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Towards a Future Metropolitan Planning Framework for Sabha and its Surrounding Settlements in Southern Libya

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نحو اطار تخطيط حضري مستقبلي لمدينة سبها وضواحيها في جنوب ليبيا

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Abstract:

Rapid urbanization, fragmented spatial development, and mounting environmental pressures have created significant planning challenges for Sabha, the largest urban center in southern Libya. Despite its strategic geographical location as a gateway connecting Libya with the Sahel and Sub-Saharan Africa, Sabha continues to experience uncontrolled urban expansion, fragmented infrastructure development, institutional limitations, and the progressive loss of productive agricultural land. These challenges highlight the urgent need for a metropolitan planning approach capable of coordinating future urban growth beyond existing municipal boundaries.

This study develops a Future Metropolitan Planning Framework for Sabha City and its surrounding settlements based on integrated spatial analysis and contemporary principles of sustainable metropolitan development. The research adopts an exploratory mixed-methods approach that combines a comprehensive review of planning literature, demographic analysis, Geographic Information Systems (GIS)-based spatial assessment, field observations, and the evaluation of historical urban growth patterns. The metropolitan study area comprises Sabha together with the surrounding settlements of Samno, Ghadwa, Al-Zieghan, and Tamanhint, which collectively function as an emerging metropolitan system characterized by increasing socio-economic and spatial integration.

The spatial analysis demonstrates that the existing pattern of dispersed urban expansion has become economically inefficient, environmentally unsustainable, and increasingly difficult to manage within current institutional arrangements. The findings further reveal the emergence of a functional metropolitan structure requiring integrated governance, coordinated infrastructure investment, protection of agricultural land and groundwater resources, and a transition toward a compact polycentric urban development model.

Based on these findings, the study proposes a strategic Future Metropolitan Planning Framework founded on six complementary planning pillars:

1. Polycentric metropolitan spatial development.
2. Metropolitan urban growth management.
3. Integrated transportation and infrastructure systems.

4. Sustainable environmental and natural resource management
5. Economic diversification and regional competitiveness.
6. Metropolitan governance supported by GIS-based decision-making.

The proposed framework provides a scientific and practical foundation for preparing a future Metropolitan Master Plan for Sabha while offering a transferable planning model applicable to rapidly growing cities in arid regions, particularly in southern Libya. The study contributes to advancing metropolitan planning practice by integrating spatial analysis, strategic urban planning, and sustainable regional development within a unified planning framework.

Keywords: Urban and Planning, Polycentric Development, Geographic Information Systems GIS, Sustainable Urban Development, Sabha Metropolitan, Southern Libya, Sabha Metropolitan Area

الملخص

تُعد هذه الورقة بمثابة مقدمة تمهيدية ومصدر لمؤشرات أولية لإطار التخطيط العمراني لمدينة سبها وضواحيها إذ تقدّم إطاراً عاماً يمهّد الطريق لإعداد دراسة شاملة ومفصلة تستند إلى منهجية تخطيطية دقيقة وعلمية لتوجيه التخطيط العمراني المستقبلي للمدينة وضواحيها. تقدم هذه الورقة رؤية مستقبلية شاملة للتخطيط العمراني لمدينة سبها وبلديات ضواحيها في جنوب غرب ليبيا وذلك استناداً إلى دراسة تفصيلية للتخطيط الحضري وتوقعات النمو السكاني وتحليل أنماط التطور العمراني التاريخي التي امتدت عبر ثلاثة أجيال تخطيطية كما نهدف بهذه الورقة إلى وضع إطار أولي للرؤية المستقبلية للحضارة التخطيطية لمدينة سبها وضواحيها في ظل التحديات التي تواجهها المدينة من زحف عمراني عشوائي على الأراضي الزراعية وضعف في البنية التحتية. وتقترح الدراسة اعتماد نموذج "متعدد المراكز" من خلال تحديد حدود عمرانية جديدة للحضارة التخطيطية وإنشاء خمس مجاورات سكنية جديدة مخططة بما يحقق التوازن بين النمو العمراني وحماية البيئة وتعزيز التنمية الاقتصادية والاجتماعية المستدامة في جنوب ليبيا. كما يسعى الإطار المقترح إلى تأهيل الحاضرة لتكون بوابة عبور نحو أفريقيا مستقبلاً عبر ربط المنطقة الحرة سرت والمنطقة الحرة مصراتة بالمنطقة الحرة تمنهنت سبها ثم امتدادها إلى العمق الأفريقي عبر الطريق الدولي sss-3 الجاري تنفيذه مع التوصية بإنشاء واستكمال مشروع السكة الحديدية.

كما تستعرض الورقة الأوضاع الديموغرافية والمكانية والاقتصادية والبيئية للمنطقة الحضرية وتحدد المعوقات الهيكلية التي تحول دون تحقيق نمو متوازن وتطرح رؤية مستقبلية ترتكز على مبادئ النمو المدمج وتعدد المراكز ومرونة البنية التحتية والتنويع الاقتصادي. كما تهدف الورقة في مجملها إلى أن تكون دراسة تأسيسية ومجموعة من المؤشرات الأولية وركيزة منهجية تمهّد لإعداد خطة حضرية شاملة تستند إلى بيانات المسح الميداني والتحليل الجغرافي المكاني ومشاورات الجهات ذات العلاقة وأصحاب المصلحة.

الكلمات المفتاحية: التخطيط الحضري، تخطيط المناطق الحضرية الكبرى، التنمية متعددة المراكز، نظم المعلومات الجغرافية (GIS)، التنمية الحضرية المستدامة، منطقة سبها الحضرية الكبرى، جنوب ليبيا.

1- Introduction.

Urbanization has become one of the defining global challenges of the twenty-first century, placing increasing pressure on cities to accommodate population growth while maintaining environmental sustainability, economic competitiveness, and social equity [13] Consequently, contemporary urban planning has evolved beyond traditional land-use regulation towards integrated metropolitan planning approaches that coordinate spatial development, infrastructure provision, environmental management, and economic transformation within functional urban regions [12].

In Libya rapid urban expansion during recent decades has generated significant planning challenges, particularly in major regional centers where demographic growth has outpaced infrastructure development and institutional planning capacity [1]. The combined effects of political instability, fragmented governance, informal urban expansion, and limited investment have further weakened the effectiveness of conventional urban planning approaches, increasing the need for more adaptive and evidence-based planning strategies [15].

Sabha, the largest city in southern Libya and the administrative center of the Fezzan Region, occupies a strategically important geographical position linking the Mediterranean coast with the Sahara and Sub-Saharan Africa (National Authority for Urban Planning, 2000.[11] Together with the surrounding settlements of Samno, Ghadwa, Al-Zieghan, and Tamanhint, Sabha increasingly functions as an integrated metropolitan area characterized by strong economic, social, and transportation linkages. Despite this functional integration, urban planning continues to be undertaken largely within separate administrative boundaries, limiting opportunities for coordinated regional development.

The metropolitan area has experienced rapid urban expansion during the past decades, accompanied by dispersed residential development, encroachment on productive agricultural land, increasing infrastructure costs, pressure on groundwater resources, and unequal distribution of public services [1],[2]. These challenges indicate

that the existing planning framework is no longer capable of supporting sustainable metropolitan growth and requires a comprehensive strategic reassessment [14]

Although previous studies have examined aspects of urban development, informal settlements, and environmental conditions in Sabha (Aljad, 2018; Journal of Insights in Basic and Applied Sciences, 2023), relatively limited attention has been given to metropolitan-scale planning that integrates spatial analysis, demographic dynamics, regional connectivity, and future development scenarios within a unified planning framework. This gap represents an important opportunity for developing a strategic metropolitan vision capable of guiding long-term urban development in southern Libya.

Accordingly, this study aims to develop a Future Metropolitan Planning Framework for Sabha City and its surrounding settlements through the integration of demographic analysis, spatial assessment, Geographic Information Systems (GIS), and urban planning principles. The study evaluates the existing metropolitan structure, identifies the principal spatial and institutional challenges affecting future development, and proposes a strategic framework based on polycentric development, integrated infrastructure, environmental sustainability, and economic diversification.

The principal contribution of this research lies in proposing one of the first integrated metropolitan planning frameworks specifically designed for Sabha and its surrounding settlements. Rather than presenting a conventional master plan, the study establishes a strategic planning framework intended to support future decision-making, infrastructure investment, land-use management, and sustainable regional development. It is envisaged as a foundational study that provides both a conceptual model and a practical basis for preparing a future comprehensive metropolitan development plan for the Sabha Metropolitan Area.

2. Study Area.

2.1 Geographic Location and Regional Context

The study area comprises Sabha City and its surrounding settlements (Samno, Ghadwa, Al-Zieghan, and Tamanhint), which collectively constitute the emerging Sabha Metropolitan Area in the Fezzan Region of southern Libya. Sabha is the largest urban center in southern Libya and serves as the administrative, economic, and transportation hub of the Fezzan Planning Region. The city is strategically located at approximately 27° 02′ 14″ N and 14° 24′ 59″ E and about 640 km south of Tripoli at the intersection of major north–south and east–west transport corridors linking the Mediterranean coast with the Sahel and Sub-Saharan Africa [11],[1]

Historically, Sabha has functioned as the principal gateway to the Libyan Sahara and an important center for regional administration, commerce, and trans-Saharan trade. This strategic location continues to provide significant opportunities for future metropolitan development through regional logistics, cross-border trade, agricultural production, and renewable energy investment, particularly in light of the proposed international transport corridors connecting Libya with neighboring African countries.

(N 27º 2' 14" - E 14º 24' 59")

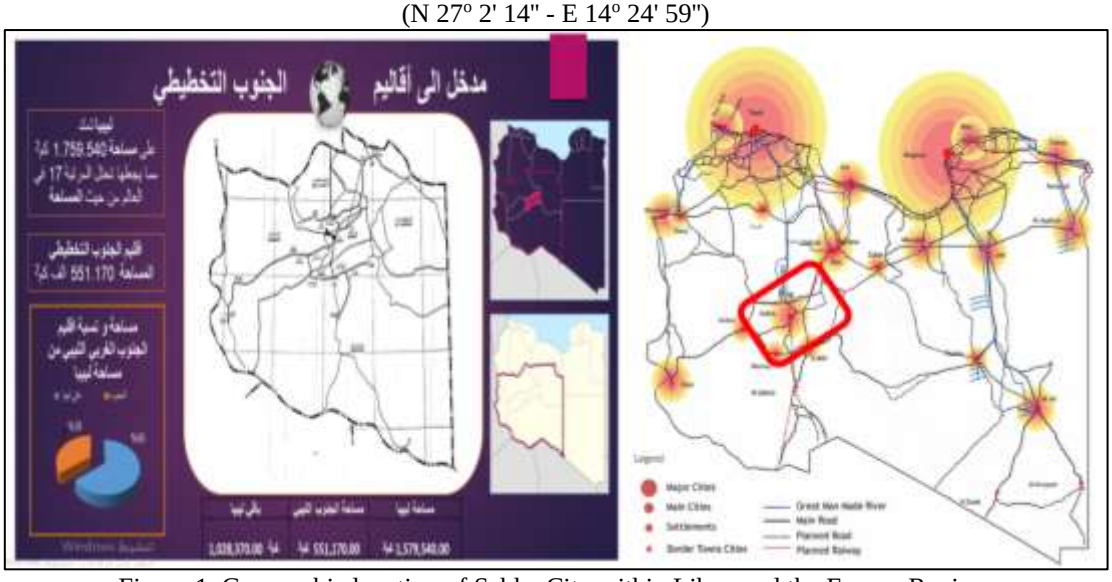


Figure 1. Geographic location of Sabha City within Libya and the Fezzan Region.

2.2 Administrative and Metropolitan Structure.

For national planning purposes Libya is divided into four principal planning regions:

Tripoli - Benghazi - Gulf (Khaleej) - Fezzan

With the latter encompassing the entire southern part of the country (NAUP, 2000). The Fezzan Planning Region is further subdivided into four planning sub-regions:

Sabha - Wadi Al-Shati - Wadi Al-Hayat (including Ubari and Ghat) - Murzuq.

Within this administrative framework the present study defines the Sabha Metropolitan Area as a functional urban region comprising Sabha City and the four surrounding settlements of Samno, Ghadwa, Al-Zieghan, and Tamanhint. Although these settlements belong to different municipal jurisdictions, they exhibit increasing functional integration through commuting patterns, service provision transportation networks, and socio-economic interactions. Consequently the metropolitan boundary adopted in this study reflects functional urban relationships rather than solely administrative limits consistent with contemporary metropolitan planning principles [14]

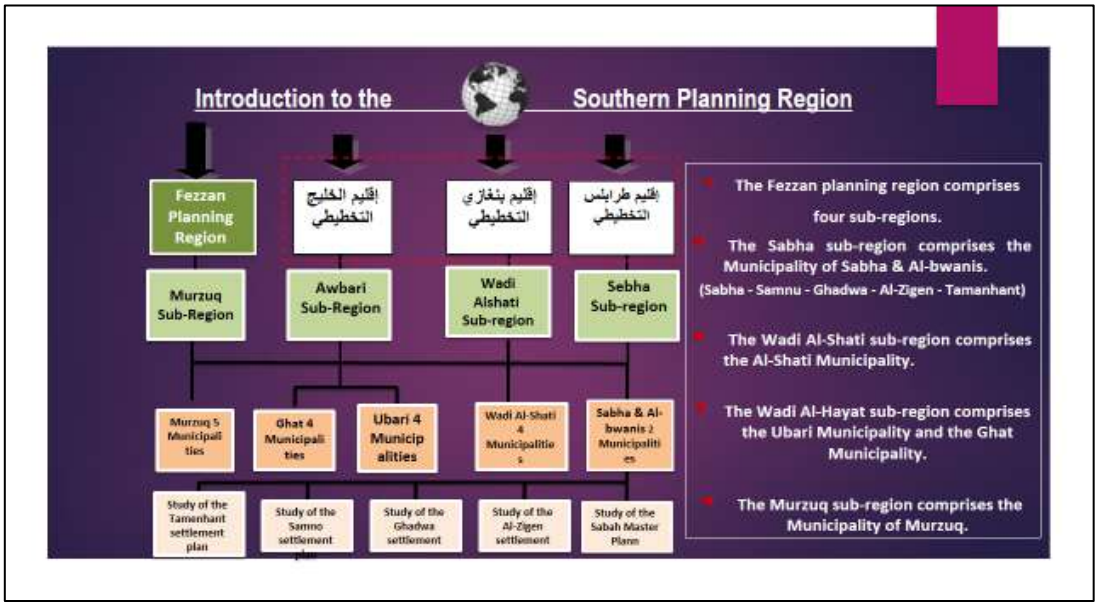


Figure 2. Administrative structure of the Southern (Fezzan) Planning Region and the proposed Sabha Metropolitan Area.

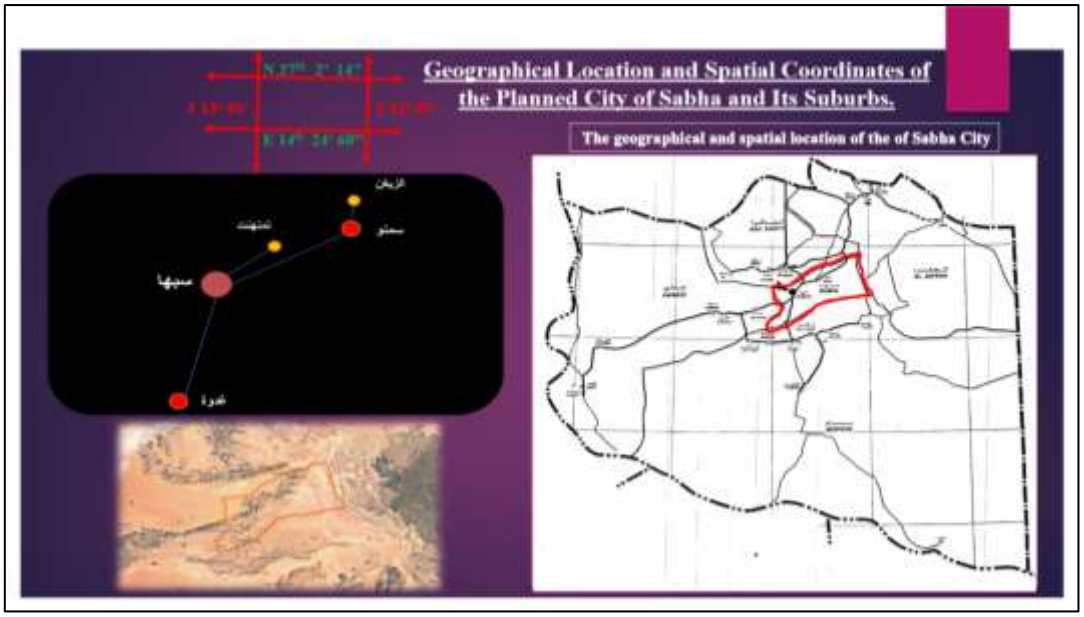
2.3- Demographic Characteristics

According to verified 2025 Civil Registry records issued by the Southern Civil Status Department of the Ministry of Interior Sabha has a registered population of 127.282 inhabitants comprising 69.241 females and 58.041 males making it the largest urban center in southern Libya. The wider Southern Planning Region records a total registered population of approximately 628.872 inhabitants.

The metropolitan study area includes four surrounding settlements that perform complementary residential, agricultural, and service functions. Samno represents the largest satellite settlement while Tamanhint has strategic significance due to its airport and designated free-zone area. Ghadwa and Al-Zieghan provide additional residential and service functions that contribute to the metropolitan urban system. The demographic distribution and settlement hierarchy indicate that Sabha already functions as the dominant metropolitan center for southern Libya despite the absence of an officially recognized metropolitan governance framework [11]

Table 1. Population, settlement classification, and distance from Sabha City.

Settlement	Classification	Population (2025)	Distance from Sabha
Sabha	Major city / sub-region canter	127,282	0 km
Samno	Residential cluster (above-local Centre)	88,653	60 km
Al-Zieghan	Residential cluster (above-local canter)	6,089	70 km
Ghadwa	Residential cluster (above-local Centre)	7,930	60 km
Tamanhint	Residential cluster (local canter)	5,672	30 km



Figures 3. Metropolitan boundary and distribution of the principal settlements within the study area.

2.4- Physical and Environmental Characteristics.

The Sabha urban area is characterized by a desert climate featuring high summer temperatures typical of the central Sahara and limited annual rainfall despite a recent increase in precipitation levels.

Groundwater extracted from deep aquifers constitutes the principal source of domestic and agricultural water supply, making sustainable water management a critical planning priority [1].

Agricultural activities are concentrated around oasis systems and irrigated lands surrounding Sabha and neighboring settlements. However, recent decades have witnessed increasing urban encroachment onto productive agricultural land, accompanied by declining groundwater reserves, infrastructure constraints, and expanding informal development. These environmental pressures have become major determinants of future spatial planning and require integrated land-use management strategies that balance urban expansion with environmental conservation [14].

Beyond its environmental characteristics, the metropolitan area possesses significant strategic assets, including fertile agricultural zones, substantial solar energy potential, mineral resources, Sabha International Airport, and proximity to the Tamanhint Free Zone. These resources provide a strong foundation for future metropolitan development based on economic diversification, regional connectivity, and sustainable urban growth.

3.Methodology.

This study adopts a mixed-methods exploratory research design that integrates qualitative planning analysis with quantitative spatial assessment to develop a future metropolitan planning framework for Sabha City and its surrounding settlements. The adopted methodology is designed as a strategic planning approach rather than a conventional master-planning exercise, enabling the integration of demographic, spatial, environmental, and institutional dimensions within a unified metropolitan perspective [4], [16].

The research methodology was implemented through five sequential stages, beginning with a comprehensive review of existing planning documents and ending with the formulation of a future metropolitan planning framework based on the analytical findings. The methodological workflow is illustrated in Figure 5.

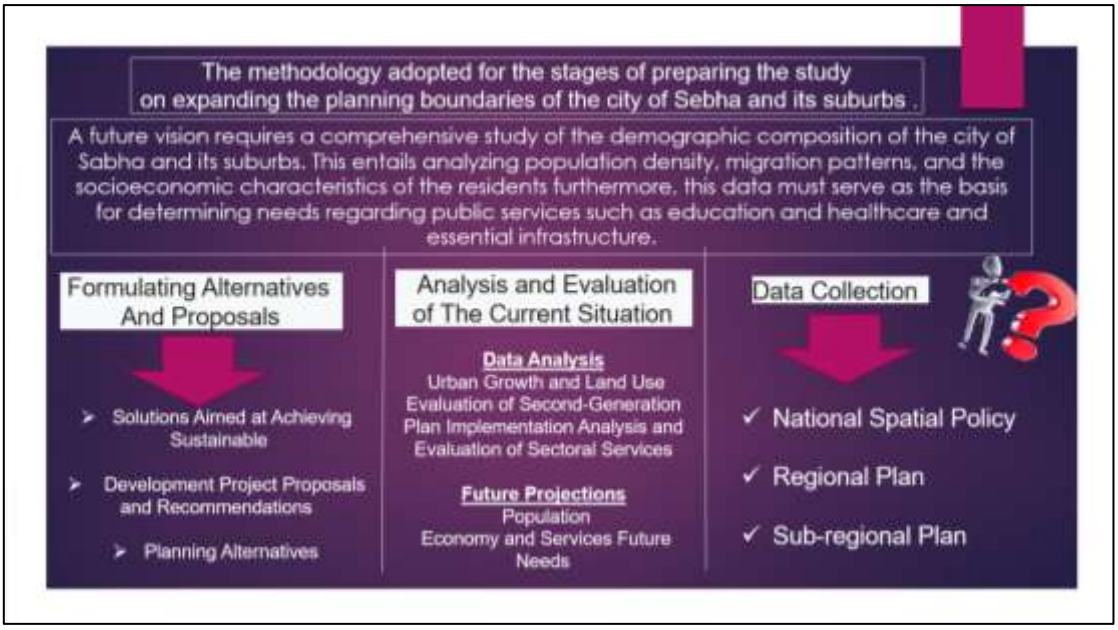


Figure 5. Research methodology adopted for developing the Future Metropolitan Planning Framework

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3.1- Literature Review and Data Collection.

The first stage involved an extensive review of available literature and planning documents to establish the theoretical and practical foundation of the study multiple sources of information were utilized, including:

1. National and regional spatial planning documents issued by the National Authority for Urban Planning (NAUP).
2. Previous academic studies addressing urban development in Sabha and the Fezzan Region.
3. Population statistics obtained from the Southern Civil Status Department (2025).
4. Satellite imagery and existing urban development maps.
5. Technical reports published by Libyan governmental institutions and international organizations.
6. The authors' previous published research concerning urban development and public–private partnerships in southern Libya [2].

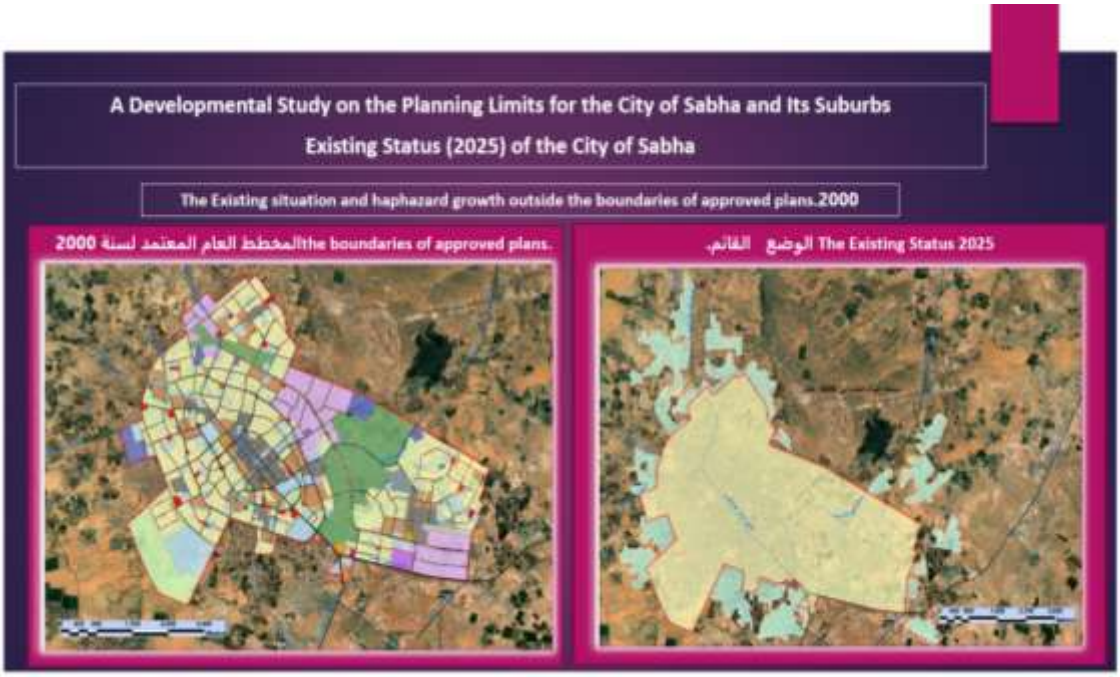
The literature review provided the conceptual basis for identifying the principal urban development challenges affecting Sabha while establishing the theoretical framework adopted throughout the study [14] , [12].

3.2- Spatial Analysis Using Geographic Information Systems (GIS).

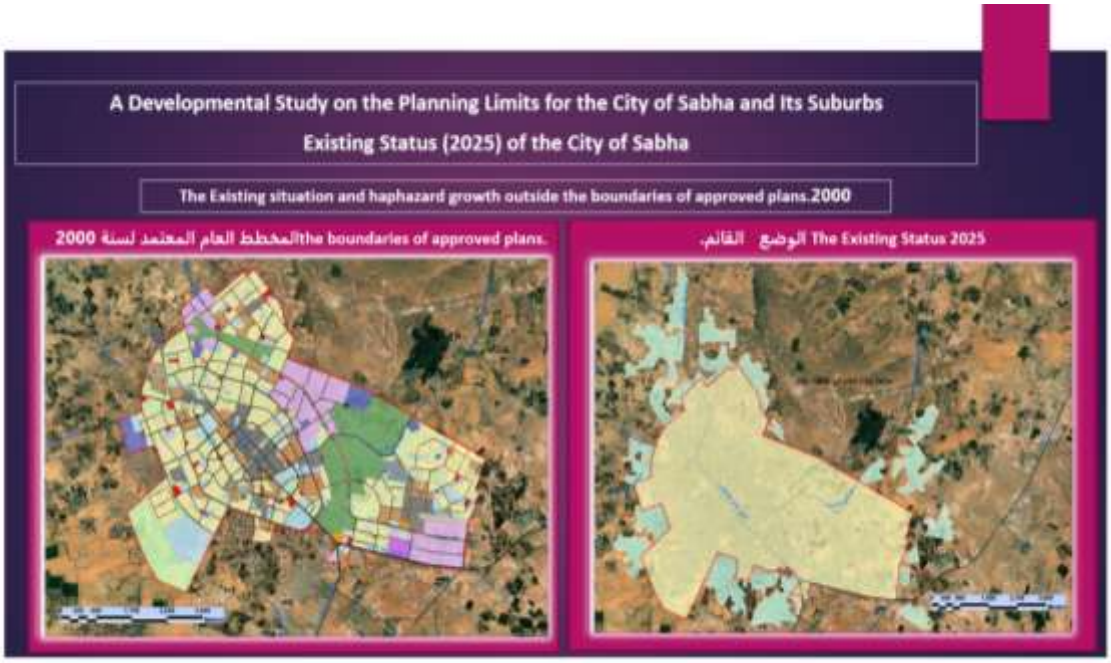
The second stage consisted of a comprehensive spatial analysis using ArcGIS Pro to evaluate the existing metropolitan structure and urban growth patterns. Geographic Information Systems (GIS) were employed to analyses:

A. Existing urban boundaries.
B. Historical urban expansion.
C. Residential land-use distribution.
D. Agricultural land.
E. Transportation corridors.
F. Major infrastructure.
G. Spatial relationships between Sabha and the surrounding settlements.

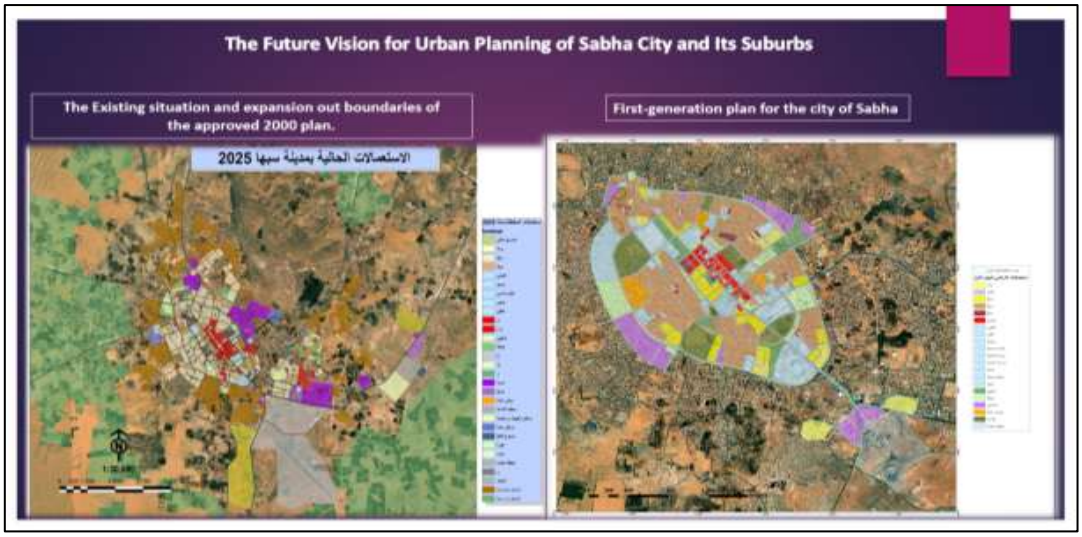
The spatial analysis enabled the identification of urban expansion beyond approved planning boundaries and provided the basis for evaluating future metropolitan growth scenarios [8]. Figures from 6 to figure 11 present the principal GIS outputs.



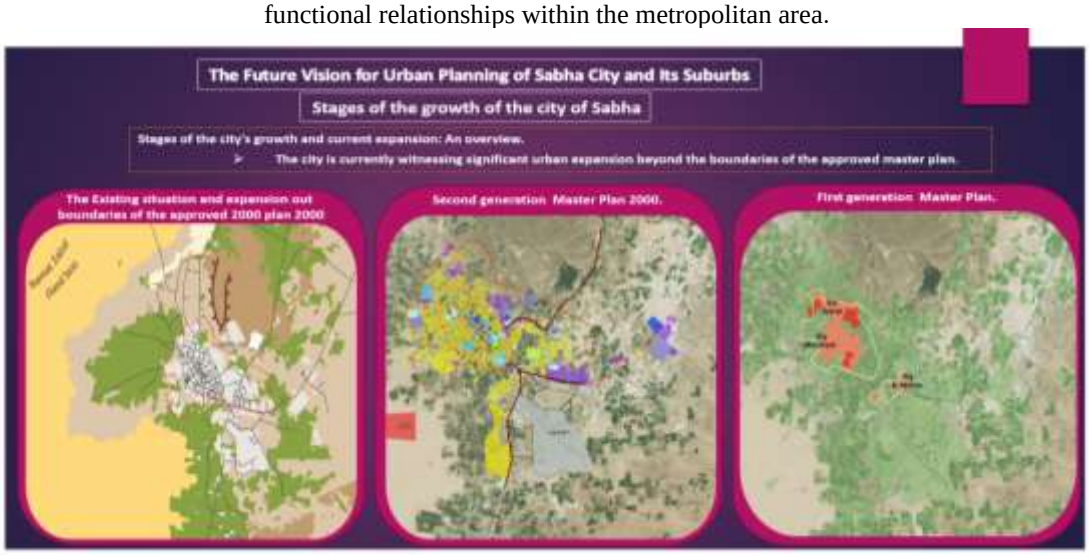
Figures 6 present the principal GIS outputs illustrating the existing urban structure, growth patterns and functional relationships within the metropolitan area.



Figures 7 present the principal GIS outputs illustrating the existing urban structure, growth patterns and functional relationships within the metropolitan area.



Figures 8 present the principal GIS outputs illustrating the existing urban structure, growth patterns and functional relationships within the metropolitan area.



Figures 9 present the principal GIS outputs illustrating the existing urban structure, growth patterns and functional relationships within the metropolitan area.

Figures 10 present the principal GIS outputs illustrating the existing urban structure, growth patterns and functional relationships within the metropolitan area

Figures 11 present the principal GIS outputs illustrating the existing urban structure, growth patterns and functional relationships within the metropolitan area

3.3- Urban Growth and Metropolitan Structure Assessment

The third stage involved analyzing the historical evolution of Sabha's urban form. Urban development was interpreted through four principal growth phases:

A. Traditional oasis settlement.
B. Oil-development expansion.
C. Rapid post-1980 urban growth.
D. Contemporary metropolitan expansion beyond approved planning boundaries.

Comparative interpretation of historical plans, satellite imagery, and recent urban expansion enabled the identification of the principal spatial challenges affecting future metropolitan development, including dispersed urban growth, informal settlements, agricultural land conversion, and infrastructure fragmentation [1].

3.4- Functional Analysis of the Metropolitan Area

Rather than examining each settlement independently, the study analyses Sabha and its surrounding settlements as components of a single functional metropolitan system.

Functional relationships were evaluated according to:

1. Population concentration.
2. Administrative functions.
3. Economic activities.
4. Transportation connectivity.
5. Infrastructure availability.
6. Strategic development potential.

This approach follows contemporary metropolitan planning principles, which define metropolitan regions according to functional integration rather than administrative boundaries [12].

3.5- Development of the Future Metropolitan Planning Framework

The final stage synthesized the findings derived from the literature review demographic analysis GIS-based spatial assessment and urban growth evaluation to formulate the proposed Future Metropolitan Planning Framework.

The proposed framework is structured around five complementary planning pillars:

1. Compact and polycentric urban development.
2. Integrated transportation and infrastructure systems.
3. Environmental sustainability and protection of agricultural land.
4. Economic diversification through logistics, agriculture, renewable energy, and regional trade.
5. Institutional coordination and metropolitan governance.

Rather than presenting a statutory master plan, the framework provides a strategic planning model intended to guide future land-use planning, infrastructure investment, and regional development in the Sabha Metropolitan Area. The framework also serves as a methodological foundation for preparing a future comprehensive

metropolitan development plan based on detailed field surveys, stakeholder consultation, and advanced geospatial analysis [14] , [15].

4.Results and discussion. Results and Spatial Analysis.

4.1- Regional Spatial Structure of the Sabha Metropolitan Area

The GIS-based spatial analysis confirms that Sabha has evolved into the dominant metropolitan center of southern Libya, functioning as the principal administrative, economic, and service hub of the Fezzan Region. The spatial distribution of urban settlements demonstrates a hierarchical metropolitan structure centered on Sabha and supported by four surrounding settlements—Samno, Ghadwa, Al-Zieghan, and Tamanhint—which collectively form an interconnected urban system rather than isolated municipalities. Although these settlements remain administratively independent, their increasing dependence on Sabha for employment, higher education, healthcare, commercial activities, and public administration indicates the emergence of a functional metropolitan region [9].

The GIS analysis further demonstrates that the existing metropolitan structure remains highly monocentric, with the majority of higher-order urban functions concentrated within Sabha City. This spatial concentration has generated increasing travel demand, infrastructure pressure, and unequal distribution of public services across the metropolitan area.

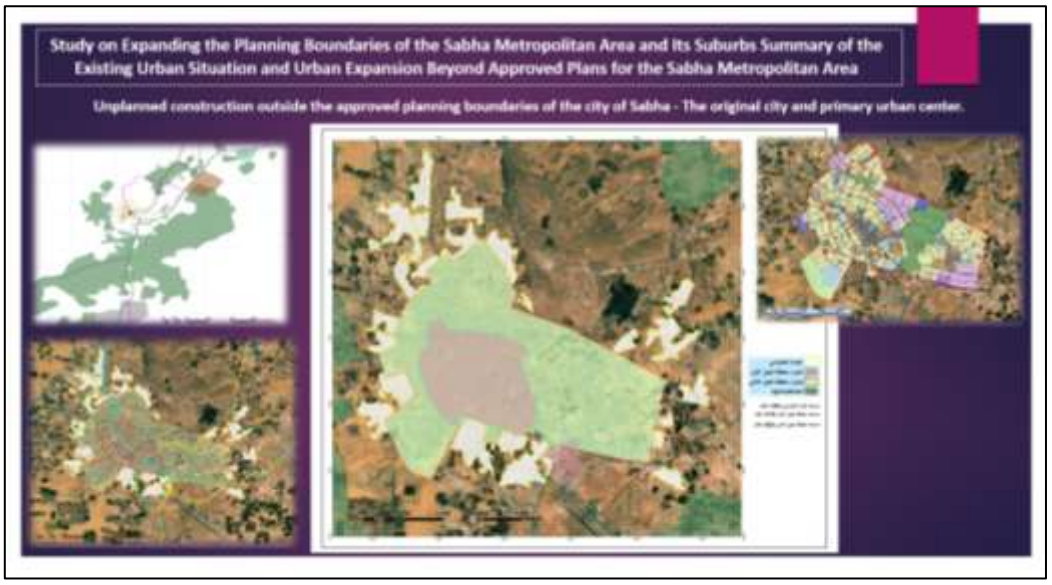
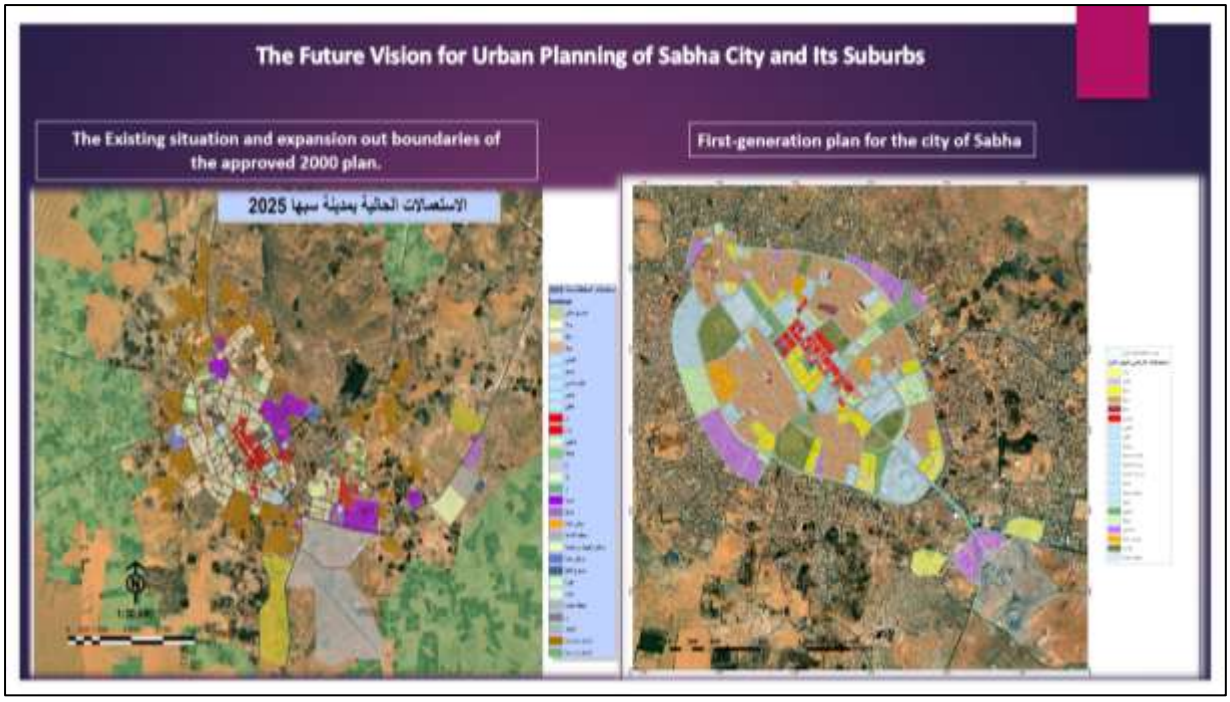


Figure 12. Existing Spatial Structure of the Sabha Metropolitan Area.

4.2- Urban Growth Pattern and Spatial Expansion.

Comparison of historical urban plans, recent satellite imagery, and GIS analysis reveals four successive stages of urban development that have shaped the present metropolitan form. The initial stage reflects the traditional oasis settlement, followed by planned expansion associated with Libya's oil development during the 1970s and 1980s. A third phase witnessed accelerated residential growth driven by internal migration and public-sector expansion, whereas the current phase is characterized by rapid metropolitan expansion extending beyond the boundaries of the approved master plan.

The GIS analysis clearly illustrates that recent urban growth has occurred predominantly along the northern, eastern, and western corridors, resulting in dispersed residential development and increasing fragmentation of the urban fabric the observed pattern represents a transition from compact urban growth toward dispersed peripheral expansion.



Figures 13. Historical Urban Growth Pattern of Sabha City.

4.3- Urban Expansion Beyond the Approved Planning Boundary.

Overlay analysis between the approved urban master plan and the current built-up area demonstrates substantial expansion beyond the officially planned urban limits. Large areas of recent residential development have occurred outside the statutory planning boundary, particularly in peri-urban agricultural zones.

This pattern has produced fragmented urban development characterized by discontinuous infrastructure networks inefficient land consumption, and increasing pressure on agricultural land and groundwater resources. The spatial mismatch between planned and actual urban growth further indicates that existing planning instruments have been unable to accommodate recent demographic and economic changes.

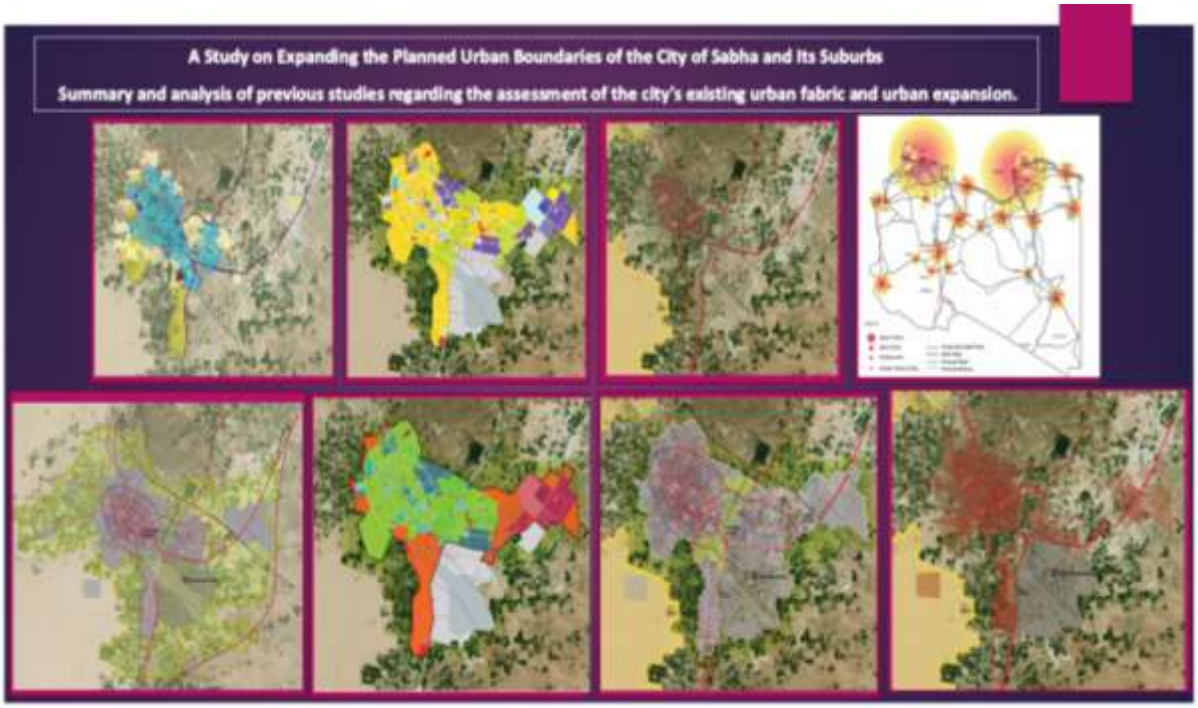


Figure 14. Urban Expansion the Approved Planning Boundary

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4.4- Functional Analysis of the Metropolitan Settlements.

The surrounding metropolitan settlements exhibit distinct but complementary urban functions.

Samno possesses the strongest agricultural base and has the potential to become the metropolitan agricultural production and agro-processing center.

Al-Zieghan occupies a strategic transport location that could support logistics and light industrial activities.

Ghadwa functions primarily as a residential and local administrative center, with opportunities for future residential expansion supported by improved transport connectivity.

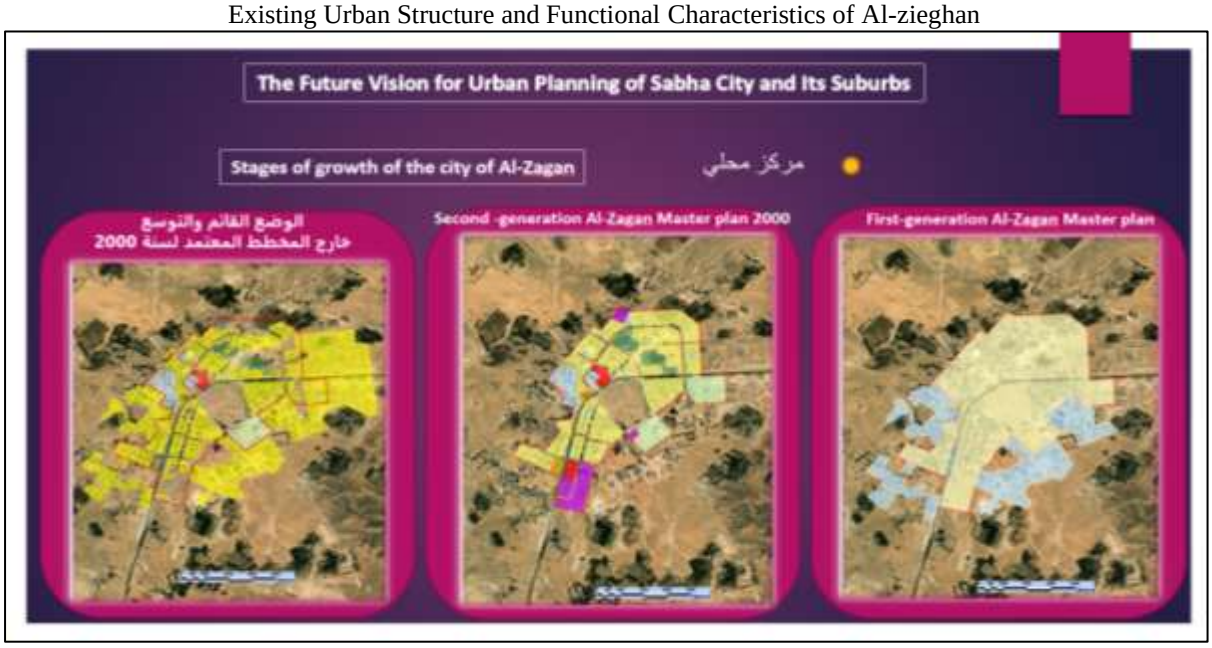
Tamanhint represents the metropolitan gateway due to the presence of Sabha International Airport, the proposed Free Zone, and planned renewable energy investments.

Rather than competing with Sabha these settlements demonstrate strong functional complementarity that supports future polycentric metropolitan development.

Existing Urban Structure and Functional Characteristics of Samno

Figures 15 Existing Urban Structure and Functional Characteristics of the Metropolitan Settlements.

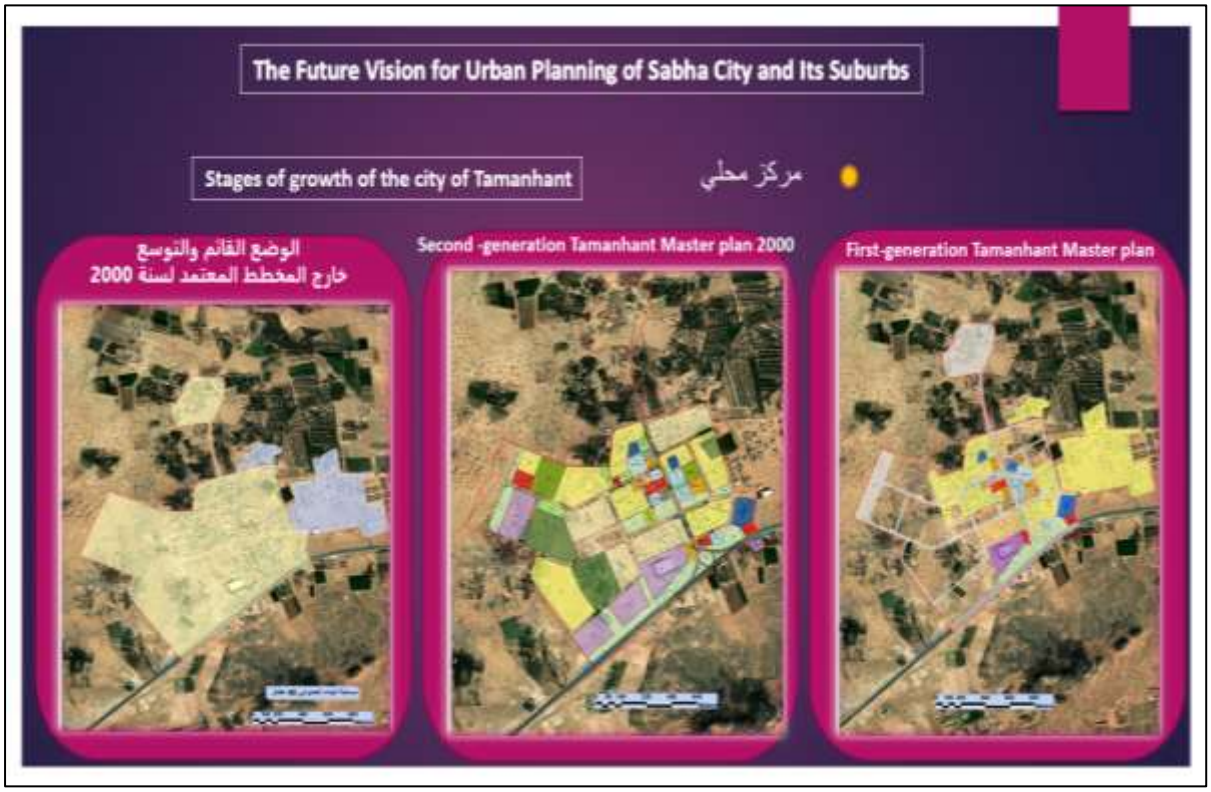
Existing Urban Structure and Functional Characteristics of Al-zieghan



Figures 16 Existing Urban Structure and Functional Characteristics of the Metropolitan Settlements

Existing Urban Structure and Functional Characteristics (Ghadwa)

Figures 17 Existing Urban Structure and Functional Characteristics of the Metropolitan Settlements
Existing Urban Structure and Functional Characteristics (Tamanhint)



Figures 18 Existing Urban Structure and Functional Characteristics of the Metropolitan Settlements

Figures 19. Existing Urban Structure and Functional Characteristics of the Metropolitan Settlements.

Figures 20 Existing Urban Structure and Functional Characteristics of the Metropolitan Settlements

4.5- Demographic Structure and Metropolitan Hierarchy.

Analysis of the verified 2025 Civil Registry database confirms that Sabha remains the largest urban center in southern Libya, with a registered population of 127,282 inhabitants. Together with Samno, Ghadwa, Al-Zieghan, and Tamanhint, the metropolitan area forms a settlement hierarchy characterised by a dominant urban core supported by secondary residential centers.

Population distribution indicates a high degree of demographic concentration within Sabha while simultaneously revealing increasing residential growth in surrounding settlements. This demographic pattern reinforces the need to adopt a metropolitan planning framework capable of distributing future population growth more efficiently among multiple urban centers.

Table 2. Population Characteristics and Metropolitan Hierarchy [10].In-text citations: (Ministry of Interior, Southern Civil Status Department, 2025).

Settlement	Classification	Population (2025)	Distance from Sabha
Sabha	Major city / sub-region canter	127,282	0 km
Samno	Residential cluster (above-local Centre)	88,653	60 km
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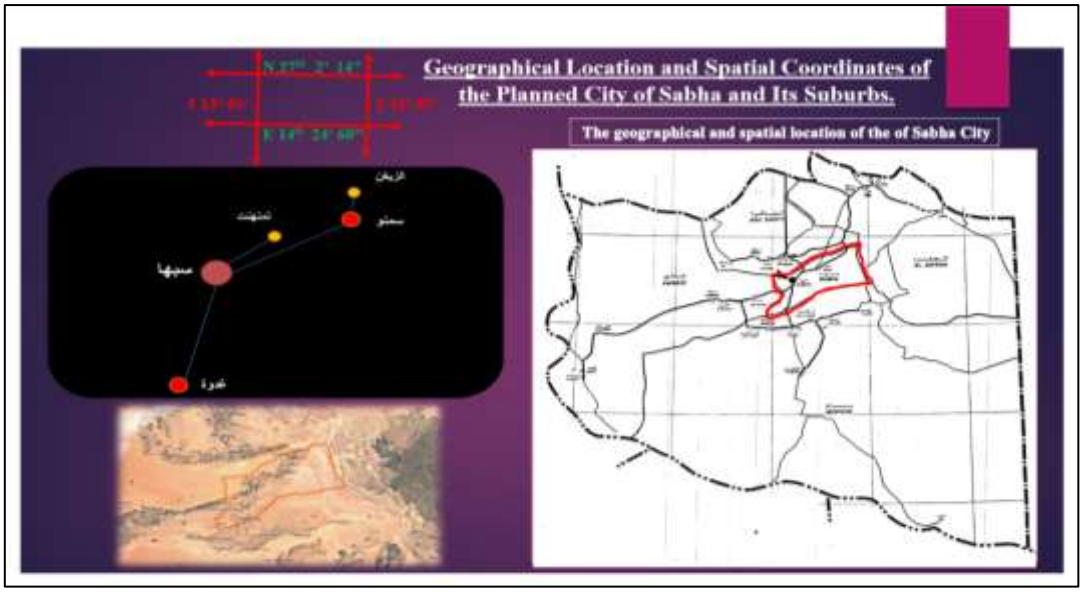
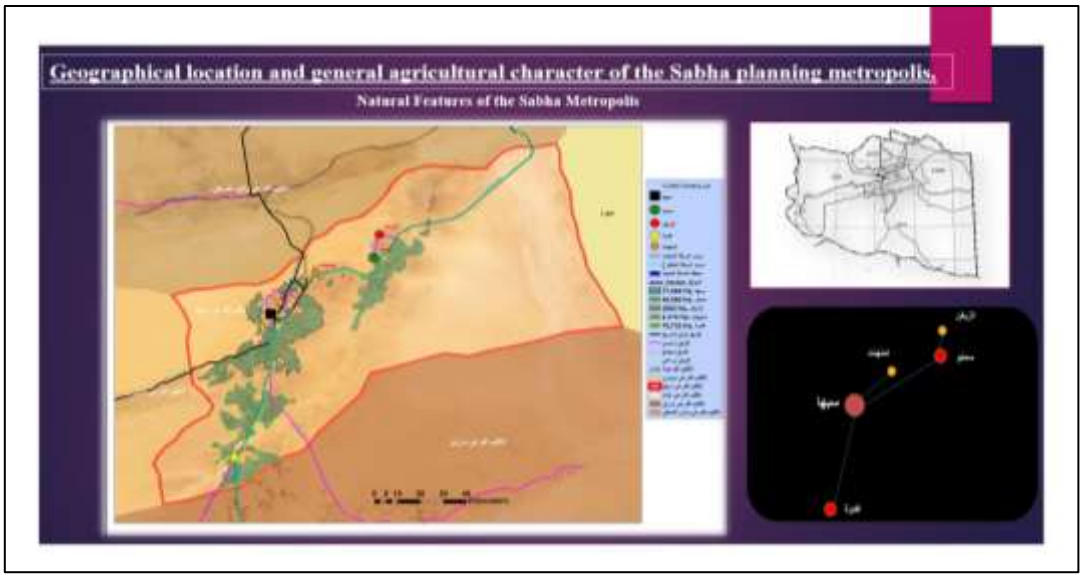
Ghadwa	Residential cluster (above-local Centre)	7,930	60 km
Tamanhint	Residential cluster (local canter)	5,672	30 km



Figures 17 Metropolitan boundary and distribution of the principal settlements within the study area.



Figures 18 Metropolitan boundary and distribution of the principal settlements within the study area.

4.6- Strategic Development Opportunities.

Spatial analysis identifies several strategic assets capable of supporting future metropolitan development. These include the city's geographical position along the Trans-Saharan transport corridor, Sabha International Airport, the proposed Tamanhint Free Zone, irrigated agricultural areas, extensive solar energy resources, and proximity to regional African markets.

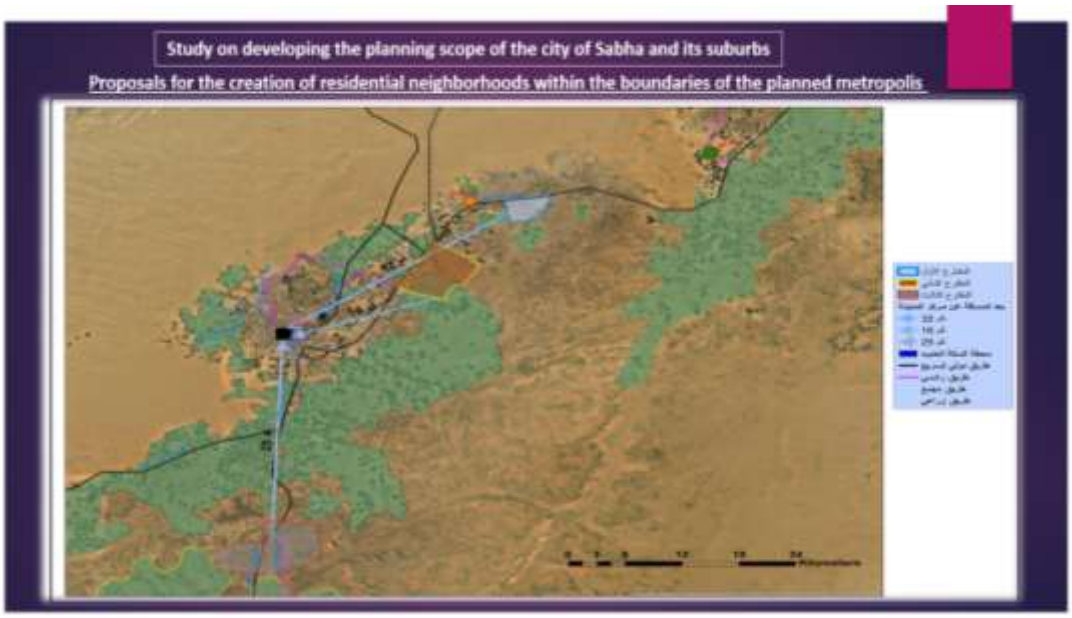
Collectively these assets provide a strong foundation for transforming Sabha from a predominantly administrative center into a diversified metropolitan growth pole serving southern Libya and neighboring Sahel countries.

4.7- Future Metropolitan Planning Framework

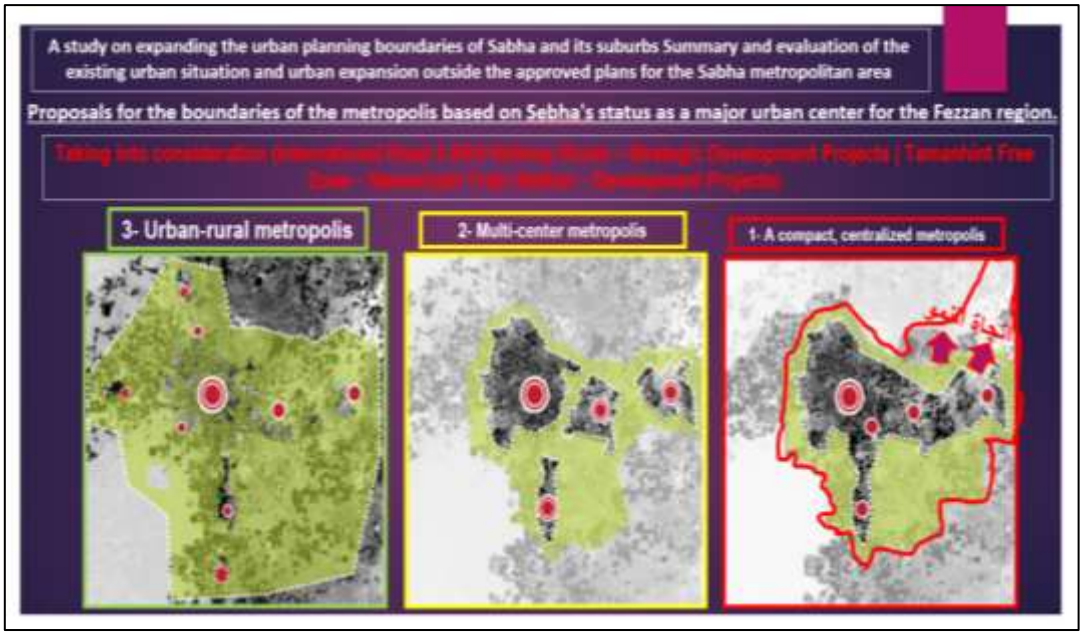
The spatial analysis and findings of this study indicate that the future development of Sabha should move beyond the traditional master planning approach towards a comprehensive Metropolitan Planning Framework that recognizes the functional integration of Sabha City with its surrounding settlements. Rather than considering Samno, Ghadwa, Al-Zieghan, and Tamanhint as separate administrative entities, the proposed framework treats them as complementary components of a single metropolitan system connected through transportation, economic activities, public services, and environmental resources [12].

The proposed framework adopts the principles of polycentric metropolitan development whereby future urban growth is distributed among multiple urban centers instead of concentrating development within the existing urban core of Sabha. Such an approach is expected to reduce development pressure on the city center, improve accessibility to public services, promote balanced regional growth, and enhance the efficiency of infrastructure investment [5].

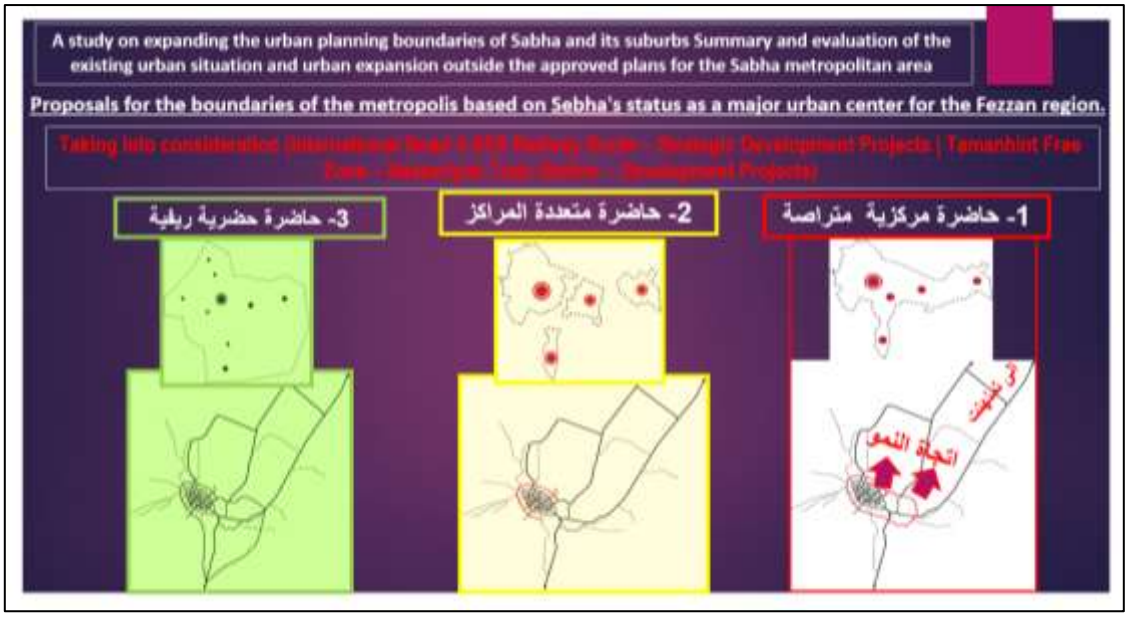
Based on the GIS spatial analysis, the proposed metropolitan framework



Figures 19 Based on the GIS spatial analysis, the proposed metropolitan framework
Development within the existing urban core of Sabha



Figures 20 Urban growth is distributed among multiple urban centers instead of concentrating
Development within the existing urban core of Sabha



Figures 21 Urban growth is distributed among multiple urban centers instead of concentrating

5- Discussion

The findings of this study demonstrate that the future development of the Sabha Metropolitan Area can no longer be effectively managed through conventional municipal planning based solely on administrative boundaries. The GIS-based spatial analysis confirms that urban expansion has already extended well beyond the jurisdiction of Sabha Municipality, resulting in the emergence of a functionally interconnected metropolitan system comprising Sabha Samno Ghadwa Al-Zieghan and Tamanhint. This observation is consistent with contemporary metropolitan planning theory, which emphasizes that metropolitan regions should be planned according to functional urban relationships rather than fragmented administrative jurisdictions [14].

One of the most significant findings concerns the spatial pattern of urban growth. Historical analysis combined with GIS assessment reveals a gradual transition from compact oasis-based urban development toward dispersed metropolitan expansion occurring primarily along major transportation corridors. Similar patterns have been documented in rapidly urbanizing cities located in arid and semi-arid regions, where uncontrolled peripheral growth increases infrastructure costs, reduces land-use efficiency, fragments urban form, and weakens long-term planning capacity [7]. In Sabha, this dispersed pattern has resulted in increasing pressure on infrastructure networks, inefficient service provision and the irreversible conversion of productive agricultural land into low-density residential development.

The study further highlights the growing functional integration between Sabha and its surrounding settlements. Although each settlement remains administratively independent, increasing daily commuting, economic interaction, public service dependency educational linkages, and transportation connectivity collectively demonstrate the emergence of a metropolitan urban system. Such findings support international experience showing that metropolitan competitiveness depends increasingly upon regional coordination rather than isolated municipal development. Consequently, future planning policies should strengthen institutional cooperation, integrated infrastructure investment, and coordinated land-use planning across the entire metropolitan region instead of maintaining fragmented local planning approaches.

The functional assessment also demonstrates that the surrounding settlements possess distinct comparative advantages capable of supporting a polycentric metropolitan development model. Rather than concentrating future investment exclusively within Sabha City the analysis suggests a more balanced distribution of metropolitan functions. Samno possesses considerable potential for agricultural production and agro-industrial development due to its extensive irrigated lands. Tamanhint offers exceptional opportunities for logistics, aviation services, renewable energy investment, and free-zone development owing to the presence of Sabha International Airport and the proposed Free Zone. Al-Zieghan occupies an advantageous position for regional logistics and transportation services, while Ghadwa provides suitable land for carefully planned residential expansion supported by improved infrastructure. This complementary functional specialization is consistent with the European Spatial Development Perspective [5] which advocates balanced regional development through networks of mutually supporting urban centers.

Environmental sustainability emerges as another central theme throughout the analysis. Continued outward urban expansion threatens oasis agriculture, accelerates groundwater depletion, and increases environmental degradation in one of the most water-scarce regions of North Africa. Because groundwater extracted from deep fossil aquifers constitutes the principal source of domestic and agricultural water supply, future metropolitan

development must prioritize integrated water-resource management, protection of agricultural land, wastewater reuse, renewable energy, and climate-resilient infrastructure. These priorities are increasingly recognized as fundamental principles for sustainable urban development in arid environments [6],[14].

Another important implication concerns metropolitan governance. The study demonstrates that many of the existing planning challenges including infrastructure fragmentation inefficient public investment land-use conflicts and service disparities are institutional rather than purely physical. The absence of an integrated metropolitan governance structure limits coordination among municipalities and national planning agencies, reducing the effectiveness of long-term urban development policies. International experience indicates that metropolitan planning institutions significantly improve policy coordination, infrastructure delivery and regional economic competitiveness by facilitating integrated decision-making across municipal boundaries.

From a strategic planning perspective the proposed Future Metropolitan Planning Framework represents an evolution from traditional master planning toward a more flexible, evidence-based, and regionally integrated planning model. Instead of prescribing rigid land-use allocations, the framework establishes strategic planning principles capable of guiding future investment decisions, infrastructure development, environmental management and regional economic diversification while remaining adaptable to changing demographic and economic conditions.

The study also highlights Sabha's strategic geopolitical position as the principal gateway linking Libya with the Sahel and Sub-Saharan Africa. If effectively integrated with the proposed Tamanhint Free Zone Sabha International Airport, the Trans - Saharan Highway and the proposed national railway network, the metropolitan area could become a major regional logistics hub supporting trade, investment, and economic cooperation between North Africa and the African continent. Such a transformation would significantly enhance the strategic importance of southern Libya within national and continental development initiatives.

Despite these contributions, several limitations should be acknowledged. The proposed framework is intentionally strategic rather than regulatory and therefore does not include detailed land-use zoning, transportation demand modelling, engineering design standards, or economic feasibility assessments. Furthermore, the analysis relies primarily on available demographic records, planning documents GIS datasets, and field observations. Future research should therefore incorporate high-resolution remote sensing, comprehensive household surveys, climate resilience assessments transport simulation models, land suitability analysis economic cost-benefit evaluation, and participatory planning involving local communities and institutional stakeholders. These complementary studies will provide the empirical foundation necessary for preparing a legally binding Metropolitan Master Plan for the Sabha Metropolitan Area.

Overall the findings demonstrate that the principal challenge facing Sabha is not merely accommodating future urban growth but establishing an integrated metropolitan planning system capable of coordinating spatial development, infrastructure investment, environmental protection economic diversification and institutional governance within a single strategic framework.

The proposed metropolitan planning approach therefore represents a practical pathway toward achieving sustainable urban development and balanced regional growth throughout southern Libya while providing a transferable planning model applicable to other rapidly expanding cities in arid regions for and by:

A. Strengthen regional connectivity.
B. Protect environmental resources.
C. Improve infrastructure efficiency.
D. Diversify the regional economy.
E. Enhance institutional coordination.
F. Increase resilience to future demographic and environmental change.

Consequently the proposed Future Metropolitan Planning Framework provides a comprehensive strategic foundation for preparing a future Metropolitan Master Plan for Sabha and its surrounding settlements. More broadly, the framework offers a transferable planning model that may be adapted for other rapidly growing metropolitan areas within southern Libya and comparable arid regions undergoing accelerated urban transformation**.**

8. Conclusion.

This study has presented an integrated Future Metropolitan Planning Framework for Sabha City and its surrounding settlements in southern Libya as a strategic response to the accelerating urban, demographic, environmental, and economic transformations affecting the region. Rather than limiting the analysis to the administrative boundaries of Sabha Municipality, the research adopted a metropolitan perspective that recognizes Sabha Samno Ghadwa Al-Zieghan and Tamanhint as components of a single functional urban system characterized by strong spatial, economic social and infrastructural interdependencies. This metropolitan perspective provides a more realistic basis for understanding current development dynamics and for guiding long-term regional planning.

By integrating demographic analysis, Geographic Information Systems (GIS) historical urban growth assessment, field observations, and contemporary metropolitan planning principles, the study identified the principal structural challenges confronting the Sabha Metropolitan Area. These challenges include uncontrolled urban expansion beyond approved planning boundaries, increasing pressure on productive agricultural land and strategic groundwater resources, fragmented infrastructure development, uneven distribution of public services, institutional fragmentation, and the absence of an integrated metropolitan governance framework. Collectively these issues demonstrate that traditional municipal planning approaches are no longer sufficient to manage future urban growth in a sustainable and coordinated manner.

The spatial analysis further confirms that Sabha has evolved into the dominant metropolitan center of southern Libya, serving as the principal administrative, commercial educational healthcare, and transportation hub of the Fezzan Region. At the same time the surrounding settlements have developed complementary functional roles that support the emergence of an interconnected metropolitan system. This functional integration provides a strong justification for adopting metropolitan-scale planning policies capable of coordinating land use infrastructure investment environmental management and regional economic development across municipal boundaries.

Based on the analytical findings this study proposed a comprehensive Future Metropolitan Planning Framework founded on six interrelated strategic pillars:

1. Polycentric metropolitan development.
2. Establishment of a Metropolitan Urban Growth Boundary.
3. Integrated transportation and infrastructure systems.
4. Sustainable environmental management and protection of natural resources.
5. Economic diversification and regional competitiveness.
6. Metropolitan governance supported by institutional coordination and GIS-based decision-making. Together, these strategic components provide a coherent framework for improving spatial efficiency, strengthening regional connectivity, protecting environmental resources, and enhancing the long-term resilience of the metropolitan area.

One of the principal scientific contributions of this research is that it represents one of the first comprehensive studies to examine Sabha from a metropolitan planning perspective rather than through the traditional municipal planning approach. The proposed framework therefore provides both a conceptual model and a practical planning methodology that can support the preparation of a future Metropolitan Master Plan for Sabha and its suburbs. Furthermore, the framework offers a transferable planning model that may be adapted to other rapidly growing cities in southern Libya and comparable arid regions facing similar urbanization challenges.

The study also highlights Sabha's exceptional strategic location as the principal gateway linking northern Libya with the Sahara, the Sahel, and Sub-Saharan Africa. Combined with its agricultural resources, renewable energy potential, international airport, proposed Tamanhint Free Zone and strategic position along emerging regional transport corridors these assets provide significant opportunities for transforming Sabha into a competitive metropolitan growth pole capable of supporting balanced regional development enhancing national economic integration and strengthening Libya's future connectivity with African markets.

Nevertheless, the present research should be regarded as a strategic planning framework rather than a final statutory metropolitan master plan. The proposed framework establishes a scientific foundation and provides preliminary planning indicators to support decision-makers, planners, and public institutions in preparing future development strategies. Its implementation will require detailed field investigations, updated demographic projections, land suitability analysis, transportation modelling, environmental impact assessments, climate resilience studies economic feasibility evaluations, and extensive stakeholder participation to ensure that future metropolitan policies respond effectively to local needs and development priorities.

Finally this study demonstrates that the future prosperity of the Sabha Metropolitan Area depends not only on accommodating urban growth but also on managing that growth through integrated metropolitan planning, sustainable resource management institutional cooperation and evidence-based decision-making. By adopting these principles Sabha can evolve into a resilient, environmentally sustainable, economically diversified, and regionally competitive metropolitan center that supports the long-term development aspirations of southern Libya while contributing to broader national and trans-African urban development objectives.

This study makes four principal contributions to metropolitan planning literature:

- ✓ It presents the first metropolitan planning framework proposed specifically for Sabha and its surrounding settlements.
- ✓ It integrates GIS-based spatial analysis with strategic metropolitan planning.
- ✓ It proposes a transferable planning model for rapidly growing cities in arid regions.
- ✓ It provides an evidence-based planning framework that can support future metropolitan master plans in southern Libya.

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