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SPATIO-TEMPORAL ANALYSIS OF LAND COVER CHANGE BASED ON URBAN EXPANSION IN TALOMO-LIPADAS WATERSHED

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Abstract
Urbanization is a large-scale population shift from rural to urban areas and the ensuing physical changes to urban areas. The condition of land use and land cover of an area reflects the socioeconomic and natural resources present, as well as how they are utilized over time and space. A significant effect is the extent and types of land use and land cover disturbances such as the conversion of grasslands to urban areas, wetlands to agriculture, orchards from cropland and agricultural land, and forestland being replaced with residential land use. Davao City is currently rapidly urbanizing, and several changes to the watershed's land cover are possible. This study was carried out to analyze the degree of urban expansion based on the land cover change in the Talomo-Lipadas Watershed from 2010, 2015, and 2020 using the Geographic Information System. The results show that the spatiotemporal change of the Talomo-Lipadas land cover from the years 2010, 2015, and 2020 is noticeable based on each land cover area and percent change in where urban land from 7.29% to 10.91% or 28.53 km^2 to 43 km^2, forest from 12.1% to 17.76% or 47.36 km^2 to 70 km^2, barren land from 0-0.25% or 0 to 1 km^2, and water from 0.35% % to 0.76% or 1.39 km^2 to 3 km^2 exhibit an increase in terms of area and percent change while cropland from 76.48% to 67.28% or 299.15 km^2 to 269 km^2 and grassland from 3.33% to 2.03% or 13.03 km^2 to 8 km^2 show a decrease. In a five-year interval, this watershed continuously experiences changes, particularly in urban land or built-up areas brought by the construction of roads, towns, houses, and other built-up areas.

Keywords: Urbanization, built-up expansion, watershed, Davao City, Philippines.

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INTRODUCTION

Urbanization is a large-scale population shift from rural to urban areas and the ensuing physical changes to urban areas (Kuddus et al. 2020). However, the expanding population puts tremendous pressure on land expansion at the expense of forests and grazing grounds (Ray 2011). Considering the spatiotemporal scope of its implications, this issue is regarded as the most severe anthropogenic environmental disturbance (Arifeen 2021). Anthropogenic changes to land usage have changed the physical surface of land properties (Lai et al. 2016), and it is related to local geomorphologic factors that have an accelerated effect on land degradation (Alkharabsheh et al. 2013). The condition of land use and land cover of an area reflects the socioeconomic and natural resources present, as well as how they are utilized over time and space (Rawat & Kumar 2015). An essential factor in comprehending how human activities interact with the environment is the spatial and temporal condition of the land use or land cover in a specific location (Etefa et al. 2018). Rapid urbanization seriously affects the structure and function of the watershed ecosystem (Sun & Caldwell 2015). A significant effect is the extent and types of land use and land cover disturbances (Caldwell et al. 2012) such as the conversion of grasslands to urban areas, wetlands to agriculture, orchards from cropland (Awotwi et al. 2015) and agricultural land and forestland (Kurowska et al. 2020) has been replaced with residential land use (Ng et al. 2015). Resulted in the alteration of soil (Mazzetto et al. 2016) and sediments (Meglioli et al. 2017). Land cover change refers to a change in some continuous land characteristics, such as vegetation type, soil conditions, and so forth (Patel et al. 2019). Assessment of land use and land cover change aids in determining the degree of human effect on the environment (Chowdhury 2020). It employs multitemporal picture data sets to identify changes in land cover based on spectral differences (Wiemker et al. 1997). Geographic Information System (GIS) is a digital technology that integrates hardware and software to analyze, store, and map geographical data (Teixeira 2018). The flexible framework offered by GIS makes it possible to gather, store, display, and analyze the digital data required for change detection (Wu et al. 2006). This research was carried out to analyze the degree of urban expansion based on the land cover change in the Talomo-Lipadas Watershed from 2010, 2015, and 2020 using a GIS. Davao City is currently rapidly urbanizing, and several changes to the watershed's land cover are possible. Therefore, it is necessary to carry out this study. The research objective is to determine the land cover change using the Geographic Information System in Talomo-Lipadas Watershed. In addition, the specific objectives are to (i) analyze the spatiotemporal change of the Talomo-Lipadas Watershed land use and land cover; (ii) determine the urban expansion in the Talomo-Lipadas Watershed from the years 2010, 2015, and 2020, respectively (iii) to assess the changes in land cover in Talomo Lipadas-Watershed; in terms of forest, agriculture area, cultivated area, and built-up area. This study's conceptual basis is from the land use land cover analysis of the Great Ethiopian Renaissance Dam (GERD) catchment using remote sensing and GIS techniques (Solomon & Lukas 2022). Using the Semi-Automatic Plugin tool, they created two land use and land cover change maps using the Geographic Information

System to estimate spatiotemporal changes and compute the changes transition between the research intervals (2011-2021) using the Semi-Automatic Plugin Tool. In addition, this study is grounded in theory functionalist behavioral theoretical approaches to land use change since it integrates human ecology theories and the theory of urban spatial organization, both of which were developed in the field of planning (Briassoulis 2020).

MATERIAL AND METHODS

The research design employed in the study was descriptive and quantitative-non-experimental. This uses the techniques used in the natural sciences to get complex data and numbers by using mathematical, computational, and statistical techniques (Surbhi 2018). Using various research techniques, a descriptive research strategy can study one or more parameters (McCombes 2019). All the findings of this study will be interpreted descriptively. Nonexperimental research is the term used to describe a study in which the researcher relies on interpretation, observation, or interactions rather than having any control over, altering, or changing the predictor variable or subjects (Kowalczyk 2022).

The Talomo-Lipadas Watershed land use and land cover statistics for 2010, 2015, and 2020 were obtained from the Department of Environment and Natural Resources-Community Environment and Natural Resources Office (DENR, CENRO). After extracting and projecting the study area inside the QGIS, the researcher subtypes land-use and cover data to produce six categories such as urban land (rural settlements and other construction land are classified as built-up areas); woodland and shrubs are classified as forests; paddy fields, dry land, and cultivated land are classified as cropland; pasture, parks, and green spaces are classified as grassland; barren land; and rivers, lakes, fish ponds, reservoirs, and canals are classified as water. To estimate spatiotemporal changes and compute the land cover across the research intervals (from 2010, 2015, and 2020), the researcher used the Semi-Automatic Plugin (SCP) tool inside QGIS. To generate three land cover change maps based on urban expansion. The analysis would be fully interpreted in a descriptive way. Basically, the analysis would be followed by the study findings and recommendations.

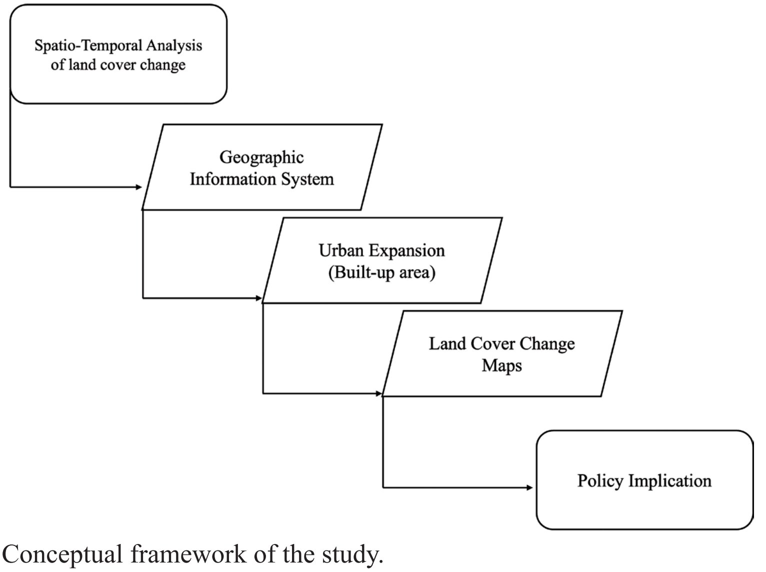

Figure 1. Conceptual framework of the study.

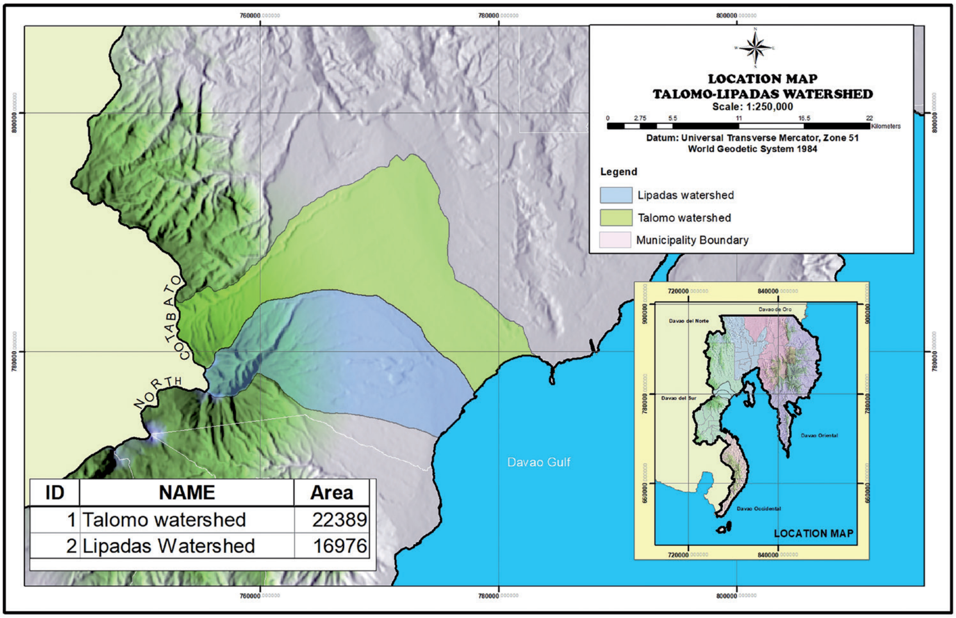

Figure 2. Location of the study.

RESULTS AND DISCUSSION

Spatio-temporal change of land cover in Talomo-Lipadas Watershed

Presented in Table 1 is the data on the spatio-temporal changes in land cover within the Talomo-Lipadas Watershed from 2010 to 2020, while Figures 1-5 illustrate the spatial distribution of land uses from 2010 to 2020. The watershed comprises six land cover classifications: urban land, forest land, cropland, grassland, barren land, and water. In 2010, cropland occupied the largest area, covering 299.15 m², representing 76.48% of the total land cover and primarily consisting of banana plantations and other agricultural vegetation (Ibañez 2012). District III, including Baguio, Calinan, Marilog, Toril, and Tugbok, remained predominantly agricultural (JICA n.d.).

Table 1. Spatio-temporal change of land cover in Talomo-Lipadas Watershed from the year 2010-2020.

Land Classification	2010 Area (km)	2010 %	2015 Area (km)	2015 %	2020 Area (km)	2020 %
Built-up	28.53	7.29	34.45	8.75	43	10.91
Forest	47.36	12.10	58.57	14.38	70	17.76
Crop	299.15	76.48	297.27	75.54	269	68.27
Grass	13.03	3.33	1.68	0.42	8	2.03
Barren	0	0	0.12	0.03	1	0.25
Water	1.39	0.35	1.39	0.35	3	0.76
Total	339.46	100	339.46	100	339.46	100

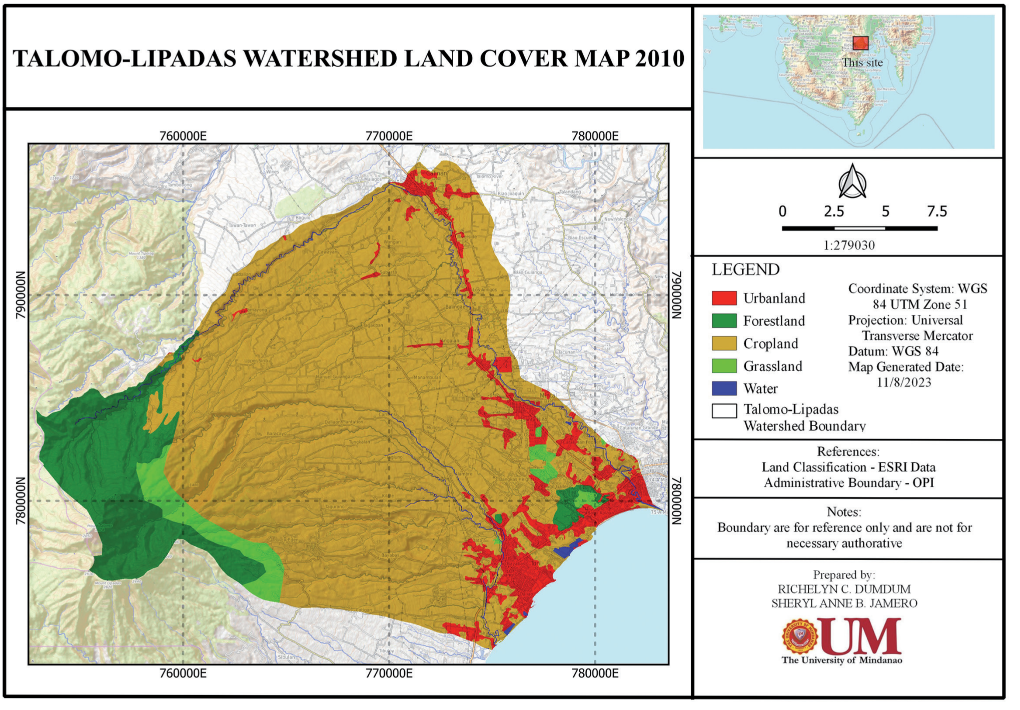

Figure 3. Land cover maps of Talomo-Lipadas Watershed in 2010.

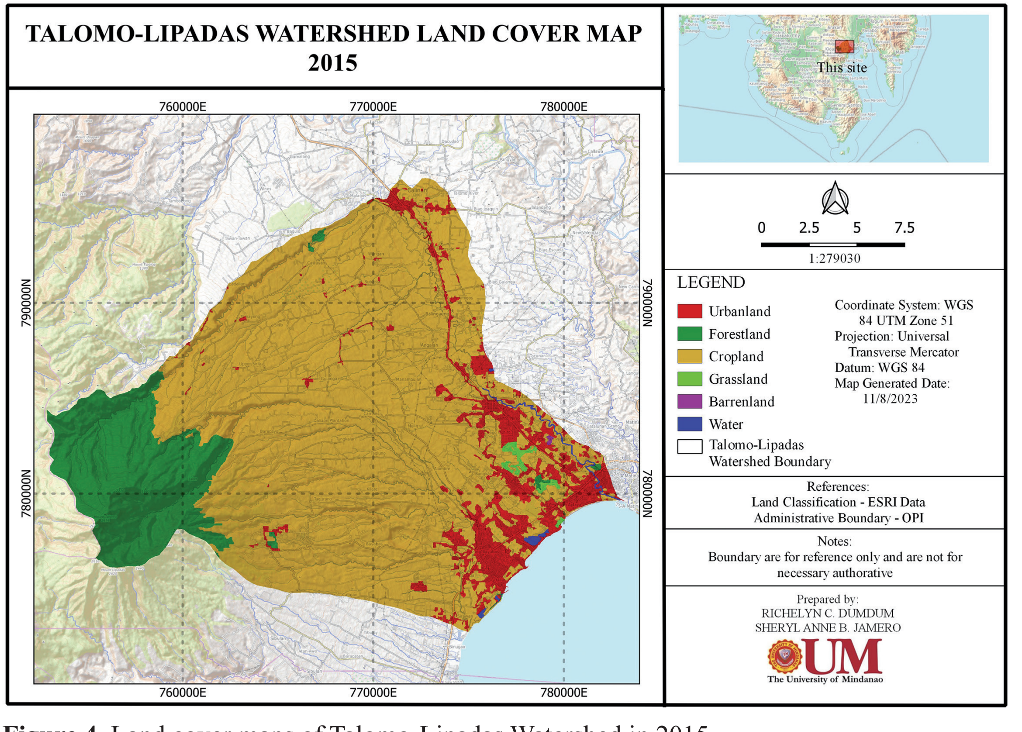

Figure 4. Land cover maps of Talomo-Lipadas Watershed in 2015.

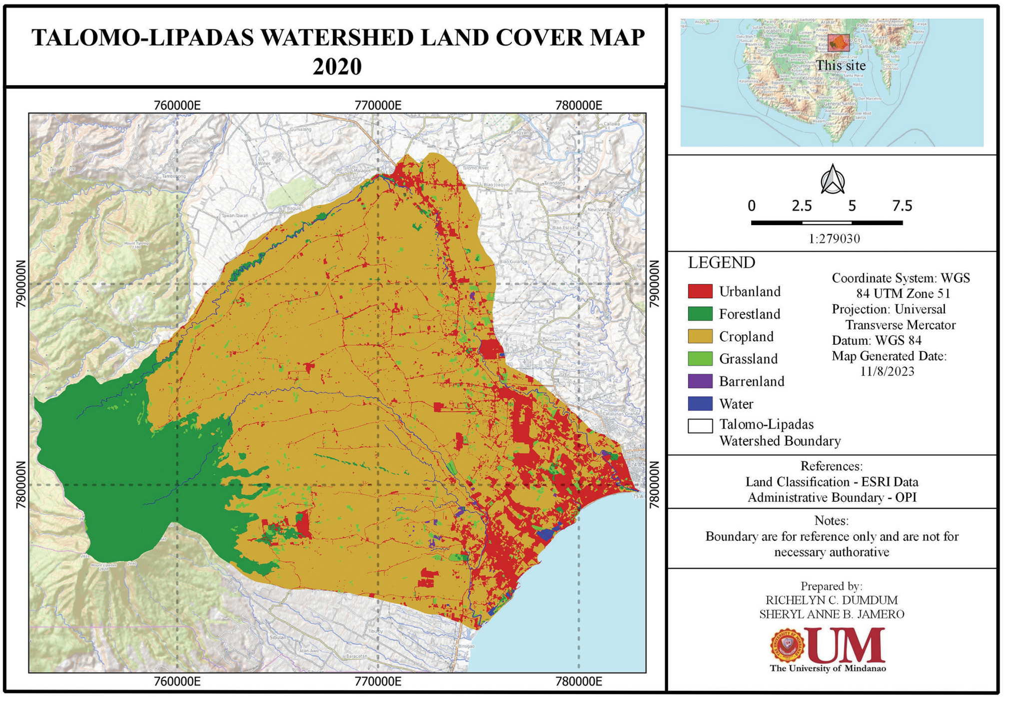

Figure 5. Land cover maps of Talomo-Lipadas Watershed in 2020.

Following cropland, forest land covered 47.36 km², accounting for 12.11%, and includes montane, dipterocarp, and mossy forests (Ibañez 2012). Urban land constituted 7.29% of the area, covering 28.53 km², with a total population of 439,998 and 88,603 households as of 2010 (NSO 2010). Water, although a minor land cover at 3.05 km², comprised 0.78% and serves as a primary source for groundwater extraction, fulfilling a significant portion of Davao City's water needs (Branzuela et al. 2015).

Grassland accounted for 3.33% with an area of 13.03 km², while no barren land was identified during this period, despite it being the fifth classification of land cover. Moreover, in the year 2015, cropland continued to dominate, covering 297.27 km², which accounts for 75.54% of the total land cover. Forest land followed with an area of 58.57 km², representing 14.88%.

Urban land emerged as the third classification, covering 34.45 km² or 8.75%. The urban area has significantly increased over the years, primarily due to rising land demands for infrastructure development driven by population growth (Lamchin et al. 2022). This year reflects an increase in area and percentage for the three major land cover classes, influenced by societal developments (Hailu et al. 2020), demographic changes (Mather & Needle 2000), and economic factors, which serve as key drivers of land use and land cover transition (Lambin et al. 2001). These shifts have resulted in a different rate of change in the recent period compared to earlier years (Gebreslassie 2014). However, grassland, water, and barren land remain minor land cover types, with respective areas of 1.68 km² (0.42%), 1.39 km² (0.35%), and 0.12 km² (0.12%). Furthermore, the year 2020 demonstrates that cropland covered the most area, 269 km² or 68.27%. Despite that, the cropland still held the highest percentage in 2015. However, the cropland shows a significant reduction in the total area of the cropland due to the expansions in existing land for development

(Zhu et al. 2021). The forest (area 70 km^2) with a percentage of 17.76%, was the second largest. With 43 km^2 or 10.91%, urban land came in third. However, at 8 km^2 or 2.03%, 3 km^2 or 0.25%, and 1 km^2 or 0.76% correspondingly, the grassland, barren land, and water are the three with the least land total area. The changes in land cover in the Talomo-Lipadas watershed from 2010, 2015, and 2020 were determined based on each land cover area and percent change. The decrease in some land cover areas and the increase in other land cover areas may have numerous effects on the watershed soon, given that this watershed is a crucial water source for the entire Davao City.

Built-up expansion

Presented in Table 4, the analyzed data on built-up expansion in the Talomo-Lipadas watershed from the years 2010, 2015, and 2020 respectively, while Figures 6-9 depict the spatial expansion in terms of built-up areas.

Table 2. Built-up expansion of Talomo-Lipadas Watershed in 2010-2020.

Land Classification	2010 Area (km)	2010 %	2015 Area (km)	2015 %	2020 Area (km)	2020 %
Built-up	28.53	7.29	34.45	8.75	43	10.91

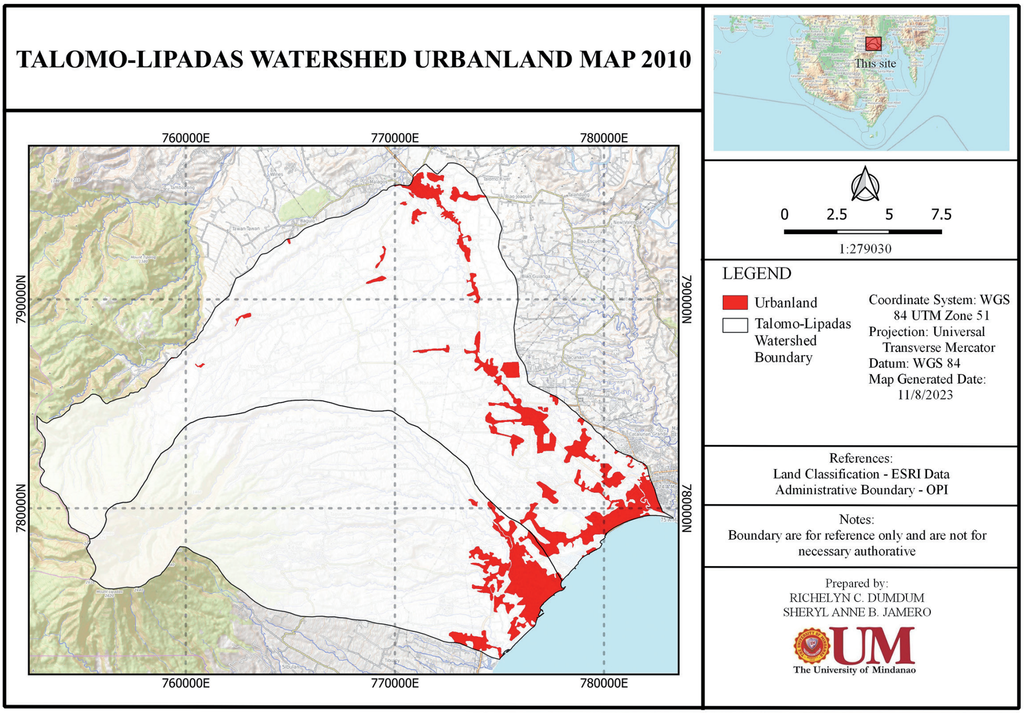

Figure 6. Built-up expansion in Talomo-Lipadas Watershed in 2010.

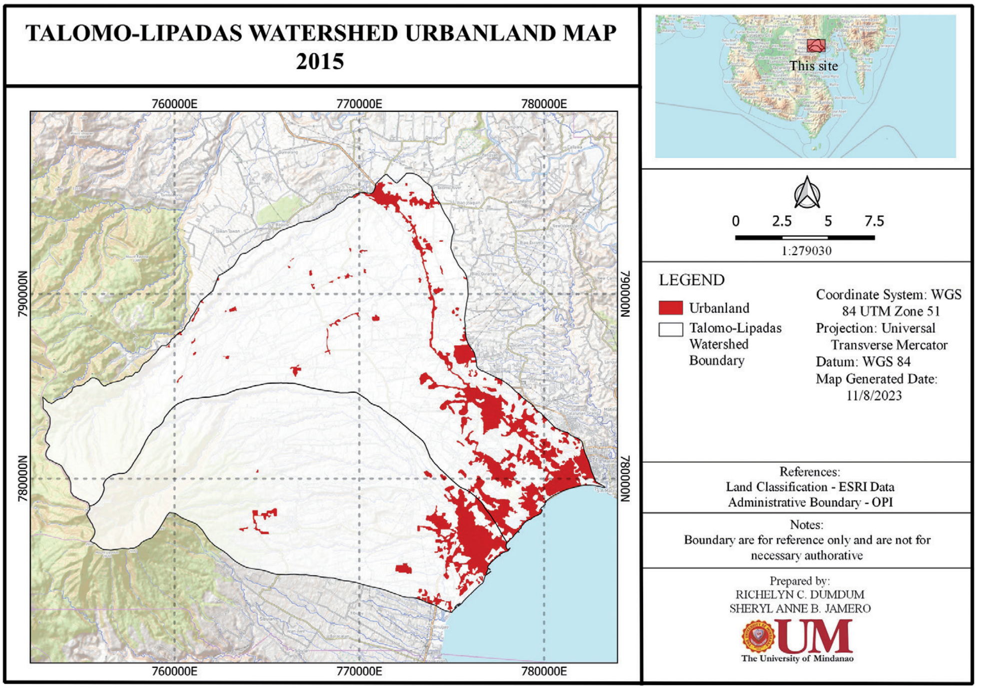

Figure 7. Built-up expansion in Talomo-Lipadas Watershed in 2015.

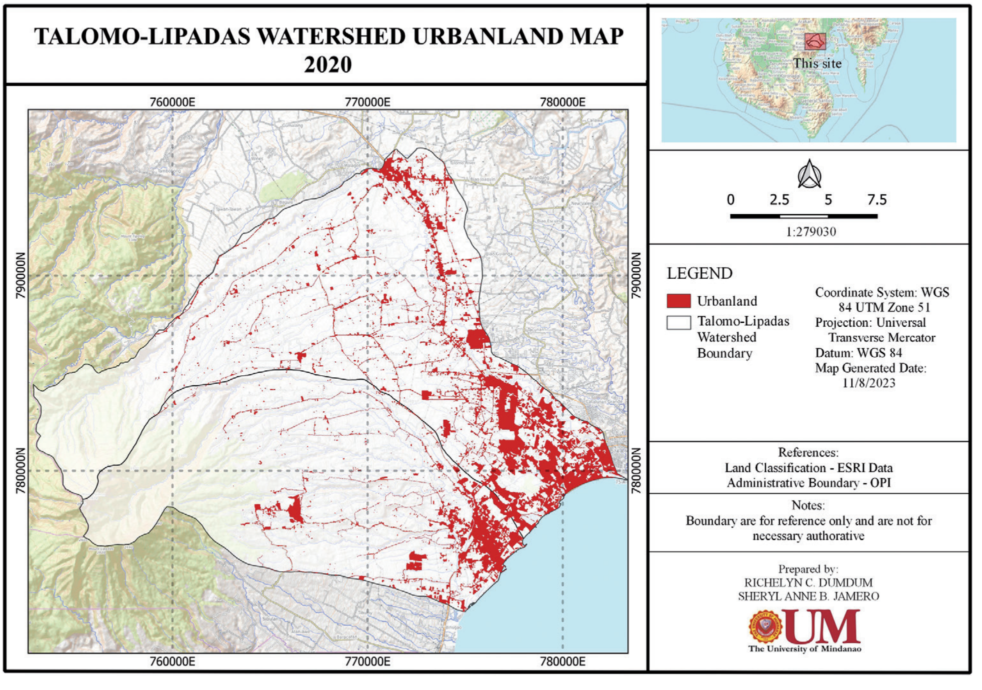

Figure 8. Built-up expansion in Talomo-Lipadas Watershed in 2020.

In 2010, some parts of the Talomo area, specifically in Bago Gallera, Dumoy, and Bago Aplaya, were also concentrated along with Catalunan Grande, Bago Oshiro, Mintal proper, and Tugbok in the Mintal area the urbanization of Talomo-Lipadas is already visible with the population in the watersheds approaching half a million (Ibañez 2012) and over 334,473 households in Davao City in the said year (Almec Corporation 2018). In addition, in 2015, the urban area expanded to 34.45 km², which represents 8.75% of the total land cover, indicating a significant increase in the built-up area of Talomo-Lipadas. In this year, the land cover underwent notable changes, characterized by a reduction in cropland area and a corresponding increase in urban land. Specifically, built-up expansion was particularly pronounced in areas such as Toril, Mintal, Talomo, and Calinan, where regions that were not urban in 2010 transitioned to urban status by 2015, resulting in a total of over 409,951 households (Almec Corporation 2018). From 2010 to 2015, the degree of change in built-up expansion was recorded at 1.49%, equivalent to 5.92 km². By 2020, the built-up area in Talomo-Lipadas increased to 10.91%, covering 43 km², indicating a continuous upward trend in urbanization. Areas that were already concentrated in 2010 saw further intensification and expansion by 2020. Notably, urban areas in Toril, Talomo, Mintal, and Calinan experienced significant growth, with some forest and cropland being converted into urban land, particularly in the Toril area. Additionally, certain regions of Mintal and Calinan, including Manuel Guiana, Sirib, Tagakpan, Tamayong, Cogon, and Wangan, have become fully urbanized, with new roads being developed throughout the Talomo-Lipadas Watershed. An assessment of changes from 2015 reveals a further increase of 2.16% or 8.55 km², over the subsequent five years.

The increasing built-up area affects the future land cover or structure in the Talomo-Lipadas Watershed, knowing that increased impervious surfaces impact the urban environment (Slonecker et al. 2001). With the growing urbanization and socio-economic expansion (Vanbergen et al. 2020), land use and land cover changes occur, which may have environmental consequences such as considerable erosion, air pollution, and deterioration of water sources (Muhammad et al. 2022) in Talomo-Lipadas Watershed.

Changes of land cover in Talomo - Lipadas Watershed

Presented in Figure 9, the land cover change in the Talomo-Lipadas Watershed is based on each class computed percentage from in the five-year interval. In the urban land class, the percentage every five years increased from 7.29% to 8.75% in the years 2010-2015 and 10.91% in the years 2015-2020.

Numerous studies have shown that population growth and economic development are the key drivers of urbanization (Li et al. 2018), in which expanding, such as developed open space and developed regions, grow through time primarily by replacing shrublands and agricultural areas (Belhaj 2022). Moreover, in terms of forest percentage from 2010 to 2020, based on the computed percentage of 12.1%, 14.38%, and 17.76% in 2020, forest area has slightly increased over time (Gurgel et al. 2021), it may be said that the forest cover is at least steady (Arnold et al. 2020). In the third, which is the cropland class, the area shows a decrease based on the percentage from 76.48% to 75.54% in 2010-2015 to 68.27% in the five consecutive years; this is primarily attributed to the increase in developing activity and the elimination of agricultural activities (Hargrove et al. 2020) of developed regions as a result of urbanization of the area, while at the same time other areas converted into forests (Belhaj 2022).

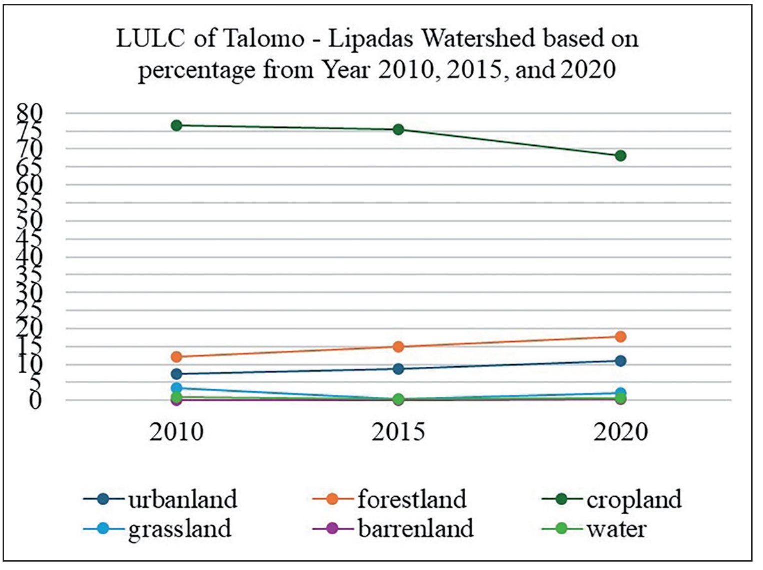

Figure 9. Land cover change in Talomo-Lipadas Watershed in three time periods.

Furthermore, the grassland area fluctuated from 2010 with 3.33% to 0.42% in 2015; several studies have indicated that two significant variables influencing the changes in the grassland ecosystem are climate change (Zhang et al. 2018) and conversion to various land uses (Yamaura et al. 2019) and 2.03% in the next five years. Barren land shows an increase from 0% in 2010 to 0.25% in 2020; this is due to the trends in the extent of barren land and rainfall variability, in which barren land reduces when rainfall rises and grows when rainfall falls (Quedraogo et al. 2014) since the barren area is located in the lower portion of the watershed and this area, rainfall is low compared to the upper area. The last class, water, slightly increased from 0.35% in 2010 to 0.76% in 2020 as watersheds were developed, surface runoff increased, and groundwater recharge decreased (USEPA 2012).

CONCLUSIONS

The spatiotemporal change of the Talomo-Lipadas land cover from the years 2010, 2015, and 2020 is measurable based on each land cover area and percent change. The cropland and grassland areas declined, but the urban land, forest, barren grassland, and water showed an increase. Urban and forest land have the highest percentage (%), and area (km^2) increases every five years. In contrast, cropland areas decreased gradually from 2010 to 2020, with the loss of areas being made up by expansions in other land types. Based on the calculated percentage and area, Talomo-Lipadas urban expansion or built-up area shows an increase from 2010, 2015, and 2020 on the projected map. This depicts that this watershed land cover continuously experiences changes in a five-year interval, particularly in urban land brought about by constructing roads, towns, houses, and other built-up areas. In assessing the changes of each land cover in the Talomo-Lipadas Watershed from 2010, 2015, and 2020 in terms of their percent change, the result shows that the urban, forest, barren land, and grassland exhibit an increase in terms of percent change while cropland and water show a decrease. This demonstrates that some of this area has been converted to other land use and land cover classes based on the changes in the percentage in the aforementioned years.

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