC 2024)							
	>Reference						
Classified	1	2	5	7	11	Area	Wi
1	0.0164	0.0000	0.0000	0.0000	0.0000	15166300	0.0164
2	0.0216	0.8244	0.0000	0.0000	0.0001	7800453	0.8461
5	0.0000	0.0000	0.0238	0.0001	0.0000	22111900	0.0240
7	0.0000	0.0000	0.0000	0.0427	0.0000	39358600	0.0427
11	0.0000	0.0000	0.0000	0.0000	0.0708	65289900	0.0708
Total	0.0380	0.8244	0.0238	0.0428	0.0709	921972000	
Est. Area	35046633	760052025	21981830	39524715	65366797		
SE	0.0009	0.0009	0.0001	0.0001	0.0001		
SE Area	863897	865475	64891	65476	54373		
95% CI area	1693239	1696332	127187	128333	106571		

PA [%]	43.1718	100.0000	100.0000	99.5797	99.8824
UA [%]	99.7623	97.4369	99.4118	100.0000	100.0000
Overall Accuracy [%] = 97.81			CI = confidence interval		
Area unit = metre^2			PA = producer's accuracy		
SE = standard error			UA = user's accuracy		

Presented in Table 2 is the data on the LULC changes from 2017-2024. For 2017, the most dominant land classification was forest which accounts the 85.57% of the total land area, followed by agricultural with 6.77%, BUA 3.06%, barren 2.78%, and waterbodies with 1.82% as shown in the map in Fig. 2. This implies the study area is heavily forested with the observed dominance of forest classification and merely considered balance ecosystems along with other land classifications. According to [5] the global forest area fell by 3% from 1940 to 2015 which was mainly at the tropics with observed rates higher in low-income countries. For 2018, forest accounts 87.32% with an increase of +2.04%, while agricultural land experience a sharp decline of 4.88% with a notable decrease of -27.86%, while BUA recorded 3.77% with an increase +23.04%, barren with 2.42% with decline accounts to -12.94% along with waterbodies with 1.61% with a decline account to -11.30%.

These years recorded notable urban growth, which led to the shrinkage of other land-use classes, particularly agricultural areas, as a result of uncontrolled expansion and land conversion to accommodate increasing land demand. According to [6] forest covers, and other land use are experiencing accelerating losses in some regions and gains in some regions where trends and patterns have shown greatest losses and gains in the tropics in which growth is linked to regrowth in plantations.

Table 2. The land use land classifications of the province of Marinduque from 2017-2024

Classification	Year								
	2017			2018			2019		
	Area (ha)	%	% (-/+)	Area	%	% (-/+)	Area	%	% (-/+)
Waterbodies	1676.97	1.82	-	1487.46	1.61	-11.30	1443.14	1.57	-2.98
Forest	78896.38	85.57	-	80504.01	87.32	2.04	76851.05	83.36	-4.54
Barren	2559.27	2.78	-	2228.21	2.42	-12.94	2227.55	2.42	-0.03
Built-up	2825.69	3.06	-	3476.81	3.77	23.04	3987.65	4.33	14.69
Agricultural	6238.89	6.77	-	4500.71	4.88	-27.86	7687.81	8.34	70.81
Total	92197.2	100		92197.2	100		92197.2	100	
Classification	2020			2021			2022		
Waterbodies	1640.67	1.78	13.69	1546.61	1.68	-5.73	1485.8	1.61	-3.93
Forest	79115.58	85.81	2.95	79862.78	86.62	0.94	80938.19	87.79	1.35
Barren	2721.39	2.95	22.17	3121.96	3.39	14.72	2488.59	2.70	-20.29
Built-up	4220.72	4.58	5.84	4067.25	4.41	-3.64	3927.36	4.26	-3.44
Agricultural	4498.84	4.88	-41.48	3598.6	3.90	-20.01	3357.26	3.64	-6.71
Total	92197.2	100		92197.2	100		92197.2	100	
Classification	2023			2024					
Waterbodies	1652.08	1.79	11.19	1516.63	1.64	-8.20			
Forest	82102.25	89.05	1.44	78004.53	84.61	-4.99			

Barren	2333.86	2.53	-6.22	2211.19	2.40	-5.26
Built-up	3561.18	3.86	-9.32	3935.86	4.27	10.52
Agricultural	2547.83	2.76	-24.11	6528.99	7.08	156.26
Total	92197.2	100		92197.2	100	

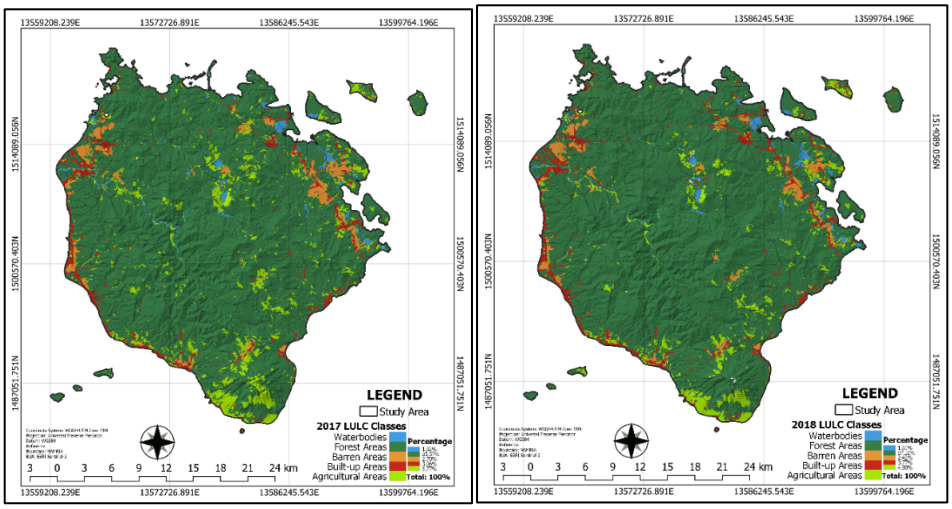

Fig. 2. Map showing LULC of the province of Marinduque from 2017-2018

For 2019, forest still dominant which accounts the 83.36% and recorded a decline of -4.54%, agriculture accounts the 8.34% which recorded a notable increase of +70.81%, BUA 4.33%, barren 2.42% with a decline of -.03%, waterbodies 1.57% recorded -2.98% decline. Although forest remains dominant, the agricultural lands marks agricultural boom reflecting notable gains along with the continued urbanization.

The study by [7] showed that contemporary land pressures have a significant impact on forest conditions, with the potential for forest regeneration declining by 4%. This indicates ongoing land conversion across spatial and temporal scales, contributing to dynamic changes in LULC at the regional level. For 2020, forest accounts the 85.81% with +2.95%, agricultural with 4.88% recorded decline of -41.48%, BUA with 4.58% with +5.84%, barren 2.95% with +22.17, and the least was waterbodies with 1.78% with increase of +13.69% as reflected in the map in Fig. 3. This indicates disturbance in other lands' classification reflecting losses and gains, indicating steady growth over the years. According to [8] the decrease in forest areas provides other land classes to expand at an unprecedented rate mainly associated with increase in population driven by unplanned development and key policy changes.

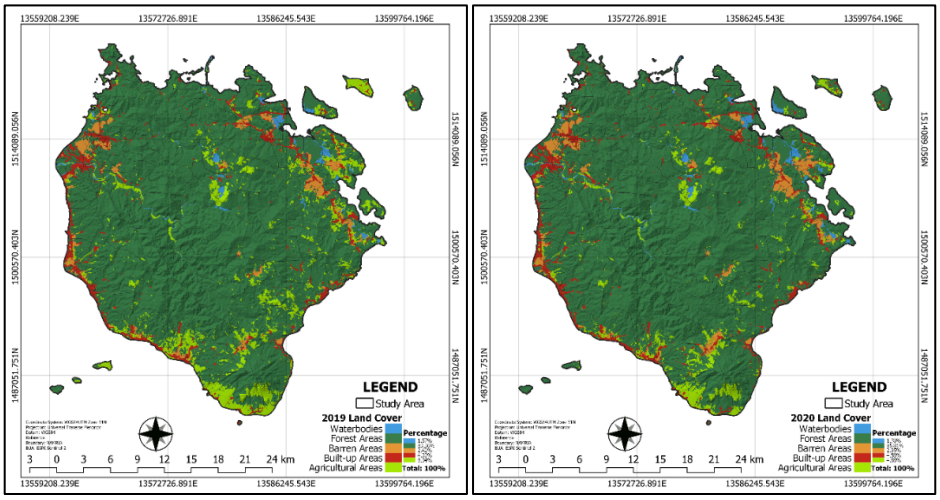

Fig. 3. Map showing LULC of the province of Marinduque from 2019-2020

For 2021, forest accounts the 86.62% with +.94%, while BUA accounts the 4.41% with -3.64%, agricultural with 3.90% decline by -20.01%, barren 3.39% which gains +14.72%, and waterbodies with 1.68% which recorded -5.73% decrease. This implies forest consolidation which reflects its wider forest resilience amidst the pressure from the other class.

For 2022, forests hold 87.79% with an increase of 1.35%, BUA with 4.26% which recorded a decrease of 3.44%, agricultural 3.64% with a notable decline to -6.71%, while barren 2.70%, and waterbodies 1.61% both a recorded decline of -.03 and -2.98 respectively. This marks the remarkable recovery on forest lands which have reached the highest since 2017 as shown in the map on Fig. 4. The study of [9] indicated that BUA continually increasing at the expense of agricultural and forest lands.

In 2023, forests accounted for 89.05% of the land cover and increased by 1.44%. Built-up areas covered 3.86% but declined by 9.32%, while agricultural land (2.76%) decreased by 24.11% and barren land (2.53%) decreased by 6.23%. Water bodies occupied the smallest proportion (1.79%) but increased by 11.19%. The study by [10] showed that BUA increased by a factor of 23, particularly in PA, between 1975 and 2014. Small and coastal forest areas, which are generally less intensively managed, experienced higher pressure from built-up expansion.

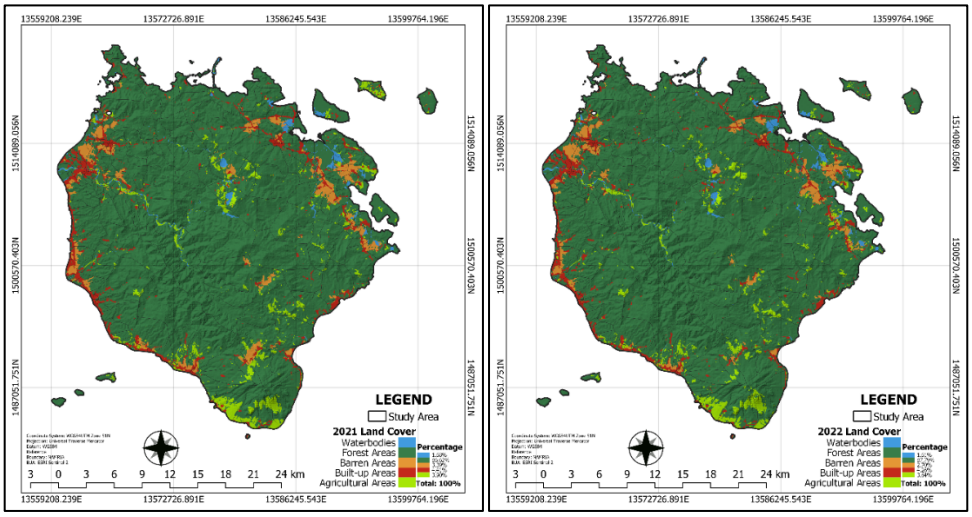

Fig. 4. Map showing LULC of the Province of Marinduque from 2021-2022

For 2024, forest remained dominant with 84.61% which have declined by 4.99%, followed by agriculture with 7.08% which increased to +156.26%, BUA with 4.27% with increase of +10.52%, barren accounts the 2.40% losing -5.26%, and the least is waterbodies accounts the 1.64% with a loss of -8.20%. This highlights a remarkable shift in the landscape, in which forest areas experienced sharp declines while agricultural areas expanded rapidly. These trends indicate a turning point in land-use and land-cover trajectories in the province, as illustrated in Fig. 5. Data from the study of [11] have shown a decrease in forest cover 51.37% in 1986 to 17.20% in 2019 driven by human activities, agricultural expansion, and urbanization.

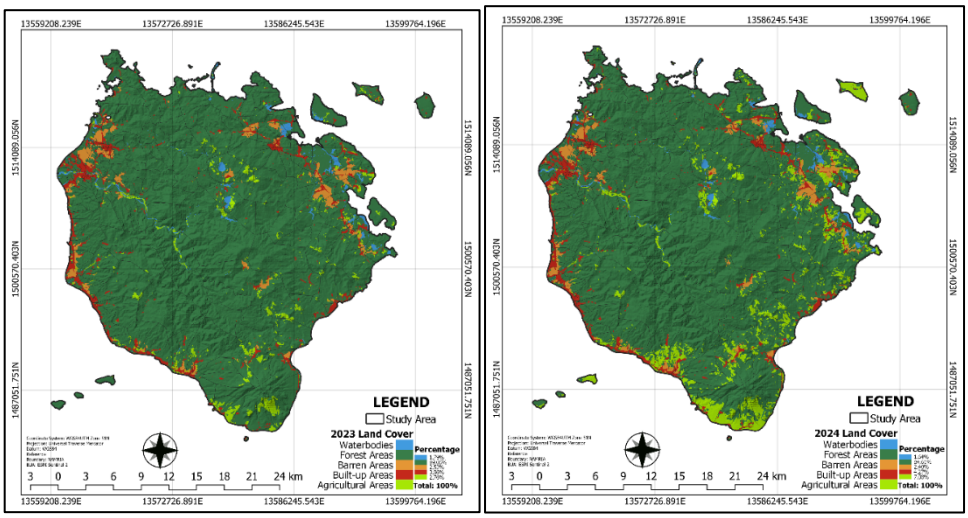

Fig. 5. Map showing LULC of the Province of Marinduque from 2023-2024

4 Conclusion

The findings of the study have shown that Marinduque is experiencing dynamic change reflecting fluctuations from 2017-2024 where waterbodies show fluctuating decline trend possible attributed to encroachment and siltation. Although forest fluctuates, it remains dominant which also marks a concerning decline likely due to conversion. Barren lands are on volatile trend with peaks and lows linked to reclamation and vegetation regrowth. For BUA it reflects long-term trend indicating growth and development pressures. Lastly, agricultural lands show the highly volatile with land conversion, policy, and economic drivers. Patterns change shows forest as the most dominant with a notable decline in some years while built-up reflects steady increase along with urbanization.

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