EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

ASSESSING THE ROLE OF TOPOGRAPHICAL ANALYSIS IN SUSTAINABLE URBAN DEVELOPMENT. INSIGHTS FROM GIS-DRIVEN TERRAIN STUDIES

Ayomide D Akinyemi[1], Andy Osagie Egogo-Stanley[2], Oluwatosin Michael Ibrahim[3], Gerald Chekwube Ezeamii[4]

[1]*Eastern Illinois University*
[2]*Bachelor of Science in Surveying and Geoinformatics*
[3]*(Applied Geology),Ladoke Akintola University of Technology, Oyo State, Nigeria.*
[4]*Department of Applied Instrumentation and control, school of Computing, Engineering and Built Environment, Glasgow Caledonian University, UK,MSc in Applied Instrumentation and Control*

Article DOI: https://doi.org/10.36713/epra20127
DOI No: 10.36713/epra20127

ABSTRACT----------
The steps regarding GIS-driven topographical analysis and its contribution towards sustainable development of the urban environment are discussed in this paper. With the increase in urbanization rates in cities around the world, environmental conditions and issues these cities are experiencing also make it compulsory to develop efficient and effective ways of planning cities. Geometry uses Geographical Information Systems (GIS) that offer essential tools for spatial analysis in addressing land utilization for the benefit of the community as well as in solving some of the environmental, social, and economic challenges that affect cities. Altogether, the main aims of this research are to examine how terrain analysis, based on GIS, can help improve urban planning, determine the problems of its utilization, and recommend potential improvements to increase efficacy when designing sustainable cities. This study adopts a qualitative research approach, with the synthesis of data drawn from seven empirical GIS research on the topic of urban development. The search was set systematically using three databases including ProQuest, Scopus, and the Web of Science. Some of the search terms used were "GIS-based; terrain analysis"; "sustainable urban development" and "topographic analysis for city planning". Based on the study domain, studies were selected according to their ability to support GIS applications within cities regarding sustainability, land usage, and the environment. The articles were screened using exclusion criteria based on relevance to GIS-driven methods, as well as the context of studies outside urban environments. Upon applying these criteria, seven of the mentioned studies were considered for further investigation.

The study found that GIS can be efficiently used to enhance land-use planning by determining the preferred locations for development while taking into account environmental, social, and economic peculiarities. Nonetheless, some of the challenges include data quality, availability of technical skills as well as governance structures that act as constraints to the broad use of GIS in urban planning. The study also presents evidence showing how GIS-driven analysis has the potential for transformation of infrastructure asset management with the proviso that multiple barriers need to be addressed for this shift to take place. These include; the increased demands for accurate, timely geographical information, consideration of socio-economic factors in planning, and increased technical competency among the planners.

Recommendations for improving the application of GIS in urban planning include: integrating the environment, society, and economy into GIS framework for fairer and more sustainable city planning; supporting data collection agencies and making real-time GIS data more accessible; tracking long term changes; and developing GIS human capital, especially in the developing world (5) developing and applying dynamic GIS systems that can observe the complexity of urban geography, among many others. ----------

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

INTRODUCTION

Sustainable urban development is emerging as an important idea in combating the impacts of rapid urban growth, environmental deterioration, and the use of limited resources effectively. It has been the case that as urban areas sprawl, the need for more efficient and effective land-use planning solutions is felt most. Here, topographical consideration has come out as one of the most important tools that, coupled with geographical information system, GIS-driven terrain analysis, is very useful for topographical data identification to meet the goals of urban planners when it comes to improved land utilization and management, minimized hugely risky environmental impacts, and long term sustainability of the planned environment. Thus, GIS can be used as a powerful tool to analyze terrain characteristics including elevation, slope, soil, and land cover, which most dictate decisions on urban development (de Paul Obade & Lal, 2013). According to Tonne, et al., (2021), as urbanization intensifies all over the world, mastering general metrics about these terrain variables and how they influence urban environments has become critical for sustainable evolution.

Researchers have paid much attention in understanding the role and relevance of topographical analysis in successful urban planning for sustainability. For instance, Oliveira and his team (2018) note that failure to consider terrain features in urban development decisions results to negative impacts on the environmental which include flooding, soil erosion and destruction of habitats. This shows that there is a sense of disconnection between spatial analysis and ecological and environmental planning which has to be addressed. Likewise, Ujang and Yadava (2024) discuss how the GIS-based terrain analysis can enhance the land-use planning to respond to the rising challenges and help urban planner plan better environments that have reduced vulnerability and enhanced urban quality almost simultaneously. This obvious the need for topographical information when designing safe cities during disaster incidences and supporting the sustainable infrastructure. In addition, GIS-based terrain analysis has been applied in identifying optimal positioning of parks, transportation systems and energy wise buildings in order to support sustainable urban growth (Costa, et al., 2024).

However, there are limitations that are left in the understanding of the topographical analysis in relation to the urban development especially in relation to other factors like social aspect, economic factors and policies that may influence urban planning. Although numerous prior research works have examined the effectiveness of GIS-based terrain analysis when used in isolation, there is no clear agreement on how topography information might be integrated with other urban development indicators. For example, Ujang and Yadava (2024) and Banerjee and Ghose (2016) are more concerned with the environmental impact of terrain analysis and even these results can be transferred to the context of urban design in other geographical locations, more so in developing nations where data and analytical capacities are not as advanced. This limitation is a major drawback in terms of comparing the effect in different regions and/or different aspects of urban environments.

Also, multiple investigations have pointed out that despite the fact that terrain data provide useful information about environmental sustainability, there is low coupling of social and economic factors that govern urban growth (Ehrlich et al. 2021; Bibri 2020; Wang et al., 2019). For example, considering the terrain may not capture the needs of urban dwellers, service delivery, fairness of land distribution as well as affordability in construction. All these social dimensions are critical for promoting a sustainable development of cities that will also be socially sustainable. The lack of such models in the current literature is an indication that further, more robust theoretical frameworks need to be developed that have the capacity to encompass physical and socio-economic characteristics of the urban structure. Secondly, although GIS based terrain analysis has been found useful for diverse urban applications, the present literature review suggested that there is scant literature, which has investigated on the effects of topographical considerations on urban development outcomes over a long period. Previous research interest has primarily involved the direct or short-term applications of terrain analysis for averting environmental hazards, or enhancing land utilisation (Deng, et al., 2016). Nevertheless, there is scant literature on how these measures compare over time especially in dynamic urban systems where social, economic and environmental situations are dynamic. Therefore, the current study aims at filling this gap through a systematic literature review and critique of how topographical analysis can be incorporated into more comprehensive urban development planning.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

Research Aim

The aim of this research is to systematically review the current literature on the involvement of topographical analysis in sustainable urban development for terrain analysis using GIS techniques and to understand the effects of such studies on land use planning aspects, environmental management, and social and economic aspects in urban settings.

Research Objectives

Given the aims of this study, the following specific objectives were raised to guide the study:

1. How can GIS-driven topographical analysis improve sustainable land-use planning in urban areas?
2. What are the environmental, social, and economic factors that influence the effectiveness of terrain analysis in urban development?
3. What challenges exist in applying GIS-based terrain analysis for sustainable urban planning in different geographical and socio-economic contexts?
4. How does topographical analysis contribute to the design of resilient infrastructure, green spaces, and energy-efficient buildings in urban settings?

METHODS

Search Strategy

A qualitative study design is used for this study to ensure that the findings offer insights into the use of GIS-driven topographical analysis in sustainable urbanization. This means of research facilitates an enhanced understanding of the both the methodological GIS terrain analysis technique and the context that surrounds this technique within the field of urban planning (Creswell, 2014; Tashakkori & Teddlie, 2010). Initial search of articles is done through three academic databases namely Scopus, Web of Science and ProQuest. These were used based on the comprehensiveness they offered, thereby capturing as many articles as possible pertinent to the study (Booth, et al., 2021). To filter the number of studies to a broader range of related and appropriate studies specific search terms are then derived from concepts such as GIS, topographical analysis, sustainability in the urban context, and urban planning. These search strings are modified by Boolean terms such as AND or OR as well as truncation symbols to allow for a number of terms and keywords such as GIS OR terrain analysis OR land use.

Table 1: Sear Strings for Databases

S/N	Data Base	Search Strings
1.	ProQuest	("GIS" OR "Geographic Information Systems" OR "Terrain Analysis") AND ("Sustainable Urban Development" OR "Urban Sustainability") AND ("Green Space Design" OR "Land Use Zoning") AND peer-reviewed AND publication-date:2014-2023 AND language: English
2.	Web of Science	TS=("GIS" OR "Terrain Analysis" OR "Digital Elevation Models" OR "Topographical Analysis") AND TS=("Sustainable Urban Development" OR "Urban Planning") AND TS=("Green Space Design" OR "Disaster Management") AND PY=(2014-2023) AND LA=(English)
3.	Scopus	TITLE-ABS-KEY(("GIS" OR "Terrain Analysis" OR "Topographical Analysis") AND ("Sustainable Urban Development" OR "Urban Sustainability") AND ("Green Space Design" OR "Disaster Management")) AND PUBYEAR > 2013 AND LANGUAGE(English)

This strategy assists in grabbing articles focusing on a wide array of GIS utilization in urban planning as in disaster management, green spaces, and land-use plans.

Inclusion and Exclusion Criteria

Inclusion criteria are adopted in this study to effectively filter out only those scientific articles that meet rigorous methodological requirements and are most closely related to the topic. Journals have to be referred to and published within the last ten years (2014-2024), in English Language only and research about the application of GIS-driven topographical analysis in sustainable urban development. The review also includes only primary research studies and empirical evidence exclusively relying on real-world GIS application (Gusenbauer & Haddaway, 2020).

Such decisions apply exclusion criteria to filter out studies unrelated to the GIS-terrain interaction in the urban sustainability context. For example, papers that are not set in urban environments or those conducted in non- randomly

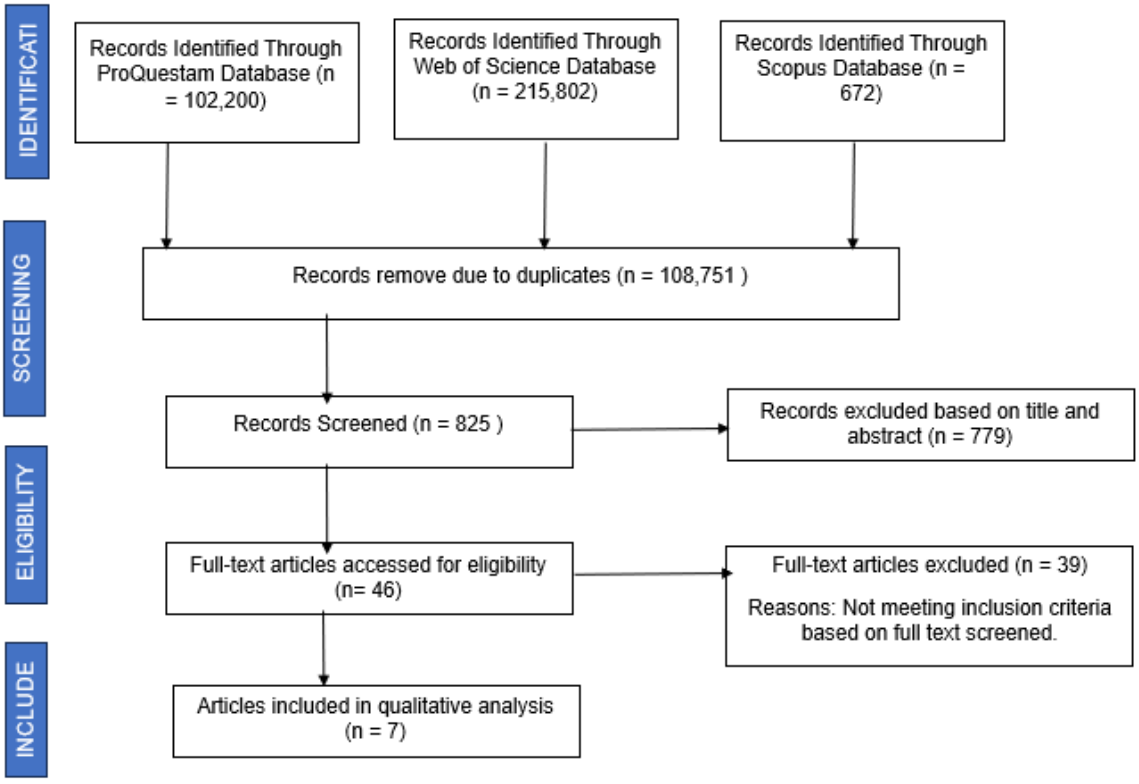
EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

selected geographic or socioeconomic locations are eliminated. The latter ones were also excluded, as the study exclusively highlights GIS cases and excludes other unrelated fields, for example, purely architectural or historical overviews (Booth, et al., 2021). Additionally, studies that are purely conceptual or involve commentary and opinion-based content are excluded from this review (Finfgeld-Connett & Johnson, 2013). This ensure that the study only focuses on the most pertinent and excellent evidence to consider in understanding the part played by topographical analysis in urban planning.

Search Results

To identify relevant literature for this study, a 4-step process utilising the PRISMA FLOW diagram model is applied in the recruitment and selection process which are identification, screening, eligibility assessment, and inclusion respectively (Moher, et. al., 2009). Initial preliminary searches in Scopus, Web of Science and ProQuest databases yielded 109,576 hits. Out of which 108,751 articles were removed due to unrelated to the current study, 779 were duplicate studies, hence 46 articles remained for further review. As the inclusion and exclusion criteria were applied to the 46 studies abstracts, 39 records were excluded and therefore the paper selection was brought down to 7 papers. Therefore, the following steps have resulted in acceding 7 research articles which do satisfy all the requirements as highlighted in figure 1.

Figure 1: Prisma flowchart



Source: Adapted from Moher, et. al., (2009)

Quality Appraisal

To enhance the quality of studies selected in this review, the Critical Appraisal Skills Programme (CASP) tool was used in appraising the articles. Only articles from scholarly and peer-reviewed databases were used to obtain information thus addressing issues to do with credibility and reliability. The CASP tool specifically and comprehensively assessed factors related to the relevance and sufficiency of each study by examining the marked research questions, defined study samples, appropriate exposure and outcome measures, and confounding factors (Long et al., 2021). Codified GIS studies investigated in this review revealed sufficient methodological relevance.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

Study objectives were stated exactly, samples were described precisely, and the mechanisms for data acquisition were sound. Some of the criteria that were not relevant to the study designs were, for example, the repeated exposure assessments, yet all the articles conformed to fundamental qualities. This appraisal made it possible to get reliable information from the included studies that favor the validity and applicability of the findings of this review on GIS applications in sustainable urban planning (See Appendix I & II).

Analysis and Synthesis of Literature

Researchers often use thematic analysis when assessing individual research works, since volume and variance enable accurate identification of distinctive trends and research difficulties. This analytic approach makes it easier to hone in on particular matters with more precision (Labra, et al., 2020). For this reason, in the current study, a data extraction table was created to aid in the interpretation of all the data collected (Attached as Appendix I).

Deliry and Uyguçgil (2020) analyzed the Eskisehir, Turkey land suitability for sustainable urban development using a Geographic Information System with Analytical Hierarchy Process. Together with another three criteria, their outcomes signified that only 0.01 % of the city area was considered suitable for development, whereas only 44% of the city area was determined as having low suitability for development. This was seen by comparing the overall rating for environmental sustainability with the other objectives of socio-economic development and effectiveness in achieving urban density. The study established that safety, connectivity, and topography are major limiting factors; in the absence of which proper urbane planning should be employed to restrain unsuitable land use. Though it is quite evident in the research how AHP-GIS integration can help in the decision-making process, the research is geographically confined and hence broad generalization cannot be done. Furthermore, the results underlined the importance of further investigations aimed at enhancing the usability of the limited space for land development. These procedures helped prepare this study for other analogical urban settings and constituted a rigid framework about which to incorporate dynamic database information to address contemporary urban issues.

Al-Ghorayeb et al. (2023) used a GIS-AHP technique to determine land suitability in Nabatiyeh, Lebanon, with elevation and slope being given more importance being part of over 70% of the criteria weights. The study showed that undertaking topographical and accessibility constraints to land use planning provided better ways to contain urban sprawl. In addition, it offered empirical and prescriptive policy directions including the redesign of administration structures and the strengthening of institutional capabilities for improved urban management. For that reason, even though the research explores the usefulness of multi-criteria GIS tools quite adequately, it has its drawbacks, primarily in the form of relying on the static set of data and geographical contexts. Further, the research stresses the importance of managing growth and development of urban space while protecting nature, which corresponds to the current worldwide tendencies of sustainable urban development. These findings may be useful to policymakers to fashion programs to support both the growth of urban areas as well as environmental conservation.

Furthermore, Rahman and Szabó (2022) developed a GIS-MCDM model selection for the appropriate levels of residential land use in Rajshahi City, with 9% higher sustainability impacts. Indeed, in this study, fuzzy membership functions and ordered weighted averaging (OWA), which were not used in the previous research, were applied to reconcile different and often opposite sustainability factors. Analyzing their results they found that strategic planning, prioritizing high risk-no tradeoff offered the greatest sustainability advantage signifying that urban planning is very much about strategic consideration. Nevertheless, by depending on OWA, there are issues of generalizing this model within the different urban contexts considered in this paper with different constraints. Thus, the study's main robustness is in utilizing GIS applications enhancing sustainability indexes as practical guidelines that can be effectively adopted in other cities with Land Use Conflicts. Nevertheless, the use of such WDS as a regular source of data in the framework can enhance the methodological development of the framework and its ability to meet the challenges of rapid urbanization required for changes in socio-economic inputs in real time. This work provides a standard for addressing the question of how sustainability might be integrated into GIS-driven urban development.

Similarly, Gelan (2021) investigated GIS-based Multi-Criteria Analysis (MCA) for planning where urban green spaces will be established in the Sululta region in Ethiopia. Of the total area the study established only 13.6% is highly suitable for green space development and only 5.5% is unsuitable. Such evidences call for a shift towards ecological and socio-economic aspects in green space planning especially in developing countries where urbanization pressures

to land exert immense pressure on the environment. What's more, even though the work of the paper is good enough to prove the applicability of GIS in solving decisional problems, the statics of the used sets do not allow the method to respond to continually developing conditions of the urban environment adequately. Lack of dynamic socio-economic factors, including population growth incidence, posing limitations on the study's real-life usefulness. Nevertheless, the given methodology could be useful when it comes to determining the priorities in green space development as a response to urbanization, yet increasing the quantity of green space regardless of the quantity of new constructions. Future research could extend this approach by including dynamic datasets as well as real-time monitoring systems.

Chen et al. (2022) proposed a dynamic planning model based on GIS and a symmetric algorithm for sustainable land use. This approach yielded an overall classification accuracy of 91.28 percent, and water and residential had a classification accuracy of more than 96 percent. Land use changes in the study were also apparent including an increase in forest coverage, stable water bodies, and other factors, which show the impact of afforestation policies and environmental management. Even though it was a technical study, fundamental aspects like policy effects and enterprise land use were not considered adding more vulnerability to the applicability of results. Similarly, the time spent on data preprocessing and analysis using ArcGIS and ENVI shows that socio-political factors should be considered in LU planning. However, the academicity of the method and high accuracy rates make this approach a useful tool in the hands of urban planners struggling to achieve strategic use of space in the context of sustainability objectives.

However, Alogayell et al. (2024) assessed the land suitability of the Saudi Arabia NEOM area using the GIS-AHP model. Their findings revealed that 28.23% of the area is very suitable for urban development because of the resemblance of their results to the NEOM's plans such as "The Line" and "Oxagon." One of the major findings of the study underlined the need to prevent uncontrolled spatial sprawl by using restricted development areas for renewable energy and purposes of nature preservation. However, the approach taken in the study provides a good way of aligning geomatics techniques with the goals of urban planning; it lacks flexibility when it comes to adapting to change through such factors as ever-changing policies and conditions of the society. The study recommends that subsequent research should include dynamic data sources and global socio-cultural impact assessment to enhance the model's accuracy. This research thereby suggests an exploratory mechanism in which GIS-based tools and frameworks can be applied for sustainable urban development in arid regions and within the wider socio-economic and environmental planning goals.

Last, Liladhar Rane et al. (2023) used a GIS-based MIF technique to determine the location of suitable areas for the development of areas of urban settlement in Nashik India. According to their study, 16.48% of the area was more suitable while 27.26% of the area was again totally unsuitable. Suitability analysis of sites for marsh-cultured fish farming was based on logistic regression coefficients of biophysical factors out of which proximity to roads, drainage networks, and health facilities were viewed as dominant factors in sensitivity analysis. Finally, model validation using ROC analysis agreed with the results, especially the calculated AUC value being 0.895. Despite the strong and efficient framework that the study proposes for urban planning, the criteria weights are set rigidly, and they may not capture the dynamic nature of urban systems. Its focus on interrelationships among variables presents a more dynamic, flexible method of analyzing site suitability, making it a useful key in the kit of planners and policymakers. Further development may include the integration of the live streams of data and the application of more advanced concepts of artificial neural networks to raise the accuracy of the model.

RESULT

Objective 1: GIS-Driven Topographical Analysis and Sustainable Land-Use Planning

Accordingly, the GIS-driven study of topographical features effectively provides a strong foundation for the sustainable approach to land-use planning in urban centres. Deliry and Uyğuçgil (2020) supported that GIS was useful for the assessment of land suitability for urban development in Eskisehir, Turkey. Concerning safety, connectivity, socio-economic factors, and eco-environmental conservation criteria, the paper showed that a very small percentage of the land is suitable for urban development. This supports GIS in enabling accurate demographic analysis to support the sustainable development of urban centers. In the same way, Rahman and Szabó (2022) applied GIS-MCDM in Rajshahi City, Bangladesh to identify the optimized residential land use based on the fuzzy membership functions and

multi-objective land allocation modules. It proved to their ideas how GIS-based optimization an increase of the 9% sustainability benefit could be achieved, this work exclusively provides a pattern that how the environmental and socio-economic concern of the urban planner may be expanded.

Al-Ghorayeb et al. (2023) also highlighted the application of GIS integrated with AHP to achieve sustainable growth of cities while conserving the environment of Nabatiyeh – Lebanon. To aid policymakers in considering areas that are most suitable for sustainable development, the study created a land suitability map that incorporated important data such as the elevation and slope of the land. Chen et al. (2022) on the technical aspects of land-use planning, used GIS, decision tree classification, and sparse coding algorithms, and effectively came out with high-accuracy results of the suitable area. These studies collectively prove that the analysis using GIS is an imperative tool for sustainable urban planning. However, the studies also indicate some of the limitations, for example use of static data sets; and real-time data integration for dynamic urban environments. However, despite these challenges, GIS plays a vital role in decision-making for the identification and management of land resources for the balanced and sustainable development of urban centers.

Objective 2: Environmental, Social, and Economic Factors Influencing Terrain Analysis

Terrain Analysis performed by GIS is deeply influenced by the social, economic, and environmental factors that impact the efficiency of the whole process in the case of urban planning. To do so, Gelan (2021) conducted a study in Sululta, Ethiopia in which the researchers noted that proximity to settlements, roads, water bodies, and the scenic attractiveness of the location are considered influential variables in urban green space planning. Accordingly, the study highlighted that the inclusion of such factors in GIS models keeps ecological aspects in focus by satisfying socio-economic requirements that are essential in urban planning processes. Costs, including construction costs and distance from infrastructure, were essential in the assessment of Saudi Arabia's NEOM region that was conducted by Alogayell et al. (2024). They observed that blank receptors nearest to infrastructure and natural resources were the best for the development of urban structure, thus there is a correlation between economic imperatives and physical limitations. Likewise, Rane et al. (2023) have identified that in Nashik, India, site suitability for residential income generation is closely associated with drainage networks, road networks, and health service facilities crucial for socio-economic conditions in the urban planning process.

The 'Environment' was essential in the areas of study by Chen et al. (2022) as some policies such as afforestation boosted forest cover. Their combination of environmental policies with the GIS analysis demonstrated the possibility of preventing further deterioration of the environment while the city expands. Population density and accessibility to health facilities also featured prominently in these studies pointing to the importance of assessing how different urban stakeholders' needs are accommodated by urban planning frameworks. Consequently, these studies demonstrate that terrain analysis encompasses multiple dimensions. GIS methods complement environmental, social, and economic criteria as a contribution to GIS-based sustainable city planning. However, the outcome of such analyses very much depends on the quality of data utilized and the ability to take into consideration a multitude of interrelated factors.

Objective 3: Challenges in Applying GIS-Based Terrain Analysis

However, GIS-based terrain analysis also has severe limitations and constraints, especially in such a multiple geographical and socio-economic terrain. Alogayell et al., (2024) noted that the limitations of the static dataset in the NEOM region of Saudi Arabia do not allow for dynamic urban form representation and meaning of growth. The study also drew some inherent weaknesses in applying the AHP method; the method assumed criteria independence as being immune to each other – an assumption that leads to a lot of oversimplification. According to Gelan (2021), the limitation of the technical know-how and available equipment in Ethiopia is a problem that has been observed in the development of other nations which hampers the advanced use of GIS technologies. Likewise, Chen et al. (2022) highlighted challenges when estimating human influencing elements like governance policies, which are not easy to incorporate statistically into urban growth simulations. Hence, other dynamic aspects of the study like natural disasters intensified the difficulties of the dynamic land-use planning. Rahman and Szabó (2022) also highlighted the importance of decision support systems that would allow for decision-making based on existing urban dynamics. Their GIS-MCDM approach, although with good results, strongly depends on the pre-set-up conditions, so it has a weak point in solving real-time problems. The presented reasons suggest that the dynamic datasets are required to be

integrated, technical skills must be improved, and collective governance should be promoted to overcome the barriers to GIS implementation.

Objective 4: Topographical Analysis for Resilient Infrastructure and Green Spaces

Topographic analysis is central for planning infrastructure, parks, and energy-efficient structures in the contemporary metropolitan environment. Gelan (2021) showed how GIS-based multi-criteria analysis for planning urban green spaces in Sululta, Ethiopia determines areas that are beneficial for improving ecological and socio-economic value. Thus, according to the research, green space planning revealed that 13.6% of the territory is highly suitable for green space and can serve as a guide for the future development of sustainable cities. Al-Ghorayeb et al. (2023) employed GIS for the optimal spatial planning of green areas required to counter the UHI impacts in Lebanon. Likewise, Alogayell et al. (2024) noted that GIS plays a critical role in planning Saudi Arabia's NEOM region by helping with initiatives such as "The Line," and "Oxagon," identifying independence terrain including the relation of infrastructure scariness with terrace sustainability.

However, Chen et al. (2022) used complex GIS techniques in the assessment of land uses for compact city forms. Thus, their work showed that the adoption of decision tree classification combined with sparse coding can improve site selection decisions and put a foundation for sustainable urban design. In contrast, Rane et al. (2023) were concerned with defining potential areas for residential development in India as dependent on infrastructure accessibility and the availability of green space. This further highlighted the immense benefits of GIS in developing techniques for a resilient physical urban infrastructure.

DISCUSSION

Efficient management of urban development is still a major global concern as cities struggle to accommodate rapid population growth, deterioration of the environment, and calls for eco-friendly methods. As pointed out in the literature, map systems and especially GIS and topographical analysis are being regarded more often as mandatory approaches to the resolution of these challenges (de Paul Obade & Lal, 2013; Tonne et al., 2021). The results of the meta-analysis of GIS studies support and extend these claims and illustrate the opportunities and limitations of incorporating terrain analysis into urban planning.

The aforementioned literature like the one provided by Oliveira et al. (2018), establishes the negative impacts associated with failures in undertaking terrain features in the planning of the urban land. Deliry and Uyguçgil (2020) and Gelan (2021) to this effect established that GIS analysis is effective in mapping out high-risk and prohibited areas for development. For instance, Gelan (2021) employed GIS to establish approaches for green space planning for Sululta Town in Ethiopia with a view of providing perspectives on the environmental impacts of the rising environmental risks and the way they can be managed to boost urban resilience. This is evidenced by the integration of MCDM frameworks with GIS as portrayed by Al-Ghorayeb et al. (2023) and Rahman and Szabó (2022) In essence, terrain studies facilitate the proper use of land due to optimum planning of the land. These studies support Ujang and Yadava's (2024) work that depicts GIS's capability to direct sustainable infrastructural and green area design; this underlines the significance of topographical information for disaster-responsive urbanism.

Nevertheless, understanding these important insights also points out the limitations of how GIS-based terrain analysis is executed across various geographical settings. For example, even if using more complex methods, based on an advanced GIS approach like in Chen et al. (2022), planning accuracy is higher, using complex algorithms and static data sets requires more organizational context and less suitability for LESS-developed regions. This view is consistent with the issues highlighted in the literature (Banerjee & Ghose, 2016), where there is a call for the development of cheaper and more flexible GISs to be available in the global market. Furthermore, the study confirms the previous research that underscores the significance of the ESP approach for integrating environmental, social, and economic aspects into sustainable urban development open to improvement, according to the ideas of Ehrlich et al. (2021) and Bibri (2020). As much as several GIS-based terrain studies focus on environmental factors, socio-economic factors are often sporadically incorporated. Alogayell et al. (2024) and Rane et al. (2023) come close to filling this relative void by bringing variables like proximity to infrastructure, cost of construction, and accessibility of services into their considerations while designing the structure, which adds more realistic goals for urban planning.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

Perhaps these findings can be related to Costa et al. (2024) who have emphasized the need for terrain studies that are supplementary to wide urban developmental goals such as equal access. For example, Rane et al. (2023) provide a focus on site suitability in the city of Nashik in India, to examine how factors such as distances to healthcare facilities, roads, and drainage facilities, show the integration of social and environmental planning. However, the low level of integration of socioeconomic factors in other works, for example, Gelan (2021) and Chen et al. (2022), shows a more significant Shortcoming observed in the literature review by Wang et al. (2019). Furthermore, using GIS to drive terrain analysis has strengths focusing on environmental data but it fails to consider the social variation of the society's well-being for instance in the issues to do with the distribution of land and provision of houses for the poor (Ehrlich et al., 2021). Altogether, these outcomes stress the call to research multi-faceted models that focus on integrated physical and social-economic stimulation.

According to Deng et al. (2016), there seems to be a dearth of literature that looks at the extended effects of topographical factors concerning urban development over time. One kind of limitation associated with the synthesis of the above-discussed GIS analyses is that such studies tend to primarily highlight short-term perspectives of GIS applications such as the reduction of environmental hazards and efficient land utilization. For example, Al-Ghorayeb et al. (2023) and Rahman and Szabó (2022) underscore the short-term utility of GIS-MCDM frameworks but offer scant knowledge of their long-term efficiency in dynamic city contexts. The literature survey underlines the importance of the chronic study of how effectively the terrain studies implemented with changing socio-economic and environmental contexts (Ehrlich et al., 2021). Even reasonably produced studies, such as Chen et al. (2022) that apply sophisticated models to tackle or explain urban land-use problems cannot assess the resilience of such approaches concerning natural calamities, policy changes, and faster urbanization.

The results obtained in this research support the literature's recommendations for enhancing the inclusiveness of planning practices where GIS-based terrain analysis is supplemented with social and economic data. The prior literature has provided evidence that GIS is effective in supporting the decision-making process in the fields that concern the assignment of land usage and environmental hazard prevention with inadequate socio-economic aspects integrated. This gap calls for more multi-dimensional models in which these aspects of sustainability are intertwined with those of inclusiveness and equity as has been pointed out by Bibri (2020) and Costa et al. (2024). Furthermore, the study shows that more flexible and affordable GIS technologies should be developed to overcome the shortcomings of GIS-related resources in different parts of the world. According to Banerjee and Ghose (2016), the usefulness of GIS-based terrain analysis lies in its ability to be scaleable and to apply to a broad range of cities in developing countries.

RECOMMENDATIONS

The following are the pragmatic implications arising from this research that would improve the use of GIS topographical analytical tools in support of sustainable urban development. Firstly, the urban planner should include the environmental, social and economic aspects of their planning model. Despite having had success in implementation through analysis of terrain information in search of prospective areas to be developed, inclusion of socio-economic factors enhances the achievements thus; available, fair and affordable. An integrated approach would see that every investment meets the needs of all the stakeholders while at the same time ensuring that the strategies of urban development meet the challenges of sustainability.

Secondly, greater attention must be paid to the availability and quality of the data. One of the key recommendations is that governments and planning authorities should direct more resources to develop effective systems for collecting data and making good quality geospatial data easily accessible in near real-time. Policymakers, researchers and private organizations can also work on refining the data collection and analyzing process in order to enrich decision-making procedures of the planning area. The next crucial suggestion is the call for researchers to undertake an investigation of the durability of GIS-couched terrain analysis on cities' results. Many modern works operate on a short-term scale, but long-term investigation would be useful for a better understanding of how the urban environment changes and for enhancing planning approaches to increase the effectiveness of the design for the future.

It is also important therefore to encourage other capacity-building measures in GIS technologies, especially for developing nations where human resources and infrastructure are constrained. GIS-aware programmes for urban

planners and decision-makers can fill these gaps to facilitate the efficient use of GIS technology. Finally, dynamic and flexible models of GIS are appropriate in the current context. The kind of models, which incorporate real-time and dynamic attributes of the urban environment adapt well to changes in conditions of urban landscape and help make urban planning more anticipative. But if these recommendations should be followed, GIS-based approaches will be well-positioned to deal with the urban growth complexity and ensure the development of more equitable, sustainable and highly resilient urban spaces in the future.

CONCLUSION

As illustrated by this synthesis of seven GIS studies this paper argue that GIS driven topographical analysis unearths a way forward towards sustainable urbanization. Overall, the studies cover GIS-positive impacts on land-use planning in the four chosen themes, environmental, social, and economic concerns, application difficulties, and the role of GIS in creating enduring infrastructures and green spaces. However, the use of GIS in development projects depends on the following factors; quality data, human resources, and governance frameworks. The problems highlighted in these works suggest that more effective and flexible mechanisms of data integration, improved technical skills, and policy cooperation to make use of the potential offered by GIS for urban planning. Given the general increase in the rate of urbanization around the globe these findings give some handy tips on how the planners and the policy makers can pursue development without compromising the environmental standards. In doing so, the current paper demonstrates how greater recognition of GIS' potential and addressing its weaknesses in the context of the urban environment can result in more sustainable, inclusive, and resilient futures.

REFERENCES

1. *Al-Ghorayeb, A., Al-Shaar, W., Elkordi, A., Faour, G., Al-Shaar, M., & Attalah, Y. (2023). Land Suitability Analysis for Sustainable Urban Development: A Case of Nabatiyeh Region in Lebanon. J, 6(2), 267-285.*
2. *Alogayell, H. M., Kamal, A., Alkadi, I. I., Ramadan, M. S., Ramadan, R. H., & Zeidan, A. M. (2024). Spatial modeling of land resources and constraints to guide urban development in Saudi Arabia's NEOM region using geomatics techniques. Frontiers in Sustainable Cities, 6, 1370881.*
3. *Banerjee, P., & Ghose, M. K. (2016). Spatial analysis of environmental impacts of highway projects with special emphasis on mountainous area: an overview. Impact assessment and project appraisal, 34(4), 279-293.*
4. *Bibri, S. E. (2020). Compact urbanism and the synergic potential of its integration with data-driven smart urbanism: An extensive interdisciplinary literature review. Land Use Policy, 97, 104703.*
5. *Booth, A., James, M. S., Clowes, M., & Sutton, A. (2021). Systematic approaches to a successful literature review. SAGE Publications Ltd.*
6. *Chen, S., Guo, Q., & Li, L. (2022). Sustainable land use dynamic planning based on GIS and symmetric algorithm. Advances in Civil Engineering, 2022(1), 4087230. https://doi.org/10.1155/2022/4087230*
7. *Costa, D. G., Bittencourt, J. C. N., Oliveira, F., Peixoto, J. P. J., & Jesus, T. C. (2024). Achieving Sustainable Smart Cities through Geospatial Data-Driven Approaches. Sustainability, 16(2), 640*
8. *Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). SAGE Publications, Inc.*
9. *de Paul Obade, V., & Lal, R. (2013). Assessing land cover and soil quality by remote sensing and geographical information systems (GIS). Catena, 104, 77-92.*
10. *Deliry, S.İ. and Uyguçgil, H., (2020). GIS-Based land suitability analysis for sustainable urban development: A case study in Eskisehir, Turkey. Afyon Kocatepe Üniversitesi Fen Ve Mühendislik Bilimleri Dergisi, 20(4), pp.634-650.*
11. *Deng, X., Li, Z., & Gibson, J. (2016). A review on trade-off analysis of ecosystem services for sustainable land-use management. Journal of Geographical Sciences, 26, 953-968.*
12. *Ehrlich, D., Freire, S., Melchiorri, M., & Kemper, T. (2021). Open and consistent geospatial data on population density, built-up and settlements to analyse human presence, societal impact and sustainability: A review of GHSL applications. Sustainability, 13(14), 7851.*
13. *Finfgeld-Connett, D., & Johnson, E. D. (2013). Literature search strategies for conducting knowledge-building and theory-generating qualitative systematic reviews. Journal of advanced nursing, 69(1), 194-204.*
14. *Gelan, E. (2021). GIS-based multi-criteria analysis for sustainable urban green spaces planning in emerging towns of Ethiopia: the case of Sululta town. Environmental Systems Research, 10, 1-14. https://doi.org/10.1186/s40068-021-00220-w*
15. *Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. Research synthesis methods, 11(2), 181-217.*

16. *Labra, O., Castro, C., Wright, R., & Chamblas, I. (2020). Thematic analysis in social work: A case study. Global social work-cutting edge issues and critical reflections, 10(6), 1-20.*
17. *Liladhar Rane, N., Achari, A., Hashemizadeh, A., Phalak, S., Pande, C. B., Giduturi, M., ... & Yadav, K. K. (2023). Identification of sustainable urban settlement sites using interrelationship based multi-influencing factor technique and GIS. Geocarto International, 38(1), 2272670.*
18. *Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group*, T. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine, 151(4), 264-269.*
19. *Oliveira, E., Tobias, S., & Hersperger, A. M. (2018). Can strategic spatial planning contribute to land degradation reduction in urban regions? State of the art and future research. Sustainability, 10(4), 949.*
20. *Rahman, M. M., & Szabó, G. (2022). Sustainable urban land-use optimization using GIS-based multicriteria decision-making (GIS-MCDM) approach. ISPRS International Journal of Geo-Information, 11(5), 313.*
21. *Tashakkori, A., & Teddlie, C. (2010). SAGE handbook of mixed methods in social & behavioral research (2nd ed.). SAGE Publications.*
22. *Tonne, C., Adair, L., Adlakha, D., Anguelovski, I., Belesova, K., Berger, M., ... & Adli, M. (2021). Defining pathways to healthy sustainable urban development. Environment international, 146, 106236.*
23. *Ujang, U., & Yadava, R. N. (2024). An Overview of Advances in Geoinformatics Technologies: Facilities and Utilities Optimization and Management for Smart City Applications. Advances in Geoinformatics Technologies: Facilities and Utilities Optimization and Management for Smart City Applications, 3-18*
24. *Wang, H., Pan, Y., & Luo, X. (2019). Integration of BIM and GIS in sustainable built environment: A review and bibliometric analysis. Automation in construction, 103, 41-52.*

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825
ISSN: 2321-6247

APPENDICES

Appendix 1: Data Extraction Table

Authors	Year/Country of Publication	Title	Study Design/Methods	Research Findings	Relevance to Nursing/Literature Review Topic	CASP Score
Deliry, S.İ., and Uyguçgil, H.	2020/Turkey	GIS-Based land suitability analysis for sustainable urban development: A case study in Eskisehir, Turkey	Multi-criteria decision analysis with GIS	Found 44% of the area as low suitability and 42% as unsuitable for sustainable urban development; only 0.01% was highly suitable.	Highlights challenges and provides GIS techniques for sustainable urban planning, emphasizing environmental conservation.	9
Al-Ghorayeb et al.	2023/Lebanon	Land Suitability Analysis for Sustainable Urban Development: A Case of Nabatiyeh Region in Lebanon	GIS-based multi-criteria decision analysis and AHP	Elevation and slope were most critical, influencing 34%-36% of suitability; produced a suitability map for informed planning decisions.	Emphasizes the integration of multi-criteria decision tools with GIS to support sustainable urban planning policies.	9
Rahman, M. M., and Szabó, G.	2022/Bangladesh	Sustainable urban land-use optimization using GIS-based multicriteria decision-making (GIS-MCDM) approach	GIS-based MCDM with fuzzy membership and OWA	Achieved a 9% increase in sustainability benefits; developed optimal decision strategies for residential land-use planning.	Demonstrates the application of GIS tools for sustainable urban planning with measurable outcomes, enhancing decision-making for urban land use.	9
Gelan, E.	2021/Ethiopia	GIS-based multi-criteria analysis for sustainable urban green spaces planning in emerging towns of Ethiopia	GIS-based Multi-criteria analysis	Identified 18.9% as poorly suitable, 13.6% as highly suitable, with recommendations for urban green space planning.	Relevant for sustainable urban planning in developing countries, providing strategies for green space development.	9
Chen, S., Guo, Q., & Li, L.	2022/China	Sustainable land use dynamic planning based on GIS and symmetric algorithm	GIS with ENVI and symmetric algorithm	Land planning accuracy exceeded 91%; demonstrated effective classification of land categories and highlighted limitations such as static data dependency.	Supports the integration of advanced GIS methodologies for land-use planning and sustainable development, addressing accuracy and limitations.	9
Alogayell, H. M., et al.	2024/Saudi Arabia	Spatial modeling of land resources and constraints to guide urban development in	GIS-based multi-criteria decision-making framework	Identified 28.23% of the NEOM region as most favorable for urban development, considering	Offers insights into urban planning models that balance growth with environmental sustainability, particularly in	9

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

		Saudi Arabia's NEOM region		proximity to infrastructure and conservation priorities.	challenging environments like deserts.	
Liladhar Rane, N., et al.	2023/India	Identification of sustainable urban settlement sites using interrelationship-based multi-influencing factor technique and GIS	GIS-based multi-influencing factor technique	Found 16.48% highly suitable and 8.77% very highly suitable for development; validated results using ROC with an AUC score of 0.895.	Demonstrates the effectiveness of using GIS in urban settlement planning, contributing to sustainable development and policy formulation.	9

APPENDIX II: CAPS Quality Analysis of the Reviewed Studies

S/N	CASP	Deliry and Uyguçgil (2020)	Al-Ghorayeb et al. (2023)	Rahman and Szabó (2022)	Gelan (2021)	Chen, Guo, and Li (2022)	Alogayell et al. (2024)	Liladhar Rane et al. (2023)
1.	Was the research question or objective in this paper clearly stated?	YES	YES	YES	YES	YES	YES	YES
2.	Was the study population clearly specified and defined?	YES	YES	YES	YES	YES	YES	YES
3.	Was the participation rate of eligible persons at least 50%?	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
4.	Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	YES	YES	YES	YES	YES	YES	YES
5.	Was a sample size justification, power description, or variance and effect estimates provided?	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
6.	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	YES	YES	YES	YES	YES	YES	YES

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal

ISSN: 2321-6247

Volume: 13 | Issue: 2 | February 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

7.	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	YES	YES	YES	YES	YES	YES	YES
8.	For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	YES	YES	YES	YES	YES	YES	YES
9.	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	YES	YES	YES	YES	YES	YES	YES
10.	Was the exposure(s) assessed more than once over time?	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
11.	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	YES	YES	YES	YES	YES	YES	YES
12.	Were the outcome assessors blinded to the exposure status of participants?	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
13.	Was loss to follow-up after baseline 20% or less?	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
14.	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	YES	YES	YES	YES	YES	YES	YES
TOTAL		**9**	**9**	**9**	**9**	**9**	**9**	**9**