USING GHSL TO ANALYZE URBANIZATION AND LAND-USE EFFICIENCY IN THE PHILIPPINES FROM 1975-2020: TRENDS AND IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

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KEY WORDS: Global Human Settlement Layers (GHSL), Urbanization, Land-Use Efficiency, Sustainable Development, SDG 11.3, Philippines.

ABSTRACT:

This study analyzed the trends and patterns of urbanization and changes in land-use efficiency in the Philippines from 1975-2020 using the Global Human Settlement Layers (GHSL). Utilizing the GHS-BUILT-S, GHS POP, and GHS-SMOD raster datasets from the GHSL Data Package 2023, we examined the spatiotemporal expansion of built-up areas and the growth of population in urban and rural regions of the country. Using the same datasets, we also measured the country's achievement of Sustainable Development Goal (SDG)11.3, particularly on inclusive and sustainable urbanization through efficient land utilization, by computing the ratio of land consumption rate (LCR) to the population growth rate (PGR), also known as LCRPGR. The results of our analysis revealed an increasing trend in the overall built-up area and population of the Philippines within the examined period. Built-up areas and population in urban regions more than tripled in size from 1975 to 2020, demonstrating a notable shift towards more urbanized regions over time. In addition to presenting evidence of the Philippines' developmental progress and urbanization, our analysis of GHSL data shows a decline in land consumption, a deceleration in population growth, and an overall enhancement in land-use efficiency within the country. These findings suggest a shift towards more controlled and sustainable land development practices, supporting the country's goal of sustainable urbanization and land management. The implications of these findings are crucial for policymakers and urban planners in the Philippines, offering valuable insights to guide the formulation of effective and comprehensive land management strategies. Further work includes conducting localized analyses at the city or municipality level to provide valuable insights into the unique urbanization patterns and land-use dynamics across different islands and regions, enabling tailored policy interventions and spatial planning strategies to promote sustainable development.

1. INTRODUCTION

1.1 Background and Motivations

Urbanization, a global phenomenon resulting from economic development and continuous population growth, attracts significant attention due to its predominantly negative effects on land resources (Ghazaryan et al., 2021; Zhou et al., 2021). Urbanization occurs when a combination of diverse economic, demographic, social, cultural, technological, and environmental factors leads to a rise in the number of people residing in towns and cities within a given region. This process is characterized by a greater concentration of the population in larger urban areas and an overall increase in population density within these settlements (Knox, 2009). Urbanization is generally associated with the spatial expansion of built-up areas to accommodate the growing population, and consequently often results to landscape changes that are coupled with negative environmental impacts (Estoque et al., 2021). Moreover, when the physical growth of urban areas surpasses the rate of population growth, urbanization can lead to inefficient land-use practices.

Given the inevitability of urbanization, there is a growing emphasis on promoting the idea of urban sustainability to rejuvenate and transform urban spaces. The primary aim of this approach is to enhance the quality of life for residents, foster innovation, and minimize environmental harm, all while maximizing economic and social benefits (European Environment Agency, 2021). Many countries have prioritized the pursuit of urban sustainability as a key objective. To evaluate and establish a framework of sustainability goals, the most effective approach involves the use of indicators (Corredor-Ochoa et al., 2020). At present, there exist a large variety of indicator framework and tools to assess urban sustainability (Huovila et al., 2019); one of them is the United Nations (UN) Sustainable Development Goal (SDG) 11+ monitoring framework (UN-Habitat, 2021).

The objective of SDG 11 is to create cities and human settlements that are sustainable, safe, inclusive, and resilient. One of the targets associated with this goal is SDG 11.3, which states that by 2030, there will be an enhanced "inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries" (UN Department of Economic and Social Affairs, 2022). Achievements of this target, particularly on inclusive and sustainable urbanization, are to be measured by the SDG indicator 11.3.1, in the form of land-use efficiency (referred to in the literature as "LCRPGR"), which is obtained by computing the ratio of the land consumption rate (LCR) to the population growth rate (PGR). If the LCRPGR of an urban area, such as a city, is equal to or less than 1, it signifies that land utilization is at its most efficient level. Additionally, this value indicates that the city is likely to be more functional due to its compact nature; the cost of providing basic services and developing infrastructure is reduced; and the city preserves or conserves outlying land for other purposes. Moreover, when LCRPGR is very close to 1, the rate at which the city appropriated land from other uses to

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urbanized functions is almost equal to the rate at which its population grew. An LCRPGR larger than 1 indicates that the city appropriates land outwards every time the population increases, making land utilization inefficient (UN-Habitat, 2018).

To be able to monitor SDG 11.3.1 and estimate land-use efficiency (LUE) using the LCRPGR metric, spatiotemporal information on urbanization rates and population growth is required. Because of the spatiotemporal nature of LCRPGR, earth observation data remains to be the best available data to use so far, as exemplified in recently published works (Estoque et al., 2021; Ghazaryan et al., 2021; Jalilov et al., 2021; Jiang et al., 2021; Laituri et al., 2021; Li et al., 2021; Melchiorri et al., 2019; Schiavina et al., 2019, 2022; Zhou et al., 2021). Among the earth observation datasets available at present, the Global Human Settlement Layers (GHSL) is by far the most comprehensive for land-use efficiency studies, particularly in monitoring the SDG 11.3.1 target. The GHSL project led by the European Commission–Joint Research Centre has produced and analyzed global built-up surface, population density, and human settlement thematic maps to understand human presence on Earth. It employs spatial data mining technologies for the automatic processing and analysis of vast amounts of satellite images, census data, and volunteered geographic information (European Commission, 2023). GHSL data products have made possible the monitoring of SDG 11.3.1 in several thousands of urban centers around the world and estimate their land-use efficiency performances (Melchiorri et al., 2019; Schiavina et al., 2019, 2022). It has also been used to assess SDG 11.3.1 and monitor the intensity of built-up changes in the major metropolitan areas of Romania (Holobâcă et al., 2022); to track changes in urban form and assess land use efficiency over time in secondary cities in Indonesia, Ukraine and Ethiopia (Laituri et al., 2021); and in evaluating the land-use efficiency of all countries at the global level (Estoque et al., 2021). The successful use of GHSL data in these studies has made the GHSL an established source of information for monitoring SDG 11.3.1 at different spatiotemporal levels (Schiavina et al., 2022).

In the Philippines, urbanization studies are few, more so those concerned with understanding land-use efficiency. As a developing country, there has been rapid economic development in the last decades, that may have been accelerated by various government-led infrastructure programs. While many studies have been conducted concerning land-use/land cover mapping with the use of earth observation data, the relationship between built-up area expansion and population growth is not well studied in the Philippines. This lack of information on how urban and other settlement areas are evolving in the Philippines, in both space and time domains, requires careful consideration and immediate attention. On the other hand, the archipelagic nature of the Philippines means that land is fragmented and dispersed across numerous islands. This poses challenges in terms of data collection, analysis, and spatial integration. Gathering consistent and comprehensive data on land use across multiple islands can be complex and time-consuming, potentially resulting in data gaps or variations in quality. To address these limitations, one advantage that can be leveraged is the availability of GHSL data.

1.2 Objectives and Significance

This study aims to examine the trends and patterns of urbanization and changes in land-use efficiency in the Philippines from 1975-2020, using the GHSL. Specifically, this study aims to answer the following research questions:

- What are the trends and patterns of urbanization and changes in land-use efficiency in the Philippines from 1975-2020 based on the GHSL?
- How has urbanization in the Philippines from 1975-2020 impacted land-use efficiency, and what are the implications for sustainable development?

To address the questions comprehensively, we analyzed both urban and rural areas in the Philippines, allowing for a comprehensive understanding of the interplay between them. This analysis would provide us valuable insights into how efficiently land is being utilized, and if urban and rural areas in the Philippines are transforming to become more inclusive and sustainable. In addition, determining the LUE can characterize the evolution of urban settlements and provide valuable assistance to authorities and decision-makers. It enables the identification of new areas of growth and aids in formulating policies for the optimal use of urban land, among other benefits (Zhou et al., 2021). By monitoring progress against the SDG indicator 11.3.1, decision-makers and stakeholders are provided with the necessary and timely information to accelerate progress toward enhanced inclusive and sustainable urbanization (UN-Habitat, 2018). With the current developmental efforts geared toward smart cities and communities, studies on urbanization and land-use efficiency can help promote the high-quality, sustainable, and intelligent development of cities and settlements in the Philippines.

2. MATERIALS AND METHODS

2.1 Datasets Used

Our country-level analysis primarily utilized the multi-temporal GHS-BUILT-S, GHS-POP, and GHS-SMOD raster layers from the GHSL Data Package 2023 (GHS P2023) (Figure 1).

The GHS-BUILT-S (Pesaresi and Politis, 2023) shows the distribution of built-up (BU) surfaces in intervals of 5 years starting in 1975, divided into two functional use categories: the total BU surface (comprised of residential and non-residential surfaces, i.e., RES+NRES) and the NRES BU surface. The data was created by spatiotemporal interpolation of collections of satellite imagery acquired by Landsat (MSS, TM, ETM sensors) and Sentinel-2. The built-up area for each pixel is expressed in m^2. For this study, we used the total BU surface component to estimate built-up areas.

The GHS-POP (Freire et al., 2016; Schiavina, Freire, et al., 2023) depicts the distribution of the residential population and expresses the number of individuals per pixel. The population estimates are obtained from the Center for International Earth Science Information Network (CIESIN) Gridded Population of the World, version 4.11 (GPWv4.11), and cover the period from 1975 to 2020, with 5-year intervals. To create the dataset, the population data was disaggregated from census or administrative units into grid cells, using the distribution, density, and classification of built-up areas as mapped in the corresponding epoch of the GHSL global layer.

The GHS-Settlement Model (SMOD) (Schiavina, Melchiorri, et al., 2023) provides a delineation and classification of various settlement typologies based on a logic of cell clusters, considering population size, population density, and built-up area density as defined by the Degree of Urbanisation stage I (European Commission Statistical Office of the European Union, 2021). This dataset is presented as a raster grid, with each grid cell being assigned a specific settlement classification. The

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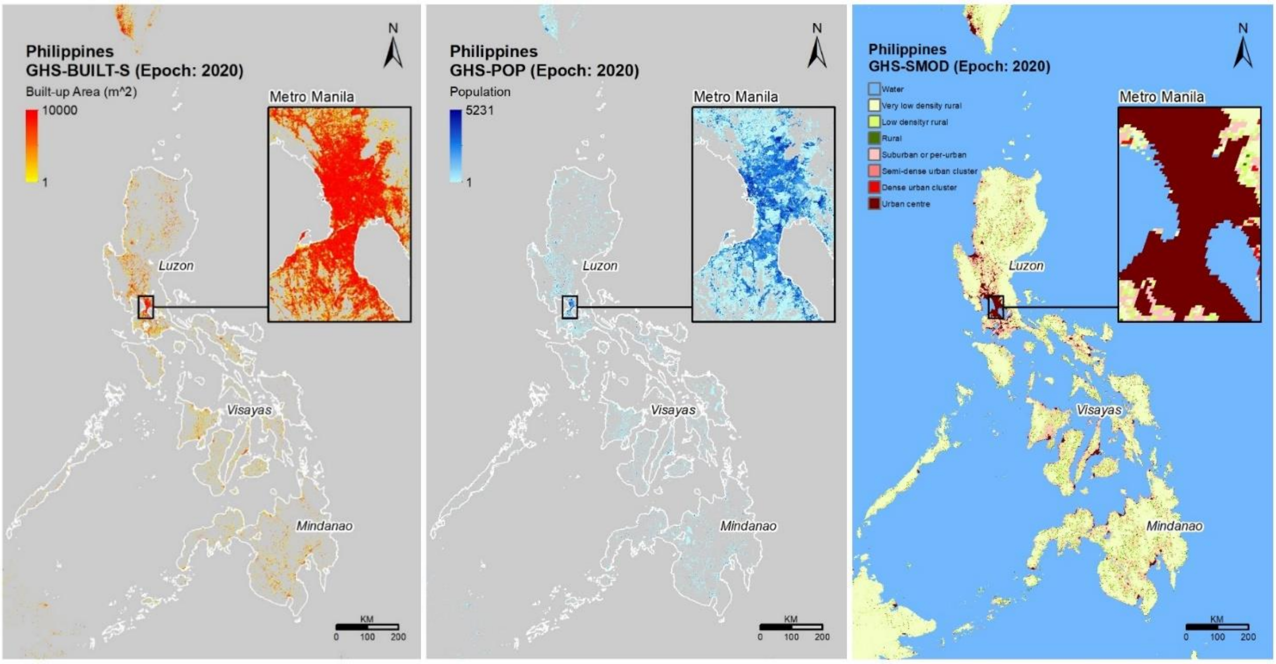

Figure 1. GHSL data examples for the Philippines, with an inset highlighting Metro Manila (National Capital Region). The GHS-BUILT-S and GHS-POP datasets have a spatial resolution of 100 m, while the GHS-SMOD dataset has a spatial resolution of 1 km. The original projection is based on the Mollweide coordinate system. However, for visualization purposes, the data is displayed in the World Geodetic System 1984 geographic coordinate system.

classifications include urban center, dense urban cluster, semi-dense urban cluster, suburban or peri-urban, rural, low-density rural, very low-density rural, and water (European Commission, 2023). GHS-SMOD is currently available at a 1 km spatial resolution.

Considering the global coverage of the datasets, we downloaded and selected only the raster tiles of the GHSL datasets that covered the Philippines in the Mollweide coordinate system at spatial resolutions of 100 m (GHS-BUILT-S and GHS-POP) and 1 km (GHS-SMOD). The ten (10) epochs of each dataset, spanning a 5-year interval (1975-2020) were downloaded from the GHSL online database maintained by the European Commission–Joint Research Centre (https://ghsl.jrc.ec.europa.eu/download.php). A mosaic for each epoch of the datasets was generated using ArcGIS-ArcMap 10.8.

For built-up area and population estimation, a shapefile containing the subnational boundaries (cities and municipalities) of the Philippines using the World Geodetic System (WGS) 1984 geographic coordinate system was obtained from the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) - Philippines through the Humanitarian Data Exchange website (https://data.humdata.org/dataset/cod-ab-phl). This shapefile is based on the Philippine Geographic Standard Code (PSGC) dataset generated by the Philippine Statistics Authority (PSA) and the National Mapping and Resource Information Authority (NAMRIA) in April 2016, using the layer created during the 2015 population census (UNOCHA-Philippines, 2022). To ensure compatibility with the GHSL datasets, the subnational boundary shapefile was reprojected to the Mollweide coordinate system, rasterized into 100-meter pixels, and then converted to a polygon shapefile. This ensured that the datasets, when overlaid, are compatible in terms of scale and extent. Based on the generated data, the computed land area of the Philippines is 295,207 km², approximately 1.6% lower than the officially reported land area of 300,000 km², which includes inland water bodies (Fabian Jr., 1991). This difference can be attributed to various factors, including the non-inclusion of inland water bodies in the computed area, variations in measurement methodology, the scale of data, data accuracy, and definitions of land area used in the respective calculations.

2.2 Built-up Area and Population Estimation

We applied the "Zonal Statistics as Table: SUM" tool in ArcGIS-ArcMap10.8 to obtain the total built-up area in all the pixels across the Philippines ($BU_{urban+rural}$), regardless of their classification as either urban or rural. We used the re-projected and re-scaled subnational boundary shapefile as the input feature zone data, and the mosaicked raster file of GHS-BUILT-S as the input value raster. This process generated ten (10) tables in *.dbf* format, with each table corresponding to a specific epoch. This procedure was repeated for getting the total population using GHS-POP ($POP_{urban+rural}$).

To obtain the total built-up area of lands classified as "urban", first we reclassified the cells in each epoch of mosaicked GHS-SMOD raster layers as either urban (1) or non-urban (0). "Urban" cells are those that are classified as either an urban center, dense urban cluster, semi-dense urban cluster, suburban, or peri-urban in the original data; the remaining classes (i.e., rural and water bodies) are classified as "non-urban". We exported the outputs into new sets of raster layers and utilized them to mask out non-urban pixels in GHS-BUILT-S and GHS-POP through a basic raster calculation. Then, the "Zonal Statistics as Table: SUM" tool was used again to get the total urban built-up area (BU_{urban}). This procedure was repeated to obtain the total urban population (POP_{urban}) using the masked GHS-POP. All the contents of the resulting tables were then imported and compiled into an MS Excel file for subsequent analysis. The total built-up area and population for rural areas (i.e., BU_{rural} and POP_{rural}) were calculated from the difference between $BU_{urban+rural}$ and BU_{urban}, and $POP_{urban+rural}$ and POP_{urban}, respectively.

2.3 Land-use Efficiency Calculations based on the LCRPGR

The LCRPGR, as SDG 11.3.1 indicator of land-use efficiency, is a dimensionless metric that is obtained by dividing the LCR by the PGR. To calculate these quantities, we used the following formulas based on the latest indicator metadata (UN Statistics Division, 2021), with minor changes in notations for consistency:

$$LCR = \frac{Urb_{t_2} - Urb_{t_1}}{Urb_{t_1}} \cdot \frac{1}{y} \quad (1)$$

$$PGR = \frac{ln\left(\frac{Pop_{t_2}}{Pop_{t_1}}\right)}{y} \quad (2)$$

$$LCRPGR = \frac{LCR}{PGR} \quad (3)$$

In these formulas, $Urb_{t_1}$and $Urb_{t_2}$are the total urban built-up area in the initial year t_1 and final year t_2, respectively; Pop_{t_1} and $Pop_{t_2}$are the total population within the urban areas in the initial and final years; and y is the number of years between the two measurement periods.

We computed the LCR, PGR, and LCRPGR every 5 years (e.g., 1975-1980, 1980-1985, …, 2015-2020). Although the formulas appear to be intended for urban areas, we also used them in the LCRPGR calculations for rural and urban+rural areas. For discussion, we converted the LCR and PGR values into percentages by multiplying them by 100. We also examined the statistical relationship between PGR and LCR through Pearson's r correlation analysis. This will help us clarify whether the expansion of the built-up area was associated with the increase in population (Estoque et al., 2021).

3. RESULTS AND DISCUSSION

3.1 Urban-Rural Land Classification of the Philippines

Figure 2 presents the urban-rural land classification of the Philippines, utilizing the GHS-SMOD data at a spatial resolution of 1 km. The data reveals a consistent pattern of urban land expansion and the corresponding decline of rural lands over the examined period. Between 1975 and 2020, urban lands experienced substantial growth, expanding from 14,766 km^2 to 50,747 km^2. Conversely, rural lands decreased from 280,441 km^2 to 244,460 km^2. Although the data supports the trend of urbanization in the Philippines, approximately 83% of the land was classified as rural, signifying that rural areas still occupy a significant portion of the country's landscape.

3.2 Built-up Area Expansion and Population Growth

There has been a steady increase in the overall built-up area and population of the Philippines over the period from 1975-2020 (Figure 3, Table 1, Table 2).

The total built-up area expanded from 824.50 km^2 to 2401.77 km^2 during this timeframe, nearly tripling in size. On average, the built-up area increased by approximately 35.05 km^2 per year, demonstrating consistent developmental growth throughout the country. Examining the urbanization trend, the results reveal an upward trajectory in urban built-up areas. In 1975, urban built-up areas accounted for 66.24% of the total, and this proportion progressively increased to 84.03% by 2020. The average annual change in urban built-up areas from 1975 to 2020 was approximately 32.71 km^2, which closely aligns with the overall average. These findings demonstrate a notable shift towards more urbanized regions over time.

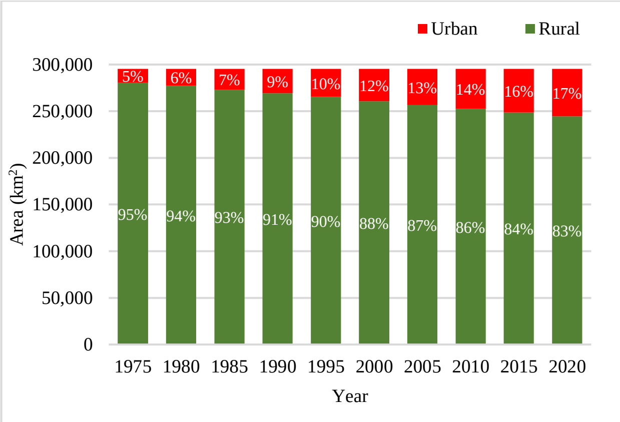

Figure 2. Urban-rural land classification of the Philippines based on the GHS-SMOD data.

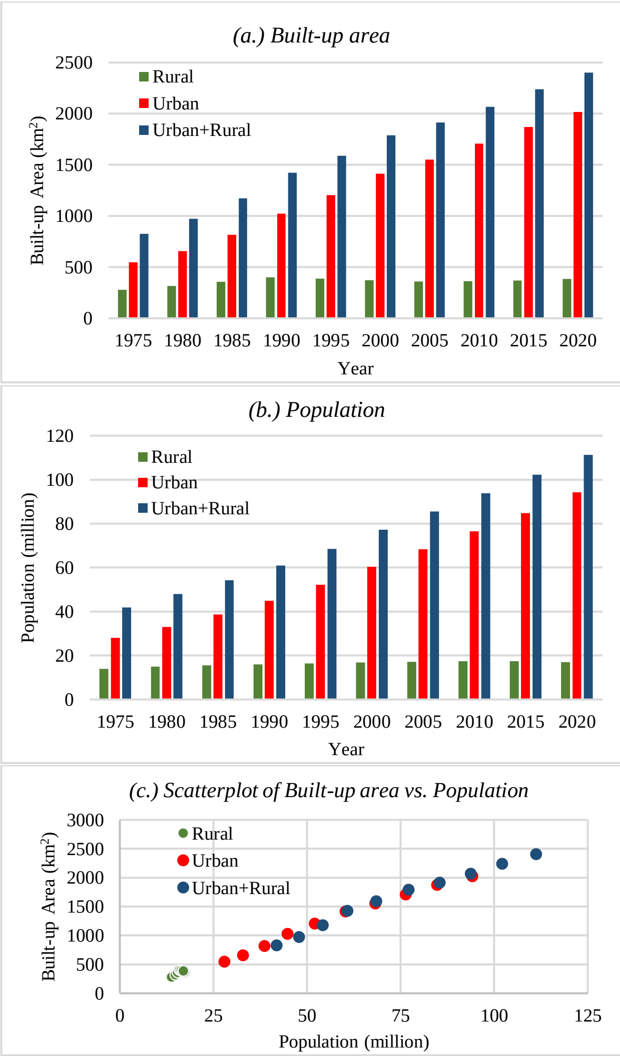

Figure 3. Trends of built-up area expansion and population growth in the Philippines from 1975-2020 estimated from GHSL data.

Year	Within Urban	Within Rural	Total	% Within Urban
1975	546.16	278.34	824.50	66.24
1980	655.59	315.54	971.13	67.51
1985	815.43	357.51	1172.94	69.52
1990	1,023.29	399.08	1422.37	71.94
1995	1,202.58	386.67	1589.25	75.67
2000	1,414.74	373.52	1788.26	79.11
2005	1,551.85	360.77	1912.62	81.14
2010	1,705.93	361.62	2067.55	82.51
2015	1,870.84	367.76	2238.60	83.57
2020	2,018.30	383.48	2401.77	84.03

Table 1. Built-up area of the Philippines from 1975-2020 estimated from GHS-BUILT-S (in km^2), categorized according to land classification.

Year	Within Urban	Within Rural	Total	% Within Urban	PSA Population
1975	28,014,373	13,910,095	41,924,468	66.82	42,070,660
1980	32,986,663	14,929,210	47,915,873	68.84	48,098,460
1985	38,723,515	15,516,458	54,239,974	71.39	*
1990	44,868,961	15,993,687	60,862,648	73.72	60,703,206
1995	52,141,977	16,414,680	68,556,657	76.06	68,616,536
2000	60,386,120	16,842,964	77,229,084	78.19	76,506,928
2005	68,319,161	17,180,772	85,499,933	79.91	*
2010	76,437,009	17,402,548	93,839,557	81.45	92,337,852
2015	84,795,515	17,389,775	102,185,290	82.98	100,981,437
2020	94,216,434	17,053,286	111,269,721	84.67	109,035,343

Table 2. The population of the Philippines from 1975-2020, estimated from GHS-POP, including the official population as reported in the Philippine Statistics Authority (PSA) website at https://psa.gov.ph/. No census was conducted in entries marked by *.

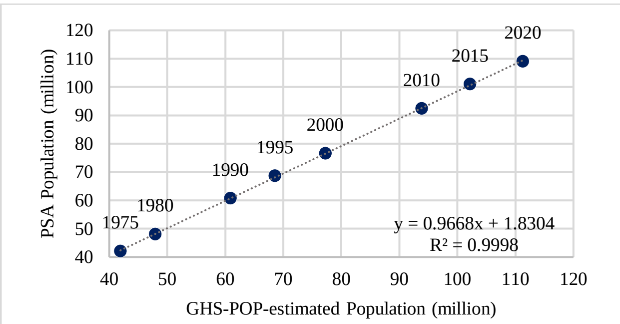

Figure 4. Relationship between the GHS-POP estimates and the actual population reported by the Philippine Statistics Authority (PSA). Each point is labelled by its corresponding year.

In contrast, the trend in rural built-up areas remained relatively stable, with an average change of 2.34 km^2/year. This indicates a relatively consistent level of development in rural areas compared to the significant growth observed in urban areas.

On the other hand, the GHS-POP data reveals a consistent increase in the total population of the Philippines over the last 45 years (Figure 3b, Table 2). The population grew from 41.92 million in 1975 to 111.27 million in 2020. This substantial growth indicates a significant demographic change and population expansion within the country.

Examining the urban population, we can see a consistent upward trajectory similar to that of the built-up area expansion. The urban population increased from 28.01 million in 1975 to 94.22 million in 2020. The rural population, in contrast, experienced a more moderate increase from 13.91 million in 1975 to 17.05 million in 2020. While the growth rate is relatively slower compared to urban areas, it signifies that rural communities continue to play a crucial role in the country's population composition.

Analyzing the percentage of the urban population relative to the total population, we can observe an upward trend. The urban population accounted for 66.82% in 1975 and steadily rose to 84.67% in 2020. This indicates a notable shift towards urbanization and urban areas as the primary dwelling places for most of the population.

It can be noted that there are differences in the GHS-POP-estimated population from the official reports of the Philippine Statistics Authority (PSA). Nevertheless, they are generally consistent and both sources indicate an increase in the Philippine population over time. The linear relationship between the GHS-POP estimates and the PSA-reported population is strong, with a high R^2 value of approximately 99.98% (Figure 4). This indicates a close association between the datasets. Although not exact, the GHS-POP estimates provide a reliable approximation of the actual population figures.

3.3 Land Consumption Rates

The results of our LCR, PGR, and LCRPGR calculations for the Philippines are presented in Figure 5 and Table 3.

Looking at the overall picture (i.e., urban+rural areas), one significant finding is the declining trend in the LCR values. From 1975 to 2020, the LCR decreases from 3.56% to 1.46%, indicating a reduction in the rate of land consumption and built-up area expansion over the years. This may suggest a shift towards more controlled and sustainable land development practices in the Philippines. The highest LCR value of 4.25% recorded between 1985 and 1990 suggests a relatively rapid conversion of land into built-up areas during that period. However, the lowest LCR value of 1.39% between 2000 and 2005 indicates a decline in the rate of land conversion during that time.

For urban areas, the LCR values also show a declining trend over the observed periods. From 1975 to 2020, the LCR decreases gradually, indicating a relatively slower rate of land consumption and built-up area expansion. The maximum LCR for urban areas, recorded in the period 1985-1990 at 5.10%, demonstrates a higher rate of land conversion during that time.

On the other hand, the LCR values for rural areas depict a contrasting scenario. These values exhibit more fluctuations and even negative values, particularly in the period 1990-2005. Negative LCR values indicate a decrease in the extent of rural built-up areas, potentially due to factors like land degradation or a shift in land-use patterns. The LCR for rural areas also remains consistently lower than the LCR for urban areas, suggesting that rural areas contribute less significantly to land consumption and built-up area expansion.

Comparing the overall LCR of the Philippines with the LCR values of urban and of rural areas, it is evident that urban areas have a higher LCR overall, signifying a more significant contribution to land consumption and built-up expansion. This result highlights the concentrated nature of urban development and its impact on land-use patterns. It also indicates that urban areas are the sole driving force behind land consumption in the country.

3.4 Population Growth Rates

The PGR data for the Philippines reveals a declining trend in overall population growth, with the PGR decreasing from 2.67% to 1.70% between 1975 and 2020. The PGR for urban areas tends

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to be higher than the overall PGR and similarly exhibits a decreasing trend, from 3.27% to 2.11% over the observed periods. This indicates a larger rate of population growth in urban regions compared to the national average. On the other hand, the PGR for rural areas shows consistently lower growth rates throughout the study period. Notably, there are negative PGR values observed for rural areas between 2010 and 2020, indicating a decline in population during that specific period. These findings emphasize the concentration of population growth in urban areas, alongside a comparatively slower pace of population growth in rural areas.

3.5 Relationship of LCR and PGR

When comparing the LCR and PGR over time, we can observe that in urban areas, the rate of land consumption was generally faster than the rate of population growth from 1975 until 2000 (Table 3). However, a reversal occurred from 2000 to 2020, where the PGR became higher than the LCR. In rural areas, land consumption occurred at a much higher rate than population growth, especially during the periods of 1975-1990 and 2010-2020.

The results of Pearson's correlation analysis reveal strong and significant positive correlations between LCR and PGR in both urban and combined urban+rural areas during the examined period (Figure 6). The correlation coefficients of 0.89 for urban (*p < .01*) and 0.78 for urban+rural (*p < .05*) indicate a substantial and coordinated relationship between LCR and PGR over time. It suggests that population growth and land consumption are intertwined and mutually influence each other more prominently in urban areas compared to rural areas. As the population increases, the demand for land rises, leading to higher rates of land consumption. Conversely, the expansion and development of urban areas, driven by increasing land consumption, can also contribute to population growth.

In rural areas, the correlation between LCR and PGR is weaker and not statistically significant (*r = 0.49, p > .10*). This implies that factors other than population growth may play a more prominent role in determining land consumption patterns in rural regions. Similarly, the relationship in rural areas suggests that factors beyond population growth, such as agricultural practices or natural resource availability, have a greater influence on land consumption.

3.6 LCRPGR

Analyzing the LCRPGR values, we observe a decreasing trend across all categories: overall (urban+rural), urban areas, and rural areas. These declining values indicate an improvement in land-use efficiency over time in the Philippines.

Starting from the period of 1975-1980, the LCRPGR for the overall (urban+rural) category was 1.33, which gradually decreased to 0.86 in the 2015-2020 period. Similarly, in urban areas, the LCRPGR decreased from 1.23 to 0.75. In rural areas, the LCRPGR declined from 1.89 to -2.19. All these trends reflect a notable shift towards more efficient land utilization practices.

Considering both urban and rural areas, the country exhibited the highest efficiency during the 2000-2005 period with an LCRPGR of 0.68. In urban areas, the most efficient land utilization occurred during the 2015-2020 period, with an LCRPGR value of 0.75.

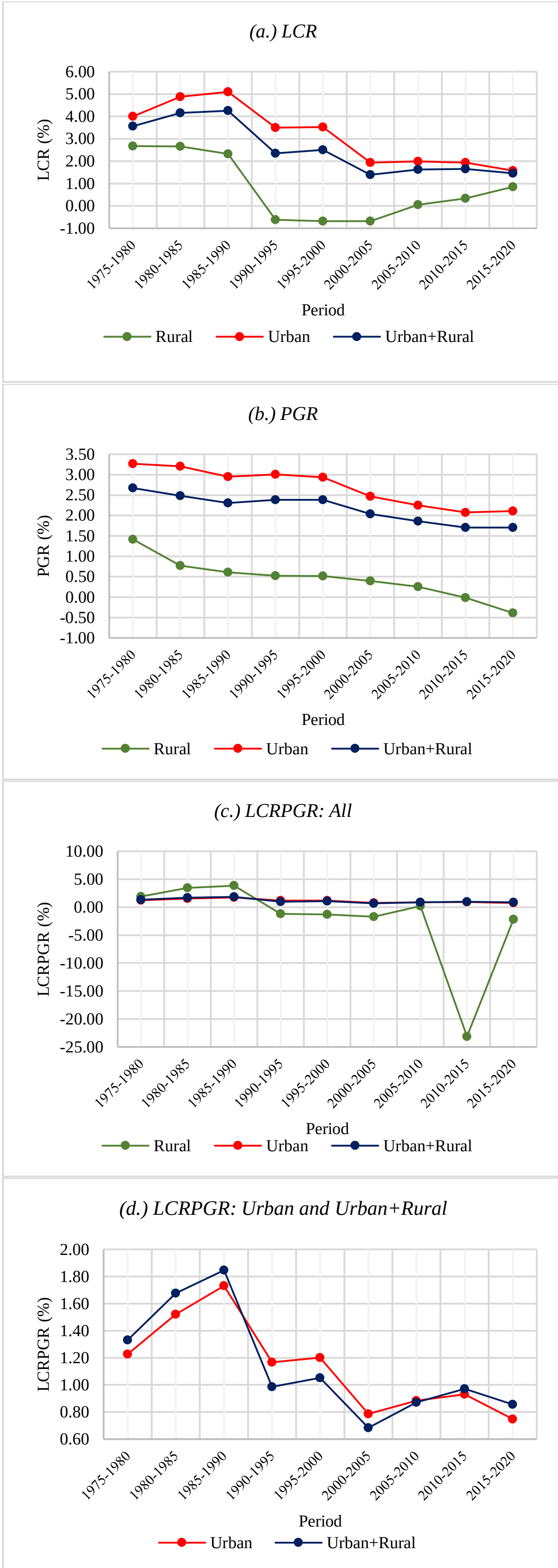

Figure 5. Trends in LCR, PGR, and LCRPGR of the Philippines. To enhance clarity and highlight the differences, a separate representation (d.) showcasing the LCRPGR trends for urban and urban+rural areas is included.

(a.) Overall (Urban + Rural Areas)			
Period	LCR (%)	PGR (%)	LCRPGR
1975-1980	3.56	2.67	1.33
1980-1985	4.16	2.48	1.68
1985-1990	4.25	2.30	1.85
1990-1995	2.35	2.38	0.99
1995-2000	2.50	2.38	1.05
2000-2005	1.39	2.03	0.68
2005-2010	1.62	1.86	0.87
2010-2015	1.65	1.70	0.97
2015-2020	1.46	1.70	0.86
(b.) Urban Areas			
Period	LCR (%)	PGR (%)	LCRPGR
1975-1980	4.01	3.27	1.23
1980-1985	4.88	3.21	1.52
1985-1990	5.10	2.95	1.73
1990-1995	3.50	3.00	1.17
1995-2000	3.53	2.94	1.20
2000-2005	1.94	2.47	0.79
2005-2010	1.99	2.25	0.88
2010-2015	1.93	2.08	0.93
2015-2020	1.58	2.11	0.75
(c) Rural Areas			
Period	LCR (%)	PGR (%)	LCRPGR
1975-1980	2.67	1.41	1.89
1980-1985	2.66	0.77	3.45
1985-1990	2.33	0.61	3.84
1990-1995	-0.62	0.52	-1.20
1995-2000	-0.68	0.52	-1.32
2000-2005	-0.68	0.40	-1.72
2005-2010	0.05	0.26	0.18
2010-2015	0.34	-0.01	-23.12
2015-2020	0.85	-0.39	-2.19

Table 3. Values of the Philippines' LCR, PGR, and LCRPGR based on GHSL datasets.

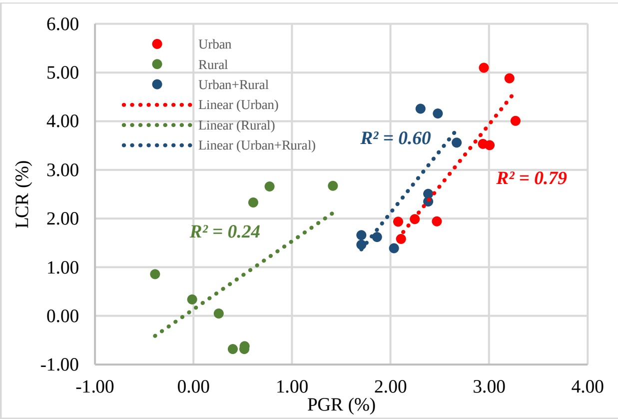

Figure 6. Scatterplot of PGR versus LCR. Each point represents a pair of country-level PGR and LCR calculated at a 5-year interval, from 1975-2020.

Reference	LCR (%)		PGR (%)		LCRPGR	
	1975-2000	2000-2015	1975-2000	2000-2015	1975-2000	2000-2015
This study	3.10	1.50	2.44	1.87	1.27	0.80
Estoque et al. (2021)	1.78	0.93	2.54	1.80	0.6999	0.5202

Table 4. Comparison of LCR, PGR, and LCRPGR of the entire Philippines (urban + rural) with Estoque et al. (2021). The LCR values were computed using the 2018 version of the SDG 11.3.1 metadata.

3.7 Comparison with Other Studies

Our study reveals a positive and significant relationship between LCR and PGR in urban and urban+rural areas of the Philippines. This finding aligns with the relationship observed at the global level, as estimated by Estoque et al. (2021).

At the regional level, specifically within the lower middle-income country group where the Philippines is categorized, Estoque et al. (2021) also found a positive relationship between the country's overall LCR and PGR. However, it is worth noting that in this regional context, the relationship was not statistically significant. This finding contrasts with the results of the present study.

The differing findings between the regional study conducted by Estoque et al. (2021) and our study on the Philippines suggest that the level of analysis may have influenced the observed relationship between LCR and PGR. When examining a specific region or country, such as the lower middle-income country group that includes the Philippines, the relationship between LCR and PGR may be influenced by unique regional factors, policy interventions, or contextual characteristics.

We also computed the LCR, PGR, and LCRPGR for the 1975-2000 and 2000-2015 periods and compared them with values calculated by Estoque et al. for the Philippines (Table 4). It should be noted that the values provided in Table 4 for the current study are the results of the computations based on the LCR formula included in the 2018 version of the SDG 11.3.1 metadata (UN-Habitat, 2018). This formula is consistent with the one employed by Estoque et al.. Overall, the two studies differ in their calculated values. Estoque et al. reported lower LCR values, slightly higher PGR values, and lower LCRPGR than in this study. While Estoque et al.'s research suggests efficient land utilization for both the 1975-2000 and 2000-2015 periods, our study indicates a relatively similar level of efficiency only during the 2000-2015 period.

The differences between our findings on the LCR-PGR relationship and the LCRPGR values can also be attributed to the datasets used and the spatial resolution employed. We utilized GHSL datasets at a spatial resolution of 100 m, providing a more detailed and localized analysis of LCR and PGR. In contrast, Estoque et al. used the 2018 GHSL built-up area data release at a coarser spatial resolution of 1 km, potentially resulting in a loss of finer details. It is also possible that the data and algorithms used in producing the latest GHSL data package have updated built-up area information. Additionally, different population datasets were employed, with the present study using GHS-POP and Estoque et al. relying on the World Population Prospects (WPP) 2019 data, introducing further variations in the estimation of PGR. These differences highlight the potential impact of dataset selection and spatial resolution on the findings and conclusions of both studies.

On the other hand, the observed downward trend in LCRPGR values within the Philippines signifies an enhancement in the country's land-use efficiency as time progresses. This general trend is consistent with the findings presented by Schiavina et al. (2022) concerning most urban centers in the Philippines included in their extensive global study on land use efficiency of functional urban areas.

3.8 Insights

3.8.1 Evidence of Urbanization in the Philippines: Our research findings reveal the developmental growth and urbanization that has taken place in the Philippines between 1975 and 2020. One notable trend is the substantial increase in the total population, closely associated with the expansion of built-up areas. This correlation is expected, as the growing population naturally generates higher demand for housing, infrastructure, and urban amenities. Consequently, urban areas have expanded, often at the expense of converting rural land into built-up areas. This expansion can be partly attributed to the local land-use planning and zoning regulations that have favored built-up land uses in the Philippines in previous decades (Malaque and Yokohari, 2007).

The significant growth of the urban population from 1975 to 2020 reflects the ongoing process of urbanization and the concentration of people in urban areas. It highlights the appeal and opportunities offered by cities and urban regions, drawing individuals away from rural areas. However, this concentration of population in urban regions also brings about certain environmental challenges. For instance, the expansion of built-up areas can reduce green spaces and increase the urban heat island effect (Almadrones-Reyes and Dagamac, 2023). These impacts emphasize the need for effective urban planning and infrastructure development to accommodate the growing urban population while also improving overall environmental quality and enhancing the well-being of urban residents.

3.8.2 On the Philippines' Land-use Efficiency: The decreasing trend in the Philippines' LCRPGR values indicates that the country is making progress in optimizing land use by minimizing the expansion of built-up areas and promoting more compact and sustainable urban development.

Moreover, the LCRPGR data suggests that the land-use efficiency of the Philippines is primarily driven by the efficiency of urban areas, especially over the last two decades. The LCRPGR values for urban areas from 2000-2020 are below one, with the land consumption rates lower than the population growth rates. This relationship implies that the land is being used more efficiently, accommodating a growing population while minimizing excessive land consumption. Meanwhile, the negative LCRPGR values in rural areas for some periods signify efficient land utilization achieved by avoiding extensive land conversion, despite stagnant or declining population growth.

3.8.3 Implications for Sustainable Development: The complexity of human settlement structures makes it challenging to generalize the significance of a single LCRPGR value for sustainable urbanization. While a value less than one could indicate urban compactness, analyzing within cities might reveal problems like congestion and subpar living conditions, contradicting the principles of sustainable development (UN Statistics Division, 2021). Nonetheless, the findings of our study are crucial for understanding the evolving urban and settlement areas in the Philippines and assessing the country's progress toward achieving SDG 11. Although the country has not formally monitored SDG 11.3 as a target (Philippine Statistics Authority, 2022), our research can stimulate the recognition of the need for enhancing inclusive and sustainable urbanization. It can also contribute to improving capacities for participatory, integrated, and sustainable human settlement planning and management in the country, which is also at the core of SDG 11.3.

Indicators like SDG 11.3.1 possess significant potential as valuable aids for decision-making processes that promote sustainable development (Waas et al., 2014). The enhancement of the country's land-use efficiency over time, as revealed by our calculations of LCRPGR as SDG 11.3.1 indicator, can serve as an impetus for policymakers and urban planners to prioritize or continue the development of well-planned urban areas with compact and mixed-use neighborhoods. Such development requires fewer resources and infrastructure per capita, resulting in cost savings and increased efficiency in providing basic amenities. It also promotes walkability, reduces commuting distances, and minimizes energy consumption, among other benefits.

Moreover, sustainable land-use practices have broader social and economic implications. By continuously monitoring the country's progress against the SDG 11.3.1 indicator, concerned agencies can effectively implement land preservation and conservation efforts, leading to reduced vulnerability, enhanced resilience, and improved community well-being.

4. CONCLUSIONS, LIMITATIONS, AND WAYS FORWARD

This study examined the trends and patterns of urbanization and changes in land-use efficiency in the Philippines from 1975-2020 using the GHS-BUILT-S, GHS-POP, and GHS-SMOD raster datasets from the GHSL Data Package 2023. These datasets have proven valuable in examining patterns and trends in urbanization and land-use efficiency in the Philippines. Its high spatiotemporal resolution and coverage provide a detailed and comprehensive view of human settlements and populations, allowing for more in-depth analysis and insights.

In addition to presenting evidence of the Philippines' developmental progress and urbanization, our analysis of GHSL data reveals a decline in land consumption, a deceleration in population growth, and an overall enhancement in land-use efficiency within the country. All these findings suggest a shift towards more controlled and sustainable land development practices, supporting the country's goal of sustainable urbanization and land management. They can serve as valuable insights for policymakers and urban planners in the Philippines, guiding them toward formulating more effective and well-rounded land management strategies. By leveraging these findings, policymakers can balance economic growth and sustainable development, fostering a future where urbanization and land utilization are thoughtfully planned and managed.

It is important to acknowledge that the findings and conclusions presented in this study are based on the analysis of the datasets included in the 2023 release of the GHSL data package. Indeed, the GHSL has become an established source of information for monitoring the SDG 11.3.1 at different spatiotemporal scales and is undeniably a valuable resource for understanding the developmental growth and urbanization in the Philippines. However, we recognize that our results are still subject to the accuracy and limitations inherent in the dataset. While our study showed that the GHS-POP estimates for the Philippines provide a reliable approximation of the actual population figures, we could not establish the same for GHS-BUILT-S. Therefore, we emphasize the need to validate the datasets used in this analysis thoroughly. Validation of the GHSL data against ground truth data, particularly in densely populated urban areas (Liu et al., 2020), is essential to ensure the accuracy and reliability of the findings. This validation process would provide confidence in the dataset's ability to capture the unique characteristics of urbanization and land use in the Philippines. Nevertheless, it is essential to highlight that the latest GHSL data package is undergoing rigorous accuracy assessment, validation, and continuous improvement processes (European Commission, 2023). This reassures us that efforts are being made to refine the dataset and enhance its reliability.

Furthermore, given the archipelagic nature of the Philippines, it is vital to conduct localized analyses at the city or municipality level. The present study provided a broad overview by examining data at a national scale. However, it is crucial to consider the diverse urbanization patterns and land-use dynamics across different islands and regions of the country. A localized approach can help us fully comprehend the unique challenges and opportunities associated with urban development in individual cities and municipalities. It could also provide more insights into the factors influencing urbanization and land-use efficiency, facilitating tailored policy interventions and spatial planning strategies.

It is also essential to incorporate two secondary indicators of SDG 11.3.1, namely built-up area per capita and the total change in built-up area, in the analysis. Integrating these secondary indicators can enhance the comprehensibility of the core indicator's values and contribute to a more comprehensive assessment of the relevant aspects (UN Statistics Division, 2021).

Finally, our analysis was conducted using conventional GIS tools. Enhancements could be implemented by utilizing programming or graphical modeling tools to create processing flows, enabling easier replication of the analysis in different geographical contexts.

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