Assessment of Land Use/Land Cover Change in Butuan City, Philippines: A Landscape Ecology Approach using GIS

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Assessment of Land Use/Land Cover Change in Butuan City, Philippines: A Landscape Ecology Approach using GIS

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Abstract: *Urban development puts an anthropogenic pressure resulting in a process of replacing natural landscapes with other land uses. Butuan City follows this trajectory as a highly urbanized city and regional center of Caraga Region. These Land Use/Land Cover (LULC) changes can be better understood from the perspective of landscape ecology. LULC change, landscape metrics, and landscape indices were determined using GIS. Results showed that there is a 41% decrease in tree cover and 36% increase in built-up areas between 2015 and 2024. There was also a decrease in fragmentation for bare land and water bodies while an increase was observed for tree cover, fields/crops, and built-up areas. An increasing trend was recorded for the Built-up Index while a higher Built-up Expansion Index was observed for the eastern portion. These results highlight the crucial role of monitoring LULC change over time in physical planning for sustainable development.*

Keywords: Land cover, landscape ecology, landscape metrics, fragmentation, QGIS

1. INTRODUCTION

Urban development is the social, cultural, economic, and physical development of the cities and their activities. This anthropogenic pressure results in a process of replacing natural landscapes with other land uses. It is one of the major factors for Land Use/Land Cover (LULC) change [1]. These LULC change can be better understood when analyzed from the perspective of landscape ecology. The use of landscape metrics provides scientific basis in understanding these landscape changes [2].

The phenomena of urban land expansion and land conversion due to urban sprawl were already documented [3] [4]. Studies on the fragmentation and aggregation of landscape elements such as Urban Green Spaces and defining the trajectory of Built-up Land Expansion also show the importance of landscape metrics in quantifying changes in landscape patterns [5] [6]. The physical planning for sustainable development of growing cities requires monitoring LULC change over time [7]. The general objective of this study is to monitor the Land Use/Land Cover Change (LULCC) in selected barangays of Butuan City from 1995 to 2024. Specifically, this study aims to:

a. generate LULC maps of selected barangays of Butuan City for 3 periods (i.e. 1995, 2014, 2024),
b. perform patch-based analysis on the fragmentation of the identified land use/land cover classes, and
c. determine urbanization indices specific to built-up areas and compare the results

2. METHODOLOGY

Butuan City is categorized as a highly urbanized city and a regional center of Caraga Region. It is poised to become a Forest-based Economic City and a Smart City [8]. The figure below shows the study area, specifically, selected barangays of Butuan City, Agusan del Norte in the Caraga region.

The study was conducted following the general steps described in Figure 2 below. It mainly utilized the QGIS software which was primarily considered due to its accessibility given that it is free and open-source.

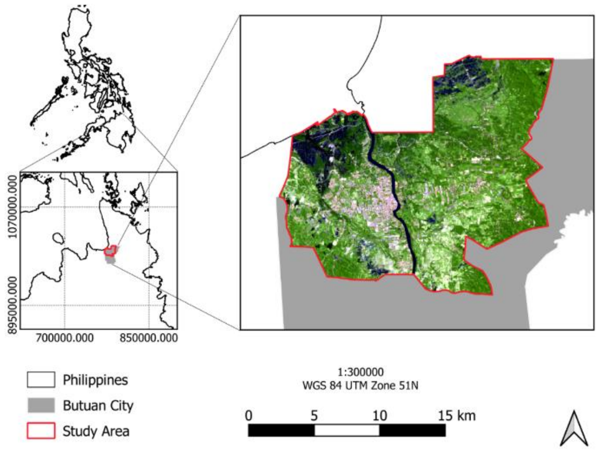

Fig. 1. Location map of the study area and clipped Landsat-8 image (2024) used for classification.

Multitemporal satellite images were obtained from USGS EarthExplorer. Three satellite images were used specifically Landsat-5 image for 1995 and Landsat-8 images for the year 2014 and 2024. These were selected for the same month on each identified year with minimal cloud cover to ensure accuracy. Additional data were obtained from the Philippine Statistics Authority (PSA) representing the political boundary maps of the country.

The downloaded satellite images and political boundary maps were imported to QGIS. These were then pre-processed which involved georeferencing, clipping the images to the boundary of the study area, and performing image adjustments including atmospheric correction using the Semi-Automatic Classification Plugin (SCP). The same plug-in was used for the supervised classification process. Each of the three satellite images were classified following the LULC classification scheme described in Table 1.

Five LULC classes were identified namely water, built-up, bare land, fields/crops, and tree cover. All the images have been prepared separately with individually designated Points of Interest (POIs) after which the Random Forest Classification was applied [9]. Accuracy assessment was conducted to achieve at least 90% accuracy. These produced the LULC maps for 1995, 2014, and 2024 which are essentially GIS raster images and served as basis for all subsequent analysis.

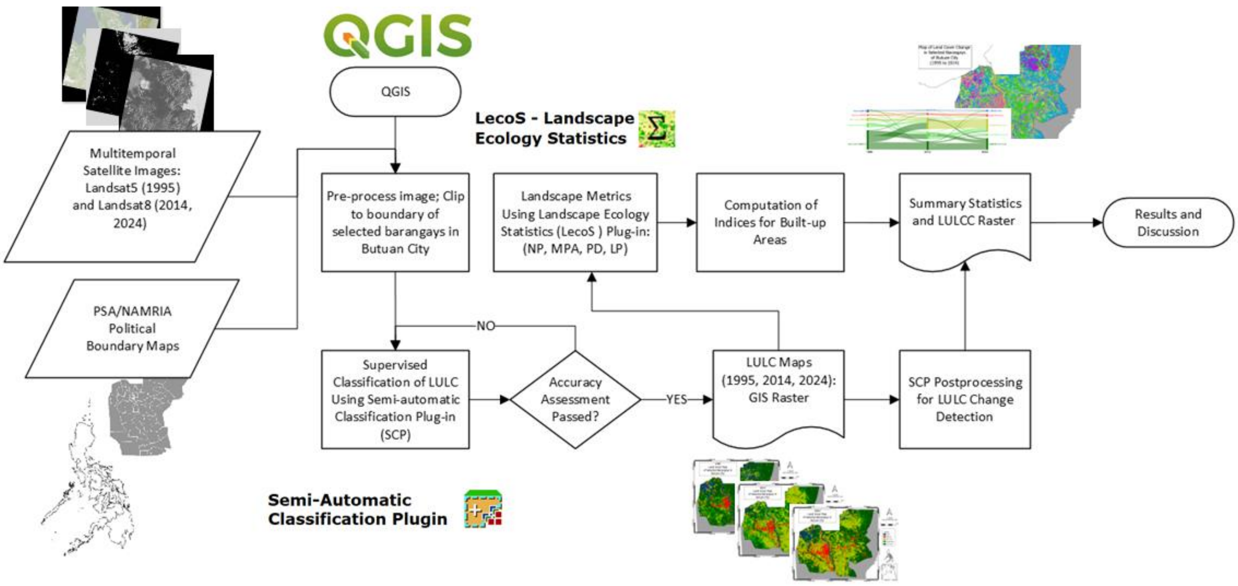

Fig. 2. Methodological framework of the study.

Postprocessing was done using SCP to produce a map of LULC changes. This resulted to a raster representing pairwise changes that occurred from one land cover class for the initial period to another land cover class for the final period. This was done for two periods: 1995-2014 and 2014-2024.

Table 1. Land Cover Classification Scheme

Land Cover Class	Description
Water	Seas, lakes, rivers, fishponds, wetlands, and all other bodies of water.
Built-up	Residential, Commercial, Industrial, and Institutional buildings or any area of man-made features; Road networks
Bare Land	Barren lands, croplands without any vegetation, and exposed mountains.
Fields/Crops	Grasslands, croplands with existing planted crop, and all other forms of vegetation
Tree Cover	Densely vegetated areas such as forests; Thick tree canopies.

The Landscape Ecology Statistics Plugin (LecoS) was utilized to determine landscape metrics related to fragmentation presented in Table 2. These include landscape proportion, number of patches, and mean patch area. Patch density was also computed but deemed redundant since it offers the same information as number of patches given that the same total area was considered in the analysis.

Two indices related to the built-up areas were then computed [5]. The Built-up Index (BI) was determined for 1995, 2014, and 2024. This represents the ratio of built-up area to total area.

Table 2. Landscape Metrics Obtained using LecoS

Landscape Metrics	Description
Landscape Proportion	Reflects the proportional abundance of each land cover classification over the total area of the landscape.
Number of Patches	Reflects the number of patches for each land cover class in the landscape.
Mean Patch Area	Reflects the fragmentation degree of the landscape for each land cover class.

The Built-up Expansion Index (BX) was computed for 1995-2014, 2014-2024, and the overall period from 1995-2024. It reflects the change in built-up area with respect to time. The equations below represent how these indices were determined.

Built-up Area Index (BI):

$$BI = \text{Built-up Area} / \text{Total Landscape Area} \quad (1)$$

Built-up Area Expansion Index (BX):

$$BX = (BI_{t2} - BI_{t1}) / BI_{t1} \quad (2)$$

where: BI_{t1} *– Built-up Index for the initial period*
BI_{t2} *– Built-up Index for the final period*

3. RESULTS AND DISCUSSION

3.1 LULC Maps

Three different LULC maps were produced for 1995, 2014, and 2024, respectively showing the spatial distribution of the identified five different land cover classes. Each of these classes is shown based on the legend. It can be observed that the tree cover class represented in dark green comprises most of the map area in 1995. The built-up areas also show an increase in amount and distribution throughout the study period.

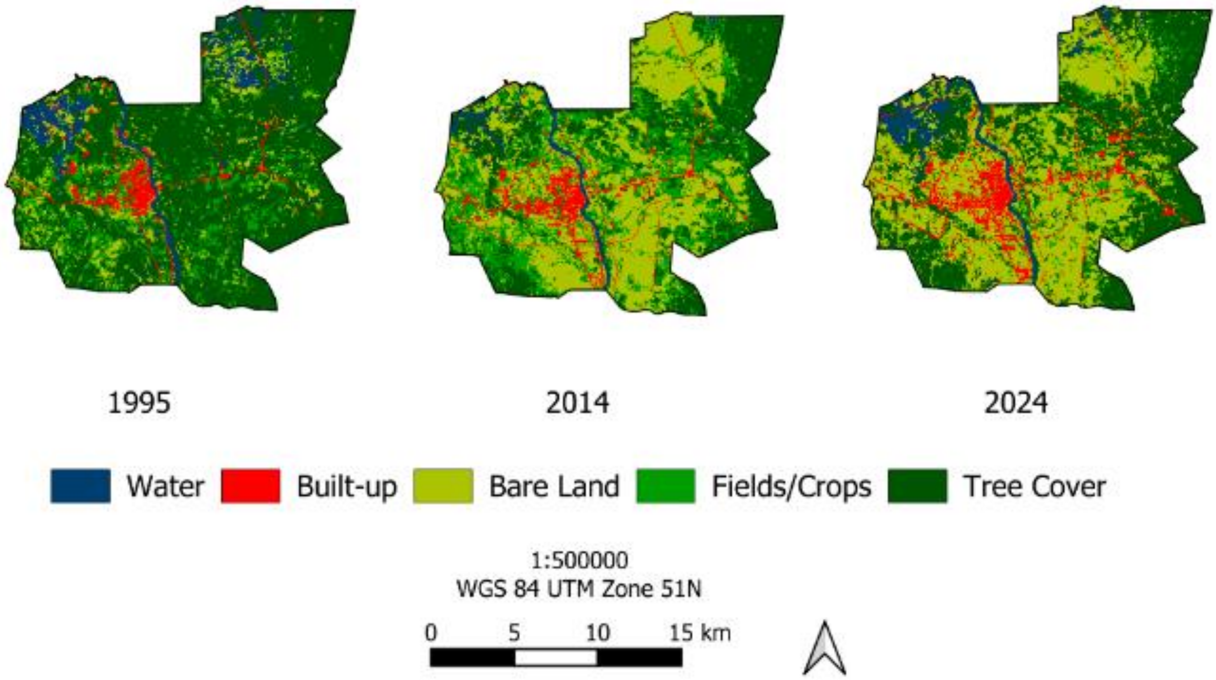

Fig. 3. Map showing Land Use/Land Cover Classes for three time periods.

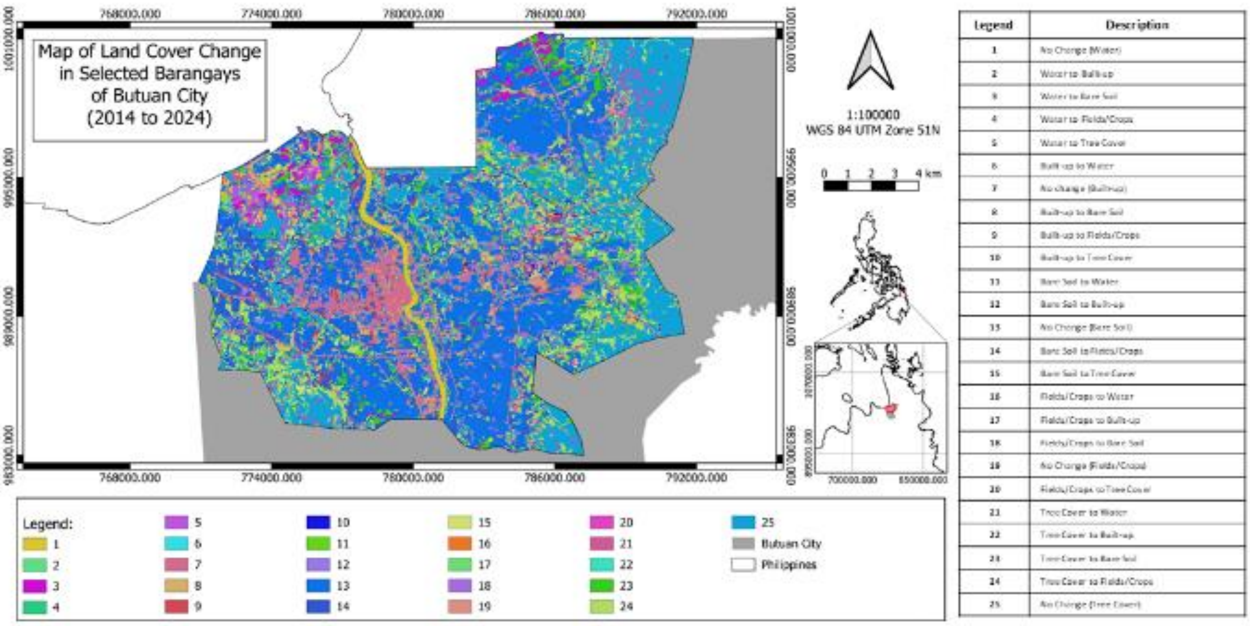

Fig. 4. LULC change comparison for 1995-2014

3.2 LULC Change

The pairwise changes for two time periods can be visualized from Figure 4 and Figure 5. These represent the periods 1995-2014 and 2014-2024, respectively.

From Figure 4, it can be observed that the tree cover class mostly distributed along the outer boundary of the study area represents the greatest change to another land cover class from 1995-2014. However, there was an observed increase in tree cover for 2014-2024 mainly from bare land and fields/crops represented by 15 and 20 in Figure 5.

The Sanley Plot shown in Figure 6 below was generated for the same time period. Bands show the actual proportion of area that changed over the 3-year period. The highest percentage of land cover class in 1995 is tree cover accounting to 58% of the total area. The values represent the area for the specific land cover class in hectares. The most notable change is described in the decrease in tree cover from 15,481.71 ha. in 1995 to only 6,927.75 ha. (26%) in 2014. Majority of this area followed a land cover change to either bare land or fields/crops. However, the tree cover increased to 9,225,54 ha. (35%) in 2024. The area for bare land also increased steadily with a total increase of 7881.39 ha. from 1995 to 2024. The total area classified as Fields/crops was reduced to only 1, 617 ha. in 2024. This can be accounted to the fact that fields with no crops were classified as bare land following the classification scheme. This gave a rise in bare land area to 10,478.25 ha. or 39% of the total area in 2024. For built-up areas, there was a steady increase up to 2,034.72 ha. for the 29-year period. Areas classified as waterbodies remained relatively steady but was reduced to 1289.52 ha. in 2024. These are generally supported by a related study on the analysis of rice cropland conversion which showed that 784 ha. of rice fields were converted for the period 2003 to 2013 and 117 ha. for 2013 to 2023 in Butuan City [4].

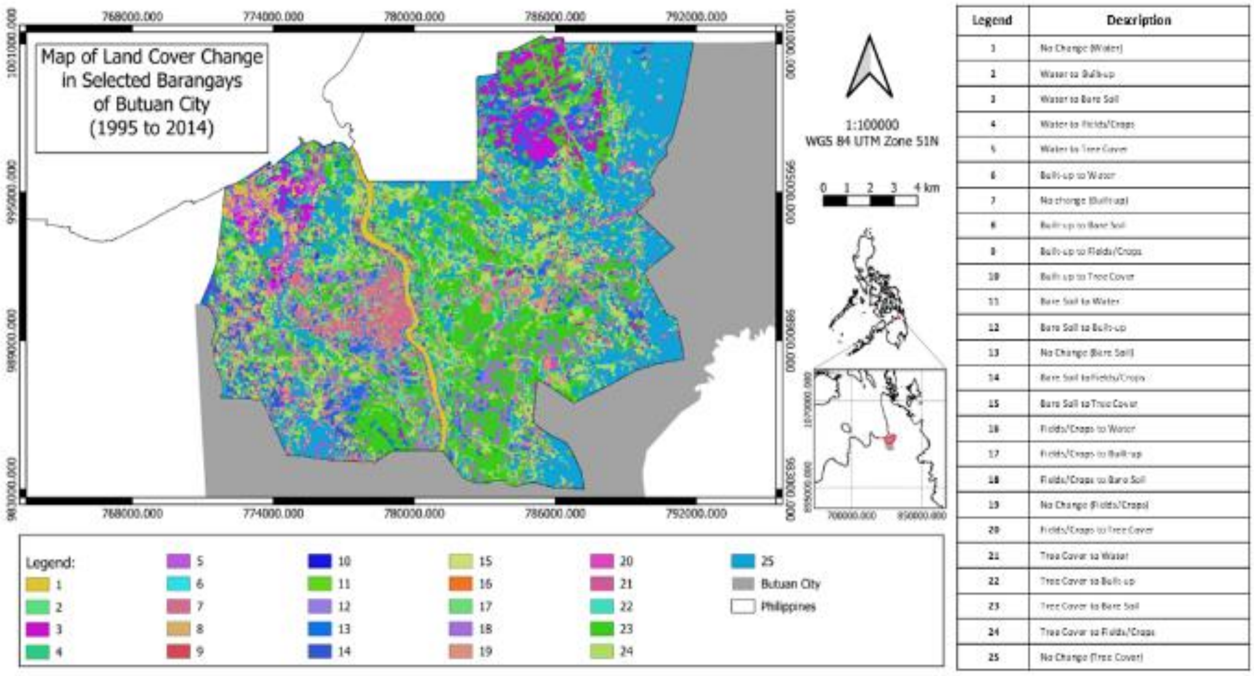

Fig. 5. LULC change comparison for 2014-2024

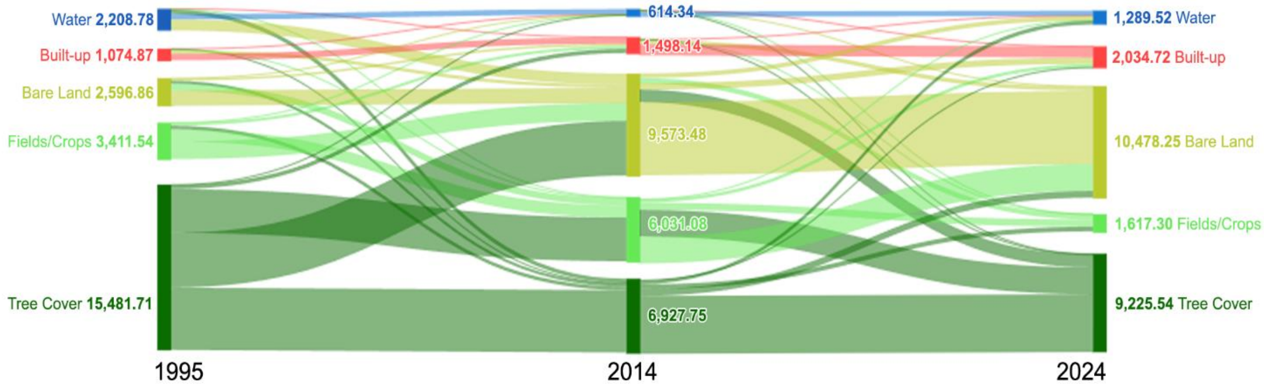

Fig. 6. Sanley plot describing the LULC change.

3.3 Landscape Metrics

The area for each land cover class over the total landscape area gives the landscape proportion. Figure 7 describes the general trend for the changes that occurred over the 3-year period. This is similar to the trend described in the Sanley plot.

There is an increase in the number of patches for tree cover, fields/crops, and built-up areas as shown in Figure 8. In contrast, there was a slight decrease in the number of patches for bare land and water. This is also related to patch density since the same total landscape area is considered.

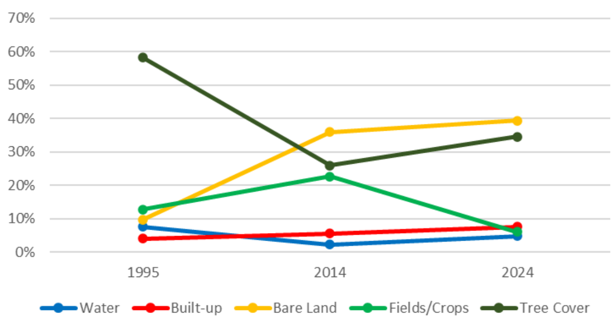

Fig. 7. Landscape proportion for each land cover class from 1995 to 2024

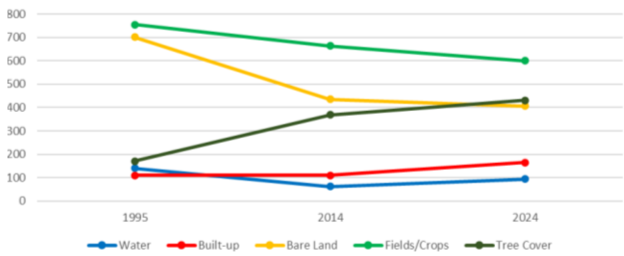

Fig. 8. Number of patches for each land cover class from 1995 to 2024

The mean patch area of the land cover classes have generally higher values when the number of patches have lower values. This inverse relationship gives a mutual confirmation that these two landscape metrics reflected an increase in the number of smaller patches for tree cover, fields/crops and built-up areas, as shown in Figure 9. This means that there is an increase in the degree of fragmentation for these land cover classes. This is in contrast with the study of Yang, et. al. which states that as built-up land matures, all patches eventually become several contiguous large urban areas [6]. In essence, fragmentation decreases for built-up areas through time. For the bare land and water, there is a slight increase in mean patch area showing less fragmentation from 1995 to 2024.

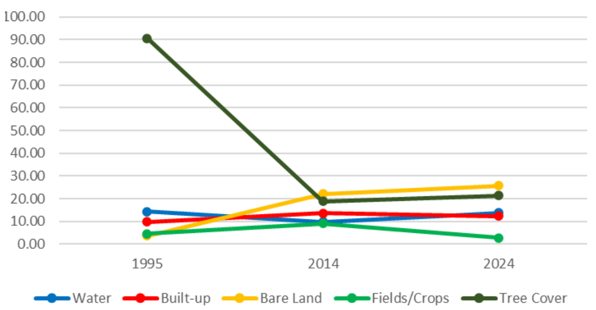

Fig. 9. Mean patch area (ha) for each land cover class from 1995 to 2024

3.4 Built-up Indices

An investigation of urbanization indices related to built-up areas showed an increase in BI for the 29 year period, as shown in Figure 10.

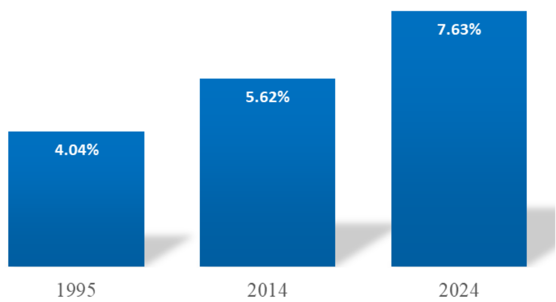

Fig. 10. Built-up area index for 1995, 2014, & 2024

On the other hand, there is relatively the same rate of urban expansion between 1995 to 2014 (4.04%) and 2014 to 2024 (5.62%), as illustrated in Figure 11. The overall BX is 89.30% from 1995 to 2024.

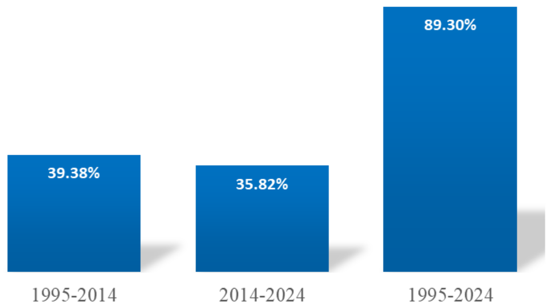

Fig. 11. Built-up area expansion index for 1995-2014, 2014-2024, & 1995-2024

An analysis was also performed comparing these indices for the western and eastern portion of Butuan City with the Agusan River as the reference. This is chosen recognizing the effect of this natural corridor in the movement of matter and energy. The study of Yang, et. al. also showed the edge effect of river channels in the trajectory of built-up areas [6]. Figure 12 illustrates the western and eastern portion used in this analysis.

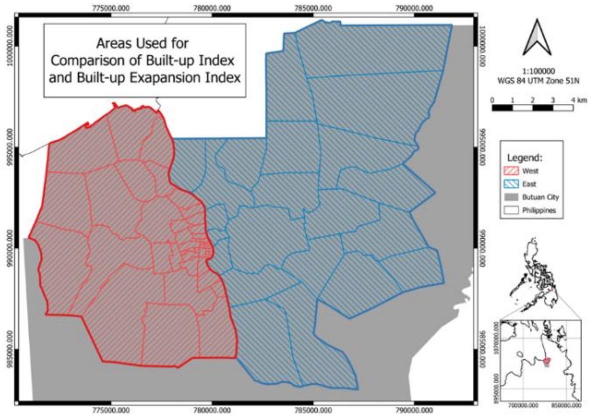

Fig. 12. Map showing western and eastern portion considered in comparing urbanization indices.

Results shown in Figure 13 illustrate that the western portion has a higher BI compared to the eastern portion for all 3 years. This supports that most of the built-up areas were originally concentrated on the western portion of the study area since 1995.

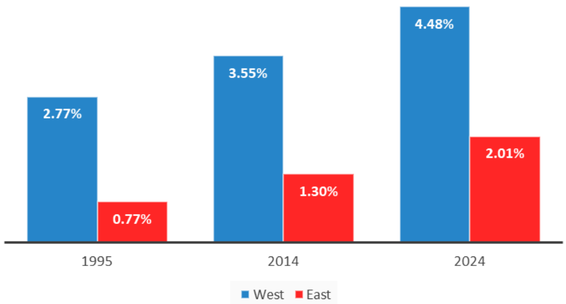

Fig. 13. Comparison of BI between western and eastern portion for 3 time periods.

However, it is notable that in terms of BX, there is a higher rate for the eastern portion, as seen in Figure 14 below. Overall, the BX is 164.71% for the eastern side compared to 63.68% for the western portion. This may explain the expansion of the city is more poised towards these eastern barangays.

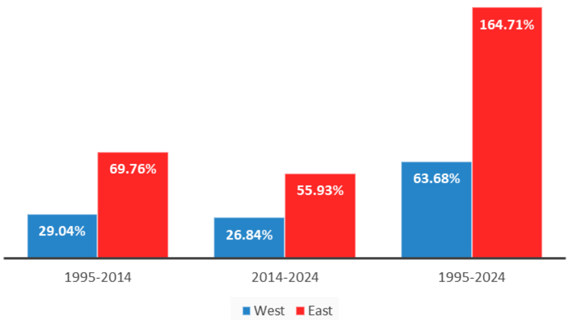

Fig. 14. Comparison of BX between western and eastern portion for 3 time periods.

4. CONCLUSION AND RECOMMENDATIONS

Results showed that there is a 41% decrease in tree cover between 2015 and 2024. There was also a decrease in fragmentation for bare land and water bodies. Over the 29-year period, a 36% increase in built-up areas was observed. Landscape metrics also reflected an increase in landscape fragmentation for tree cover, fields/crops, and built-up areas. Comparing the Built-up Index (BI) for 1995-2014 and 2014-2024, an increasing trend was recorded. The Built-up Expansion Index (BX) computed for the same time periods were relatively equal. Further analysis comparing the BX between the western and eastern portion of Butuan City revealed that there is a higher rate for the eastern side. Overall, these results highlight the crucial role of monitoring LULC change over time in physical planning for sustainable development.

Based on these results, it is recommended that the protection of forest areas be given priority as shown by the decreasing tree cover and its subsequent conversion to other land uses. Urban expansion may also consider expected fragmentation levels based on the observed increase of fragmentation for built-up areas. Lastly, these results may provide basis for conducting more in-depth studies looking at the application of other landscape metrics including landscape agglomeration and landscape complexity.

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