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Strategic Cartography: Geospatial Insights into Building age Dynamics for Sustainable Urban Resilience in Dormaa Ahenkro, Ghana

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Abstract: Dormaa Ahenkro town ship has been in existence for many centuries and that, there are different kinds of buildings in the city. With regard to the ages of the buildings which is very important for authorities to track the history of some buildings for safety and economic resources. This study navigates the intersection of geospatial technology and urban development. Leveraging QGIS 3.16 and Google Earth pro, a meticulous analysis of 243 buildings in Dormaa Ahenkro unveils a nuanced understanding of their temporal and functional dynamics. The digitization process reveals 220 old and 23 new structures, forming the foundation for an exploration of the architectural evolution of the city. Temporal insights, spanning from the year 1820 to 2023, illuminate the historical narrative of Dormaa Ahenkro, while an SQL (Structured Query Language) was used to categorize buildings based on their conditions and purposes. Clusters of buildings, as depicted spatially, not only signified temporal patterns but also conveyed functional diversity, with some structures serving dual purposes-commercial and residential. The SQL used to query data from the geodatabase in GIS highlighted the urgency of addressing aging structures, identifying 133 buildings in need of maintenance and emphasizing the historical significance of the oldest building at 193 years. The study recommends targeted preservation initiatives for historical buildings, balanced urban planning strategies, routine maintenance programs, resilient design regulations, and community engagement initiatives. These recommendations provide a strategic framework for Dormaa Ahenkro to preserve its heritage, foster sustainable growth, and fortify resilience against evolving urban challenges. The integration of geospatial insights and strategic cartography emerges

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as a powerful tool for informed decision-making in shaping a resilient and sustainable urban future for Dormaa Ahenkro, Ghana.

Keywords: Urban Resilience, Building Age Dynamics, Sustainable Development, Gis, Geospatial Analysis.

1. INTRODUCTION

A distribution map of buildings is a graphical representation of the spread and concentration of different age groups of buildings in a specific area (Jordan et al., 2021). In the dynamic interplay between urban development and geographic information systems (GIS), the strategic application of cartography becomes a linchpin for sustainable urban resilience. In contrast, a residential age distribution map may indicate that older buildings are scattered throughout the city, while the new residential areas are mainly visible in suburban or outlying areas (Pateman, 2011). This study ventures into the realm of strategic cartography, utilizing advanced geospatial insights to unravel the intricate dynamics of building age within the vibrant urban landscape of Dormaa Ahenkro, Ghana. Grounded in the principles of sustainability, this research seeks to shed light on the spatial nuances of the architectural evolution of Dormaa Ahenkro, offering valuable perspectives for strategic urban planning and resilient development in the unique context of Ghana. Urban centres, such as Dormaa Ahenkro, serve as living narratives of historical transitions, cultural amalgamation, and adaptive responses to environmental challenges. Beyond the static nature of buildings, the age dynamics encapsulate a dynamic story, reflecting the ebb and flow of societal evolution.
The importance and values of map have been long recognized by humans. The history of maps can be traced to more than 5,000 years ago (Knoop et al., 2023). Maps are fundamental tools for the map maker to record the location of places of interest, and source of learning about the geography of the mapped area. Age distribution maps of buildings play a significant role in gaining insights into urban development, architectural heritage, and decision-making processes. Previous studies have emphasized their importance in planning, historical preservation, and urban decay mitigation (Knoop et al., 2023) It is crucial to tailor strategies and consider local contexts when analyzing age distribution maps. While progress has been made in this field, further research is needed to explore the relationships between building age, architectural style, energy consumption, and the development of standardized methodologies.

Since the advent of new mapping techniques, several studies have been conducted within the areas of Cartography. Rosser et al. (2019) did a study on Predicting residential building age from map data. In this paper, a methodology is introduced for automatically identifying the construction period of houses to enhance urban energy modelling. The approach involves a two-stage process: a per-building classification model utilizing morphology and neighbourhood characteristics, and post-classification analysis to refine accuracy. However, a limitation lies in the dependency on available data, highlighting the need for comprehensive and consistent datasets for optimal model performance. Van Hoesen and Letendre (2013) utilized historical maps for determining building age to identify suitable properties for implementing energy efficiency measures. They faced challenges with the manual digitization process, which required substantial time and effort. In the context of the United Kingdom (UK), there have been demonstrations of inferring construction periods through automatic analysis of building footprint shape and context. Reimer et al. (2022) did a study on Data description of "building age map, Vienna, around 1920. This paper addresses the scarcity of building age maps for the distant past, emphasizing the unique case of Vienna around 1920, where 80% of building footprints within the contemporary city boundary are available in analogue format only. The authors employ a meticulous process, manually vectorizing 80,640 building footprints from historical map sheets and assigning construction dates through digitization and cross-referencing with a historical building registry. While the resulting dataset provides valuable insights into the urban development of Vienna, a limitation lies in the 23% of buildings lacking construction period assignments due to missing data, underscoring the challenge of completeness in historical mapping efforts. Herfort et al. (2023) also did a study on A spatial and temporal analysis investigating completeness and inequalities of global urban building data in OpenStreetMap. This study evaluates the global completeness of OpenStreetMap (OSM) building data for urban analyses, revealing significant variations across urban agglomerations. While some cities demonstrate high completeness exceeding 80%, nearly half of the urban population resides in areas with less than 20% completeness. The research underscores persistent spatial biases in OSM data and provides practical recommendations for addressing and assessing these disparities.

From these literature, existing methods for determining building age or construction period are limited. The authors rely on exhaustive manual digitization, which is not feasible for large urban areas, or depend on datasets that may not always be available or consider multiple sources of building and neighbourhood data specific to the study area (Pan et al., 2023). Furthermore, the authors overlooked the importance of location and spatial context in the inference process. To address these limitations, this study proposes the use of Geospatial methods to automatically infer building age for sustainable urban resilience. It aims to leverage a variety of geospatial data types such us vector and raster (Xu et al., 2019). Age distribution maps have proven valuable in various contexts.

Through the lens of strategic cartography, this study endeavours to decipher the layers of history embedded within the urban fabric of Dormaa Ahenkro, recognizing that each building holds clues to the resilience and potential of the city for sustainable growth. The impetus for this research stems from the recognition of Dormaa Ahenkro as a dynamic urban entity at the nexus of tradition and progress. Strategic cartography, enriched by geospatial insights, emerges as a powerful tool to unlock the potential for sustainable urban resilience in Dormaa Ahenkro. The study contributes not only to local urban development but also to provide a strategic framework that resonates with broader discussions on sustainable urbanism in Ghana.

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2. MATERIALS AND METHODS

Study Area

Dormaa Ahenkro as shown in Fig. 1, situated in the Brong-Ahafo Region of Ghana, serves as a captivating study area with its rich historical, cultural, and urban fabric. This bustling town holds the distinction of being the capital of the Dormaa Central Municipality, carrying a legacy that spans centuries. Nestled in the heart of Ghana, Dormaa Ahenkro is not merely a geographical location but a living canvas that tells the story of societal evolution and architectural heritage. Historically, Dormaa Ahenkro has been a centre of cultural significance, serving as the traditional seat of the Dormaa Kingdom (Dormaa Ahenkro, 2023). This heritage is palpable in the architecture of the town, customs, and community life. The study area boasts a unique blend of traditional and modern influences, creating a dynamic urban environment that reflects the interplay between tradition and progress. Urban development in Dormaa Ahenkro is characterized by a diverse array of structures, each with its own story to tell. The landscape of the town is a mosaic of old and new buildings, representing different epochs of construction and societal needs. This diversity provides an intriguing backdrop for studying building age dynamics, as it encapsulates the evolving nature of urban spaces over time. Moreover, the strategic location and economic activities of Dormaa Ahenkro make it a focal point for understanding urban resilience. The role of the town as a commercial and administrative centre amplifies the importance of studying its built environment for sustainable development. Challenges and opportunities inherent in the urban landscape of Dormaa Ahenkro make it a microcosm for exploring solutions to broader urban issues in Ghana. In essence, Dormaa Ahenkro is not just a geographical location for this study; it is a dynamic, living entity that encapsulates the essence of the history and contemporary urban challenges of Ghana. Studying this vibrant town provides insights that extend beyond the physical structures, offering a holistic understanding of the cultural, social, and economic dimensions that shape urban resilience in the Ghanaian context (Dormaa Ahenkro, 2023).

Fig. 1 A Map of Dormaa Ahenkro in Dormaa Central Municipal

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Materials Used

In this study, a combination of geospatial data obtained through QGIS 3.16 software and Google Earth has been employed for a comprehensive analysis of building age dynamics in Dormaa Ahenkro. QGIS, a powerful open-source GIS platform, facilitated the extraction and digitization of building footprints, enabling a detailed mapping of the spatial distribution of structures within the study area. Google Earth, serving as a supplementary tool, provided high-resolution satellite imagery, enhancing the precision of spatial analysis. Additionally, insights from interviews with property owners enriched the dataset, offering valuable non-spatial information about the age, usage, and historical context of buildings. This multi-source approach ensures a holistic understanding of the urban landscape of Dormaa Ahenkro, blending advanced geospatial technologies with qualitative insights from local stakeholders. The data used with their sources are shown in Table1.

Table 1: Materials Used with their sources

Material	**Source**
QGIS 3.16 software	https://www.qgis.org/en/site/forusers/download.html
Google Earth	https://earth.google.com/web/@7.26862982,-2.87470975,263.69494464a,5077.84229066d,35y,0h,0t,0r/data=OgMKATA
Interviews	Property owners in the study area
Hand-held GPS	Germin GPS device
MS Excel 2019	Microsoft

3. METHODS

Data Preparation, Processing and Digitizing

Fig. 2 is the flow of the methods upon which this study was conducted. The study focused on conducting a building survey in Dormaa Ahenkro using Handy GPS as shown in Table 2. A section of Dormaa Ahenkro town was selected for this study based on its population density and development significance. This area offers a diverse range of building types, including residential, commercial, and public buildings, making it suitable for the survey. Data collection was done through field surveys (interview) and GPS survey for location. To aid in spatial information, Google Earth was utilized as a reference tool. A detailed information about each building, including its location, type, size, and condition were recorded. This data collection process ensures a comprehensive understanding of the buildings in the selected section in Dormaa Ahenkro. The collected data was then organized and prepared for further analysis using MS Excel. This step involved cleaning and structuring the data to ensure its accuracy and consistency. Attributes such as building type and condition were categorized to facilitate data analysis in later stages.

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Geotagged images (images with coordinates) of buildings were digitized as shown in Fig. 3 using GIS software (QGIS). This process involved tracing the building footprints from the images and capturing relevant attributes. Each building was assigned a unique ID to ensure proper identification and management of the data. This digitization process allows for the creation of a digital representation of the buildings, which can be easily analyzed and visualized. The digitized buildings and their attributes were imported into a geodatabase using QGIS software. A geodatabase is a spatial database that enables efficient storage, management, and analysis of spatial data. By organizing the data within a geodatabase, various spatial analyses and queries were performed to gain insights into the building characteristics and their relationships. Finally, a spatial analysis was conducted to generate an age distribution map of the buildings in Dormaa Ahenkro. This analysis involved categorizing the buildings into different age ranges based on available information. The age distribution map provided valuable insights into the historical development and planning patterns within the study area. It can help identify areas with older or newer buildings, assess the preservation of historical structures, and inform future development and renovation plans.

Spatial Analysis and Queries Using GIS
Identifying Old Buildings
The distribution of buildings based on their construction year or age were created using the geodatabase. This makes it easier to pinpoint areas with a high concentration of older buildings. Identifying older buildings was done by querying the geodatabase using SQL. The Age Field in the Geodatabase was used to query for buildings greater than or equal to 20years (Age > = 20years) as shown in Fig. 5. This query helped in preserving historical, architecture, understanding the evolution of a neighborhood or city, or even assessing the need for renovation or restoration projects. The analysis provided in a building survey report will help property owners, prospective buyers, or renovation contractors to make informed decisions. It outlines the current condition of the building, highlights any urgent repairs or safety concerns, and estimate the potential cost involved in restoring or maintaining the structure.

Identifying New Buildings
New buildings were queried from the geodatabase using by using SQL for buildings whose age is less than or equal to 20years (Age < = 20years) as shown in Fig. 6. When analyzing the impact of new buildings on age distribution map several interesting trends and patterns can be observed. The construction of new buildings often attracts younger population, as these areas offer employment opportunities, better infrastructure and modern amenities. This influx of younger residents can lead to a shift in the age distribution of a surrounding area. One possible analysis is to compare the age distribution before and after the construction of new buildings. You can examine the changes in different age groups and determine if there is a significant increase or decrease in specific age ranges. This analysis provided insight into the impact of new buildings in the demographics of the study area as shown in Fig. 6.

Specifying Buildings that Needs Maintenance
When analyzing an age distribution map of buildings to specify those in need of maintenance, several key factors need to be considered. Age alone may not be the sole indicator of

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maintenance needs, some older buildings may have been well maintained, while newer buildings may already require repair. However, age was used as a starting point for identifying potential maintenance issues in the study area because field survey and interview showed that old buildings has not been maintained in the past 20years. Buildings that are relatively older were identified from the geodatabase and was compared to others in the area within the geodatabase. This was done by categorizing building based on their construction year or age as shown in Fig. 7. Assessing building materials and construction, consider the materials and construction techniques used in older buildings. Certain materials, such as asbestos or lead-based paint, may require special attention due to health and safety concerns. Additionally, buildings constructed with outdated techniques may be more prone to structural issues or deterioration. Using the age, a comprehensive analysis was created to specify buildings that may require maintenance (Fig. 7) and buildings in Good conditions (Fig. 8). The buildings that requires maintenance were queried using Age >= 16years and buildings in Good conditions within the study area were queried using Age <= 10years as shown in Fig. 7 and Fig. 8 respectively.

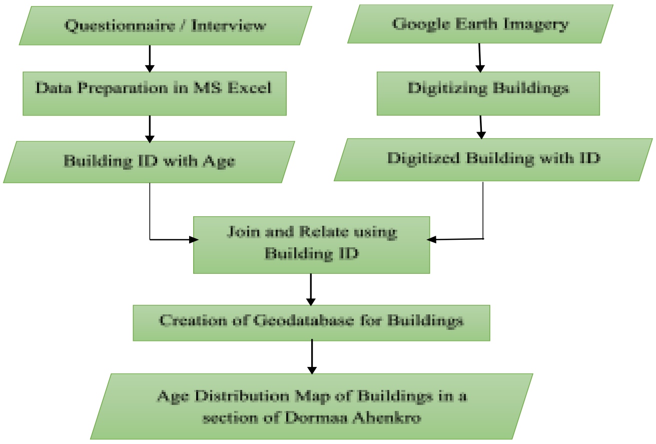

Fig. 2 Conceptual Framework of the study

3. RESULTS

Map of Buildings Digitized in the Study Area

A total of 243 buildings were digitized from the study area (Fig. 3) of which 220 were old buildings and 23 new buildings. Non-spatial data gathered from the field work as shown in Table 2 indicated that the buildings in the study area were constructed within the period of 1820 and 2023 as shown in Fig. 4. This map show clusters of buildings built in different time periods and the purpose it served. Some buildings served as commercial, residential, and others both commercial and residential depending on the number of people living in the house and other activities the building was used for.

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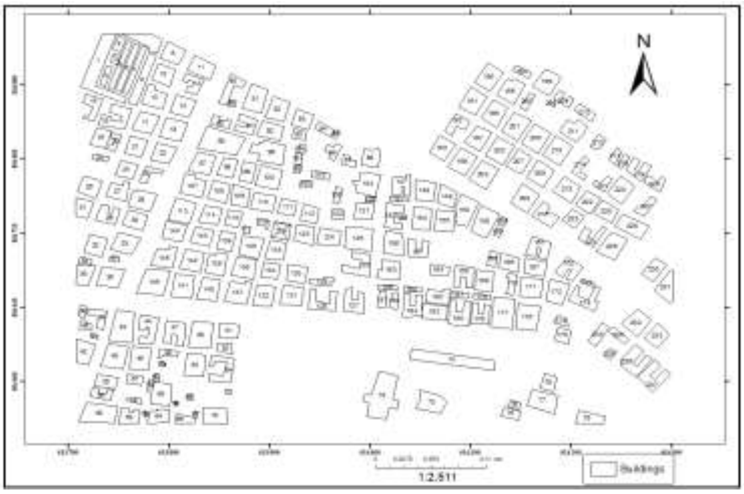

Fig. 3 Map of Buildings Digitized in the Study Area

Query for the Categorization of Buildings

209 houses felt under old buildings after the SQL query as shown in Fig. 5. These buildings are so old that they need to be checked in case of any disaster. It was observed that the oldest building within the study is 193 years old. 29 buildings were identified as new buildings as shown in Fig. 7. 133 Buildings were identified to require maintenance and 8 buildings were identified to be in a good condition as shown in Fig. 8.

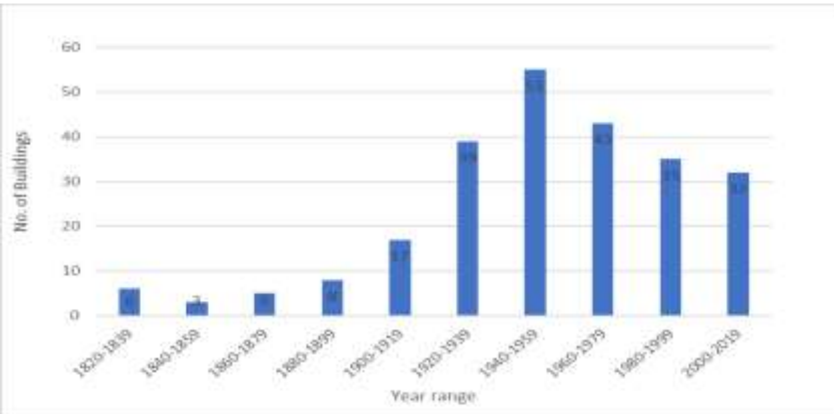

Fig. 4 Distribution of the age of buildings within the study area

Table 2: Survey of buildings within the study area

Year Range	Number of buildings
1820-1839	6
1840-1859	3
1860-1879	5
1880-1899	8
1900-1919	17
1920-1939	39

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1940-1959	55
1960-1979	43
1980-1999	35
2000-2019	32

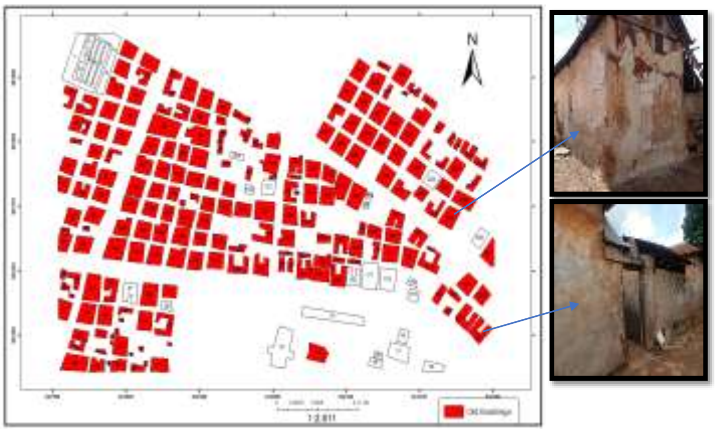

Fig. 5 Spatial distribution of Old buildings within the study area

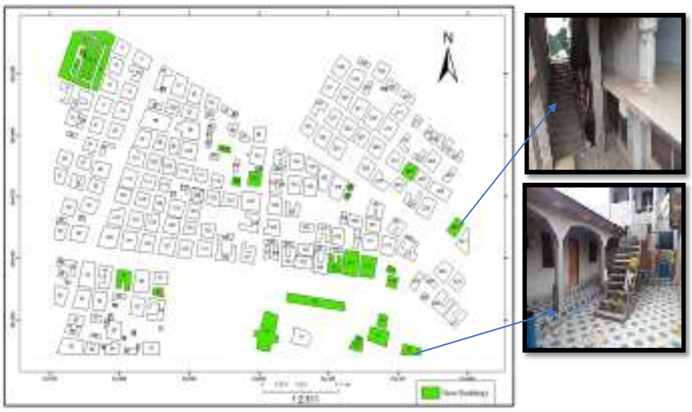

Fig. 6 Spatial distribution of new buildings within the study area

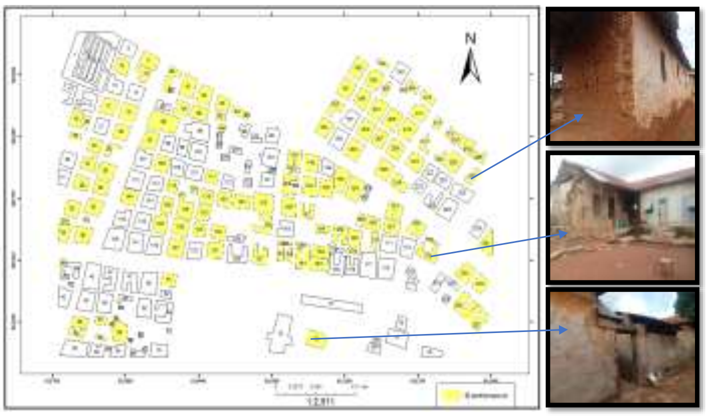

Fig. 7 Spatial distribution of buildings that requires maintenance within the study area

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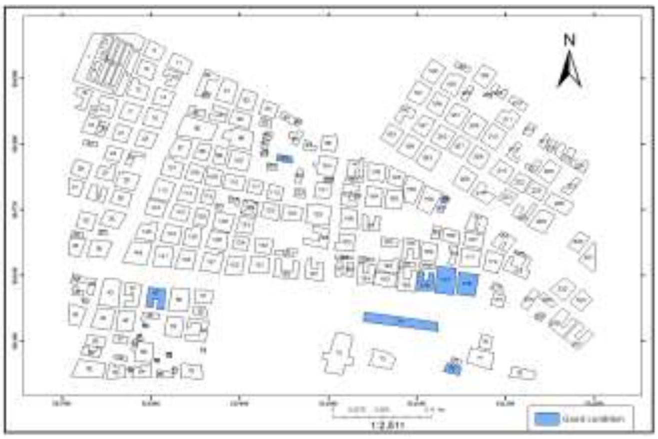

Fig. 8 Spatial distribution of buildings in a good condition within the study area

4. DISCUSSION

The digitization and categorization of 243 buildings in the study area provide compelling insights into the temporal and functional dynamics of the urban landscape of Dormaa Ahenkro. The data, showcased in Fig. 3, delineates 220 old buildings and 23 new buildings, forming the basis for an in-depth exploration of the architectural history of the town. The temporal distribution, depicted in Figure 4 and summarized in Table 2, reveals a fascinating chronicle of construction spanning from 1820 to 2023. The mapped clusters underscore distinct periods of urban development, reflecting both historical and contemporary trends.

Notably, the categorization of buildings through a SQL query (Fig. 5) facilitated a nuanced understanding of their conditions and purposes. Of the 243 buildings, 209 were identified as old structures, signalling the prevalence of aged architecture within the study section in Dormaa Ahenkro. This finding raises concerns about the vulnerability of these buildings, particularly the 29 structures identified as new constructions. The age distribution, ranging from 1820 to 2023, allows for a comprehensive assessment of the architectural evolution of the city, shedding light on the different epochs that shaped Dormaa Ahenkro. The identified clusters, as shown in Fig. 4, are not only indicative of temporal patterns but also offer insights into the diverse functions served by these structures. The dual-purpose nature of some buildings-serving as both commercial and residential-reflects the adaptability of urban spaces to meet the varied needs of the community. Understanding this functional diversity is crucial for effective urban planning and disaster preparedness, as buildings with mixed-use may require distinct considerations. The findings of the SQL query regarding building conditions (Fig. 5) reveal a pressing need for attention to the aging structures in the study section within Dormaa Ahenkro. With 133 buildings requiring maintenance and 8 deemed to be in good condition (Fig. 8), it becomes evident that a significant portion of the architectural heritage of the city demands careful scrutiny and potential interventions. The identification of the oldest building, aged 193 years, underscores the historical significance of Dormaa Ahenkro and the importance of preserving its heritage. This comprehensive analysis enriches our understanding of the urban morphology of Dormaa Ahenkro, unravelling the threads of its architectural history and offering valuable insights for sustainable urban development. The identification of old and new structures, coupled with their functional diversity and condition

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assessments, serves as a foundation for strategic urban planning, emphasizing the imperative of balancing preservation with modernization to ensure a resilient and sustainable future for Dormaa Ahenkro.

5. CONCLUSIONS

In conclusion, the detailed examination of 243 buildings in Dormaa Ahenkro has provided a comprehensive understanding of the architectural landscape of the town, emphasizing the historical, temporal, and functional dimensions of its urban development. The mapping and categorization of buildings, distinguishing between 220 old and 23 new structures, unveil the evolving narrative of the town across different epochs. The temporal distribution, ranging from 1820 to 2023, encapsulates the rich architectural heritage of Dormaa Ahenkro, with clusters reflecting distinct periods of construction. The SQL query-driven categorization using GIS has shed light on the condition and purposes of these structures. The identification of 209 old buildings, the oldest being 193 years, underscores the historical depth of Dormaa Ahenkro. The existence of 29 new buildings signals contemporary urban growth, prompting considerations for sustainable development and preservation. The mapped clusters not only reveal temporal patterns but also showcase the diverse functions of these structures, with some serving as both commercial and residential spaces. This dual-purpose nature reflects the adaptability of the urban fabric of Dormaa Ahenkro to meet the multifaceted needs of its community. However, the findings from the SQL query regarding building conditions present a pressing concern. With 133 buildings requiring maintenance, and only 8 identified as being in good condition, there is a critical need for strategic interventions to address the aging structures in Dormaa Ahenkro. Preservation efforts must be carefully balanced with modernization initiatives to ensure a resilient and sustainable future for the city. In essence, this study not only contributes to the local understanding of the architectural heritage of Dormaa Ahenkro but also provides a foundation for informed decision-making in urban planning and disaster preparedness. The rich history of the city, embodied in its buildings, serves as a testament to the dynamic interplay between tradition and progress. Moving forward, strategic efforts must be undertaken to preserve this heritage, foster sustainable growth, and fortify the resilience of Dormaa Ahenkro in the face of evolving urban challenges.

Recommendations

1. The town should iimplement targeted preservation initiatives for the identified 209 old buildings, ensuring the conservation of the historical architectural legacy of Dormaa Ahenkro.
2. The town should iintegrate urban planning strategies that balance the preservation of heritage clusters with the contemporary development needs of the city, fostering a harmonious coexistence.
3. The town should establish a routine maintenance program for the 133 buildings identified as requiring attention, addressing structural vulnerabilities and mitigating potential risks.
4. The town should enact building regulations and guidelines that consider the dual-purpose nature of structures, promoting resilient designs that cater to both commercial and

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residential needs.

5. The town should facilitate community engagement initiatives to raise awareness about the historical significance of the architecture and garner support of Dormaa Ahenkro for sustainable urban development practices.

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