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# Spatiotemporal Analysis of Land Cover Change: The Case of Talomo-Lipadas Watershed, Davao City

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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 and 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 have been replaced with residential land use. Davao City is currently rapidly urbanizing, and several changes to the watersheds land cover are possible. This research was carried out to analyze the degree of Built-Up expansion based on the land cover change in the Talomo-Lipadas watershed from 2010–2020 using Geographic Information System (GIS). 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, Land Cover, Watershed, GIS*

## 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), resulting in land degradation (Paris, 2022). Considering the spatiotemporal scope of its implications, this issue is regarded as the most severe anthropogenic disturbance to the environment (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 (Mazetto et al., 2016), sediments (Meglioli et al., 2017). Land cover change refers to a change in some continuous characteristics of the land, 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), a digital technology, integrates hardware and software to analyze, store, and map geographical data (Teixeira, S., 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 Geographic Information System.

Davao City is currently rapidly urbanizing, and several changes to the watersheds land cover are possible. Therefore, it is necessary to carry out this study. The research objective is to determine the land cover change using Geographic Information System in Talomo -Lipadas Watershed. In addition, the specific objectives are to (i) analyze the spatio-temporal 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 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 et al., 2022). Using the Semi-Automatic Plugin tool, they created two land use and land cover change maps using 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).

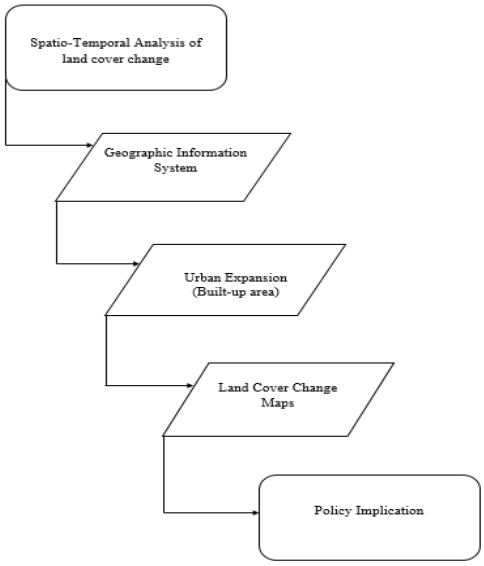


**Figure 1**. Conceptual Framework of the Study

## METHOD

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 in a descriptive manner. Non-experimental 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 area of the study is located in Davao City, specifically the Talomo Lipadas Watershed, with a precise location between 07°08'02" and 07°09'14" latitude and 125°20'50" and 125°29'01" longitude, correspondingly, with a total land area of 38,375 hectares (Branzuela, 2015). The Talomo-Lipadas watershed is mostly made up of agricultural areas, marshes, farmland, and woodlands, which are home to various animals and plants. Given that, it is essential to study this watershed in the present because it is a significant source of water for the city and because previous studies have shown that it is changing due to unsustainable resource use and rising demand for urban land and water supplies in many areas both inside and outside the watershed.

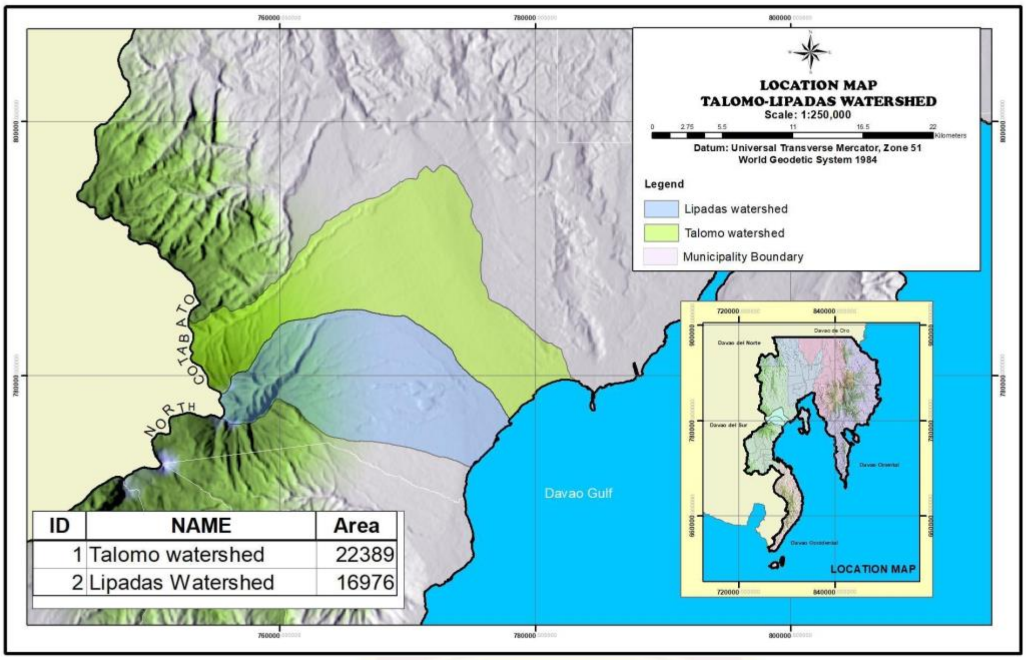


**Figure 2.** Map Showing the Location of the Study

The following tools were used in conducting this research.
1. QGIS- This study utilized this tool, particularly in producing land cover change maps.
2. MS Excel - the researcher utilized this tool to tabulate the changes.

Using the statistical tools indicated below, the researchers would compute and examine the data that was acquired for this study. Percentage – This was employed to examine the area changes in each land cover class.

## RESULTS AND DISCUSSION

### *Spatio-Temporal Change of Land Cover in Talomo-Lipadas Watershed*

Presented in Table 1 is the data on spatio-temporal change of land cover change in the Talomo-Lipadas watershed. Also, Figure 3. presents the maps and the spatial distribution of land uses for the year 2010. During the study, it was observed that Talomo-Lipadas has six classifications for its land cover: urban land, forest land, cropland, grassland, barren land, and lastly, water. In the year 2010, land cover, the highest area the cropland, which has a total area of 299.15 $km^2$ or 76.48%, the areas which continued to be predominantly agricultural areas are all of District III, which includes Baguio, Calinan, Marilog, Toril, and Tugbok (JICA, n.d.) which is within the Talomo-Lipadas. Followed by the forest land, which has an area of 47.36 $km^2$ and a percentage of 12.11% which comprises montane forest, dipterocarp forest, and mossy forest.

**Table 1.** *Spatio-Temporal Change of Land Cover in Talomo-Lipadas watershed in the year 2010*

| LULC | ($km^2$) | (%) |
|---|---|---|
| Urban | 28.53 | 7.29% |
| Forest | 47. 36 | 12.1% |
| Crop | 299.15 | 76.48% |
| Grass | 13.03 | 3.33% |
| Barren | 0 | 0 |
| Water | 1.39 | 0.35% |
| Total | | 100% |

Legend: LULC – Land Use/Land Cover

Presented in Table 1 is the data on spatiotemporal change of land use and land cover in the Talomo-Lipadas watershed in the year 2010. Then, the urban land has a percentage of 7.29% and an area of 28.53 $km^2$ and the minor land cover was water which has a percentage of 0.78% and an area of 3.05 $km^2$ which is the primary source of groundwater extraction that supplies a significant percentage of the water needs of Davao City (Branzuela et al., 2015) followed by the grassland that has a percentage of 3.33% and an area of 13.03 $km^2$. No barren land exists, which is supposed to be the fifth (5) land cover this year.

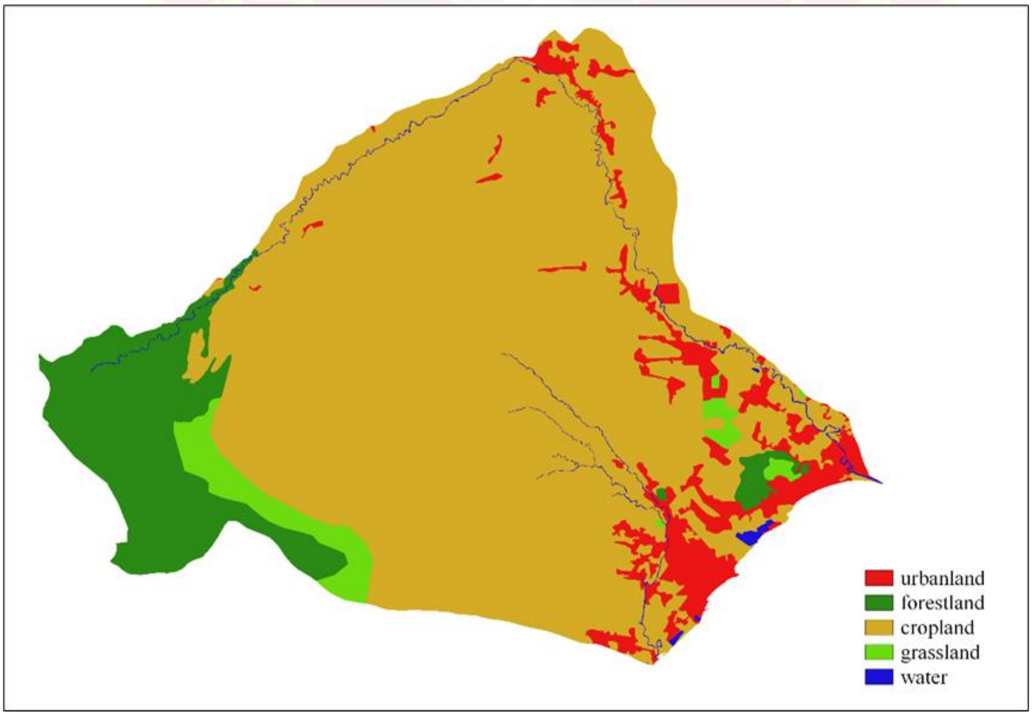


**Figure 3.** Land Use/Land Cover Change in Talomo- Lipadas Watershed in the year 2010

Exhibited in Table 2 is the data on the spatiotemporal change of land use and land cover in the Talomo-Lipadas watershed in the year 2015. Also, Figure 4. presents the maps and the spatial distribution of land uses for the year 2015 still; the cropland area holds the highest area with a total land cover of 297.27 $km^2$ or 75.54%. Forest is next, with 58.57 $km^2$ or 14.88%. The third land cover comprises urban land, which covers an area of 34.45 $km^2$ with a total percentage of 8.75%. Urban was significantly increasing throughout all the periods, mainly caused by increased land requirements for infrastructure development due to higher population growth rates and to meet the needs of the increasing population (Lamchin et al., 2022).

**Table 2.** *Spatio-Temporal Change of Land Cover in Talomo-Lipadas watershed in the year 2015*

| LULC | ($km^2$) | (%) |
|---|---|---|
| Urban | 34.45 | 8.75% |
| Forest | 58.57 | 14.38% |
| Crop | 297.27 | 75.54% |
| Grass | 1.68 | 0.42% |
| Barren | 0.12 | 0.03% |
| Water | 1.39 | 0.35% |
| Total | | 100% |

Legend: LULC - Land Use/Land Cover

Demonstrated in Figure 4 is the data on spatiotemporal change of land use and land cover in the Talomo-Lipadas watershed in the year 2015. This year exhibits an increase based on their area and percentage in the three-land cover class due to societal developments (Hailu et al, 2020), demographic changes (Mather et al, 2000), and economic factors as the primary initiators of LU/LC transition (Lambin et al, 2001) which cause the rate of change in the recent period has differed from that of preceding periods (Gebreslassie, 2014). Numerous physical, ecological, and economic effects result from LULC modification (Pellikka et al., 2013). However, grassland, water, and barren land, on the other hand, still hold the minor land coverage, with respective areas of 1.68 $km^2$ or 0.42%, 1.39 $km^2$ or 0.35%, and 0.12 $km^2$ with a percentage of 0.12%.

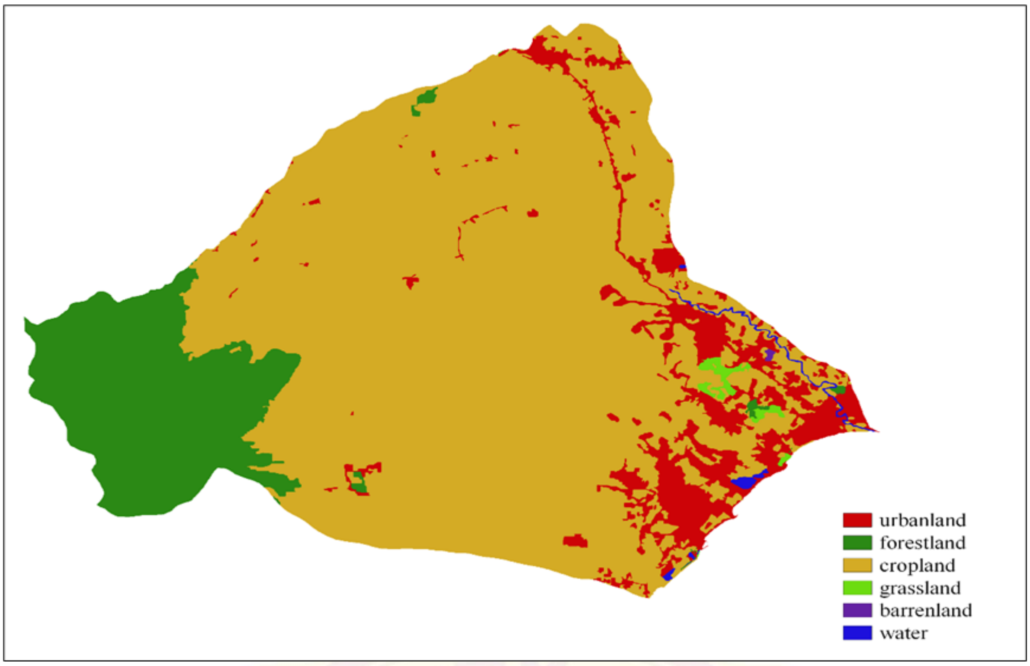


**Figure 4.** Land Use/Land Cover Change in Talomo-Lipadas Watershed in the year 2015

Furthermore, shows in Table 3 the data on spatiotemporal change in land use and land cover in the Talomo-Lipadas watershed in the year 2020. And also, Figure 5. presents the maps and the spatial distribution of land uses for the year below, demonstrating the land cover change in 2020. The cropland covered the most area, 269 $km^2$ 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, 2021). The forest, with 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.

**Table 3.** *Spatio-Temporal Change of Land Cover in Talomo-Lipadas watershed in the year 2020*

| LULC | ($km^2$) | (%) |
|---|---|---|
| Urban | 43 | 10.91% |
| Forest | 70 | 17.76% |
| Crop | 269 | 68.27% |
| Grass | 8 | 2.03% |
| Barren | 1 | 0.25% |
| Water | 3 | 0.76% |
| Total | | 100% |

Legend: LULC - Land Use/Land Cover

Presented in Table 3 is the data on spatiotemporal change in land use and land cover in the Talomo-Lipadas watershed in the year 2020. However, at 8 km2 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.

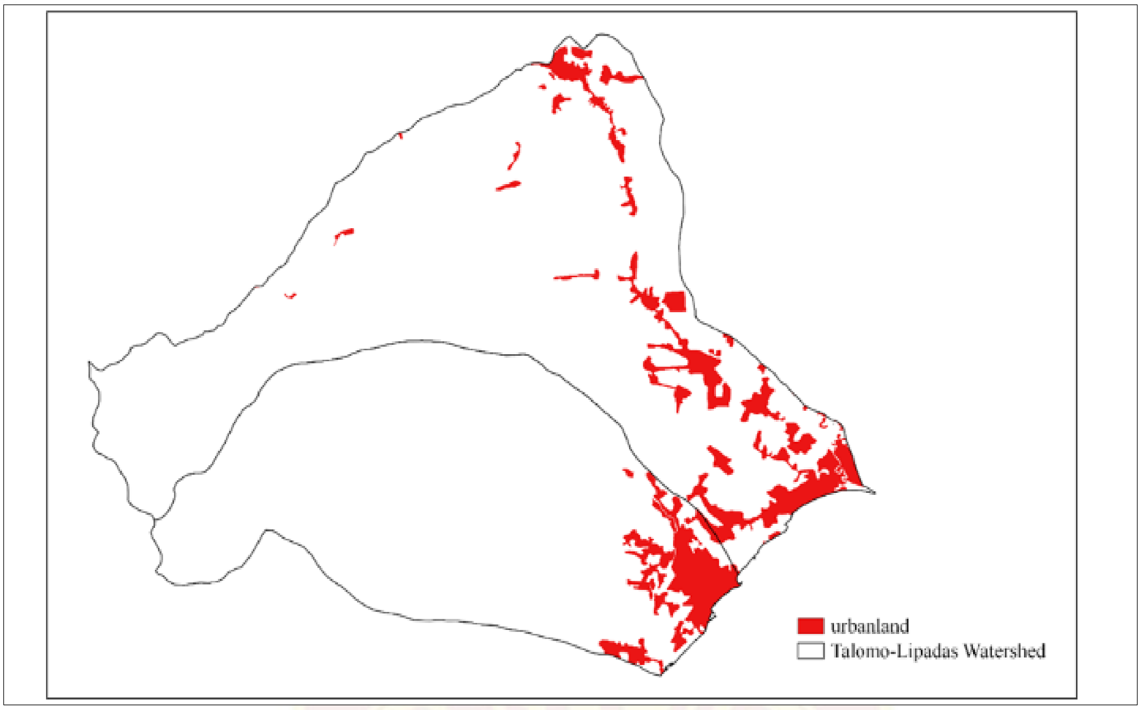


**Figure 5.** Land Use/Land Cover Change in Talomo- Lipadas Watershed in the year 2020

***Built-Up Expansion in Talomo-Lipadas Watershed***

Presented in Table 4 is the Built-Up expansion of the Talomo-Lipadas watershed in the year 2010. Moreover, Figure 6. shows the map, and the spatial distribution of built-up expansion for the year below demonstrates the land cover change in 2010. The area of built-up expansion in the year 2010 is 28.53 $km^2$ or 7. 29%, and the area where built-up expansion is concentrated within the Talomo-Lipadas watershed is located in the Toril area, particularly in Daliao, Crossing Bayabas, Marapangi, Sirawan, and Bato.

**Table 4.**
*Built-Up Expansion of Talomo - Lipadas Watershed in the year 2010*

| Land Use | (%) | ($km^2$) |
|---|---|---|
| Built-up | 7.29% | 28.53 |

Presented in Figure 6 is the data on built-up expansion in the Talomo-Lipadas watershed in the year 2010. Some parts of the Talomo area, specifically in Bago Gallera, Dumoy, and Bago Aplaya, are 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 over 334,473 households in Davao City in the said year (Almec Corporation, 2018).

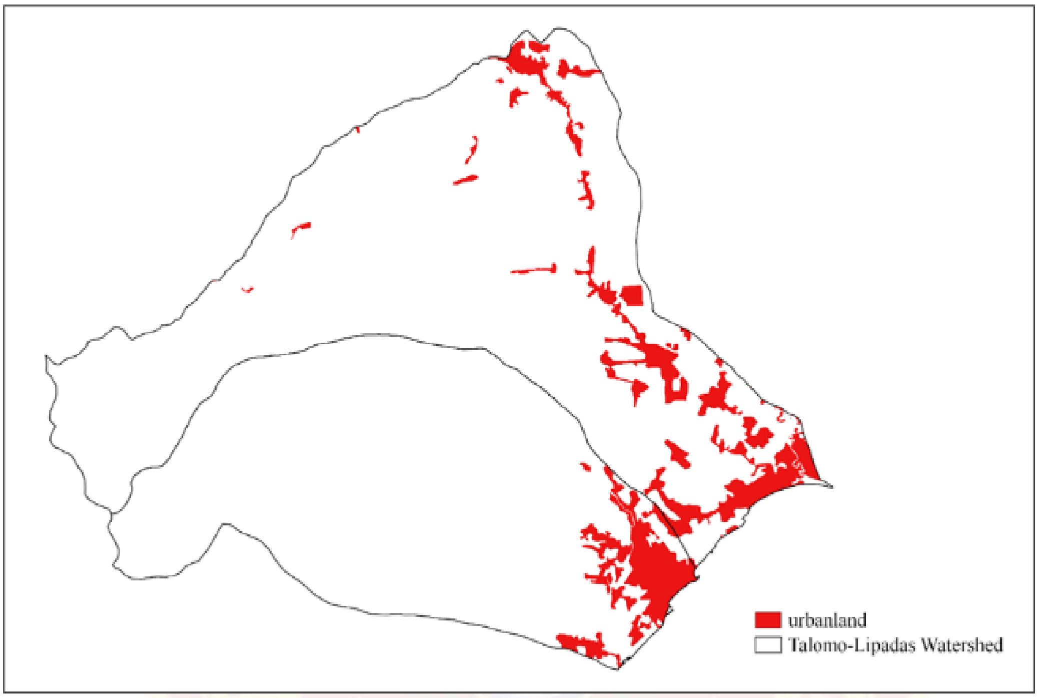


**Figure 6.** Built-Up Expansion in Talomo - Lipadas Watershed in the year 2010

Meanwhile, demonstrated in Table 5, the built-up expansion of the Talomo-Lipadas watershed in 2015. Furthermore, Figure 7. presents the maps and spatial distribution of built-up expansion for the year 2015. The urban area became 34.45 $km^2$ or 8.75%, which illustrates that Talomo-Lipadas built-up area increased according to the computed percentage and area ($km^2$). The land cover of Talomo-Lipadas changed in 2015, with a reduction in cropland area and an increase in urban land.

**Table 5.**
*Built-Up Expansion of Talomo - Lipadas Watershed in the year 2015*

| Land Use | (%) | ($km^2$) |
|---|---|---|
| Built-up | 8.75% | 34.45 |

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Presented in Figure 5 is the data on built-up expansion in the Talomo-Lipadas watershed in the year 2015. The Toril, Mintal, Talomo, and Calinan built-up expansion is growing, and some regions that were not urban in 2010 became urban in 2015.

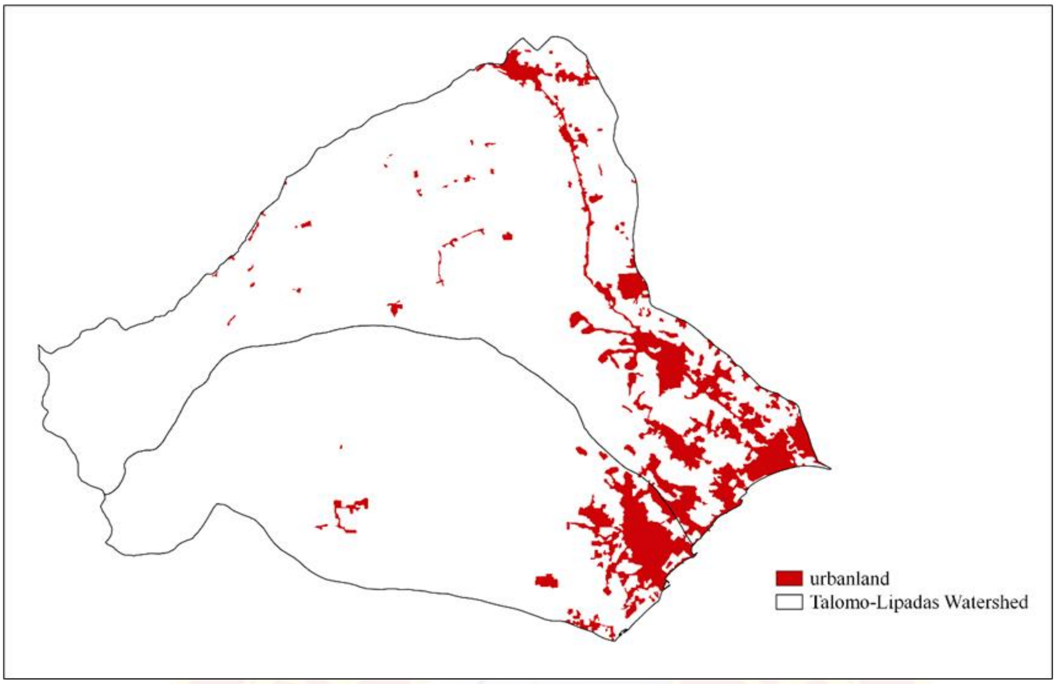



**Figure 7.** Built-Up Expansion in Talomo - Lipadas Watershed in the year 2015

Presented in Table 6 is the built-up expansion of the Talomo-Lipadas watershed in 2020. Moreover, Figure 8. presents the maps and spatial distribution of built-up expansion for the year 2020. In accounting, the degree of change of built-up expansion from years 2010 to 2015 was 1.49% or 5.92 km$^2$. The Talomo-Lipadas built-up area goes up to 10.91% or 43km$^2$ this shows that built-up expansion in this watershed has been continuously increasing based on its area and percent change from 2010, 2015, and 2020, where some areas that were already concentrated in 2010 became more concentrated and expanded in 2020.

**Table 6.**
*Built-Up Expansion of Talomo - Lipadas Watershed in the year 2020*

| Land Use | (%) | (km$^2$) |
|---|---|---|
| Built-up | 10.91% | 43 |

Presented in Table 6 is the data on built-up expansion in the Talomo-Lipadas watershed in the year 2020. The area of Toril, Talomo, Mintal, and Calinan shows an expansion in urban areas compared to the previous year, where some forest and cropland are converted to urban land, as seen in the Toril area. Some parts of Mintal and Calinan, particularly the Manuel Guianga, Sirib, Tagakpan, Tamayong, Cogon, and Wangan areas, have already been urbanized, with roads being built inside the

Talomo-Lipadas. In assessing the changes from 2015 after a five-year interval, the degree of changes was 2.16 % or 8.55 $km^2$.

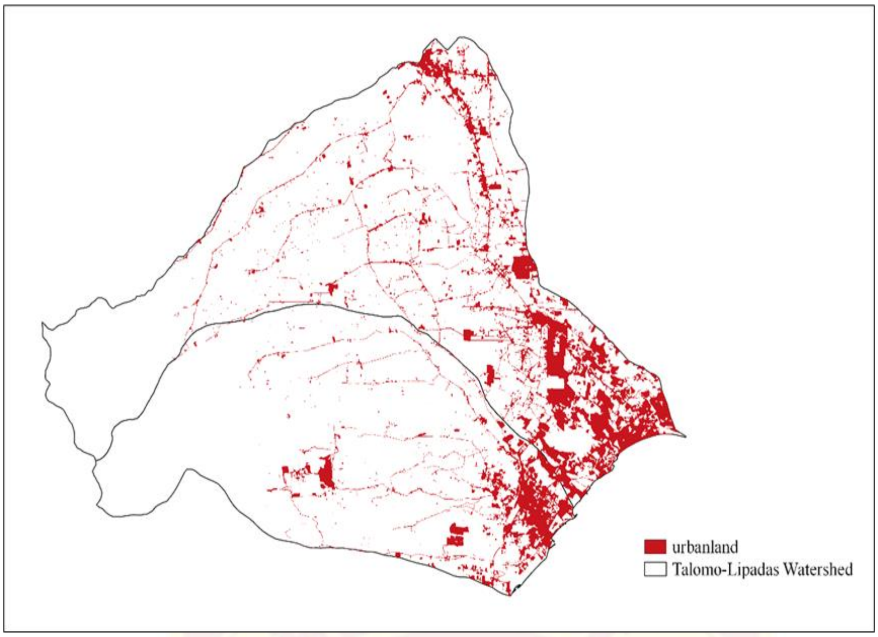
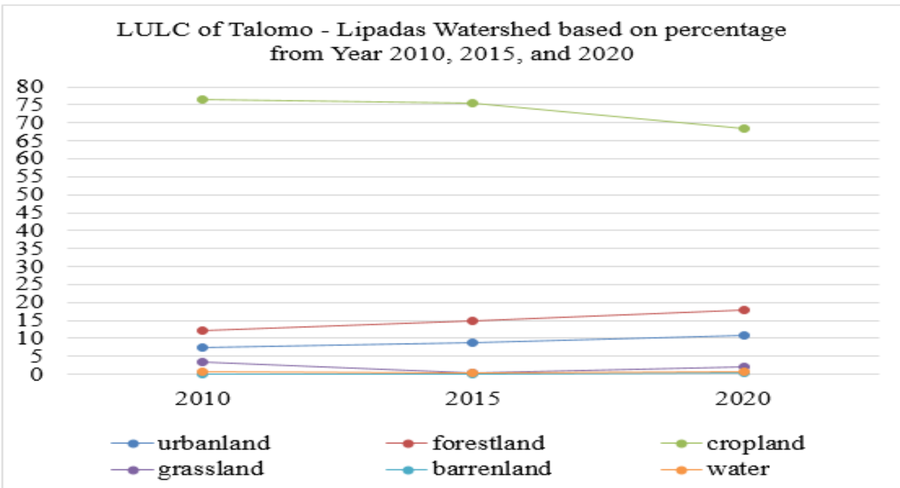



**Figure 8.** Built-Up Expansion in Talomo - Lipadas Watershed in the year 2020

### *Changes of Land Cover in Talomo - Lipadas Watersh*

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

**Figure 9.** Land Cover Change in Talomo - Lipadas Watershed in Three Time Periods



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).

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. While the last class, which is the water, slightly increased from 0.35% in 2010 to 0.76% in 2020 as watersheds are developed, surface runoff increases and groundwater recharge decreases (USEPA, 2012).

***Policy Implication***

Based on the findings of the study, there has been a change in land cover in the Talomo-Lipadas Watershed for the years 2010, 2015, and 2020. An increase in a particular land cover class is the opposite of a decrease in another land cover type. The continuous increase of urban land or built-up area and the decrease of cropland may impact the watershed balance system. In line with the statement, urban planners, land managers, and decision-makers must pay more attention to how the land cover is changing over time, especially how built-up areas are expanding inside the watershed and its impact, in order to balance the demands of the growing urban area with environmental sustainability.

***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 decline, but the urban land, forest, barren, grassland, and water show 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.

***Recommendation***

To the **Urban Developer**. This study can be used to improve the importance of balancing urban development and the environment. They could also conduct a primary survey of the area to identify and assess which part of the watershed is open for urbanization.

To the **Government Officials**. They may use the significant findings of this study to imply a policy that can aid the expansion of urban areas inside the Talomo-Lipadas, such as RA No. 10884 or the An Act Strengthening the Balanced Housing Development Program, Amending for the Purpose Republic Act No. 7279 (Official Gazette, 1992). They may also collaborate with Non-Government Offices for better planning, preservation, and protection of the watershed.

To **Academe and Future Researcher**. They could make improvements to urban development to assist individuals in better comprehending the preceding projects and services. They could conduct a more thorough investigation using various methodologies, such as distributing interview questionnaires to residents of the Talomo and Lipadas watersheds and surveying the area of the said watershed to identify the parts of the watershed that are highly vulnerable to urban expansion.

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