URBANIZATION AND ITS IMPACT ON LAND USE AND LAND COVER IN AL BURAIMI CITY, OMAN USING REMOTE SENSING AND GIS

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ABSTRACT

Rapid urbanization poses significant challenges that can transform the physical and socio-economic environment of a city. Oman, a coastal country, has experienced a rapid increase in urbanization over the past decades. As statistical data show, the population increased significantly from 1955 to 2023, ranging from 2.5 % to 88 %. Similarly, the population in Al Buraimi Governorate has doubled since 1993, with an estimated population of 121,802 (NCSI, 2021) Al Buraimi City facing significant challenges. The city's rapid growth in population burdening its infrastructure, traffic, municipal, education and public health capacity. This paper investigates the transformation of Land Use (LU) / Land Cover (LC) change from 2003 to 2023 in relation to population growth, employing both spatial and non-spatial methods to analyze the urban sprawl. The study focuses on the four main objectives: 1. To identify distinct types of sprawls (e.g., continuous, leapfrog, ribbon) and their spatial distribution proximity areas. 2. To examine the factors driving urban sprawl, including population growth, industrial development, socio-economic and educational opportunities. 3. To assess LU/LC changes over the study period using geospatial methods. 4. To forecast urban sprawl pattern using statistical models, providing insights into potential future developments. Given the limited understanding of urban sprawl in the study area, this research aims to address the complex challenges of urbanization and recommends sustainable resource development strategies. The results show that between 2003 to 2023, built-up areas increase from 13.14 % to 14.88 %, roads and other areas from 9.92 % to 11.23 % and vegetation cover decline from 3.93 % to 3.37%. Population, road and built-up area densities show significant increase. The population density rose from 27.72 % to 44.12 %, road density surged from 13.86 % to 47.04 %, built-up area density grew from 25.68 % to 41.92 %. Depending on the forecast results of urban sprawl, the low sprawl (45 %-55 %) with higher density and less probability, medium sprawl (55 %-65 %) with moderate expansion probability, high sprawl (65 %-75 %) with increased probability of expansion and very high sprawl (> 75 %) with lower density, high probability of expansion. The areas with a high population, road or built-up area density are less likely to sprawl in the city of Al Burami. Additionally, three sprawl patterns, continuous, leapfrog and ribbon pattern in the study area were identified, helping in further solutions to urbanization.

Keywords: Urban Sprawl, Land Use (LU)/Land Cover (LC), Landsat, Al Buraimi, Continuous Sprawl, Leapfrog Sprawl, Ribbon Sprawl etc.

INTRODUCTION

Population outburst in cities typically occur due to either a higher birth rate than deaths or due to migration. Earlier requires a long span and can be mitigated via effective public policies but the latter happens quickly and majorly due to economic and employment reasons. According to Snyder, (2002) five fundamental aspects define great, livable cities: strong neighborhoods, walkability, a network of attractive public spaces, affordability, and regional connections. Economists believe that three underlying forces population growth, rising household incomes, and transportation improvements are responsible for this spatial growth (Mieszkowski & Mills, 1993). In the area of interest, urbanization is majorly due to migration, more houses, roads and institutes (educational, public health etc.), but resources are limited. Resources are constrained by nature (land, water and vegetation) pose significant challenges and main drawbacks of urbanization. The population growth and socio-economic situation are one of the key drivers of urban sprawl (Badwi, 2024).

Context of Urban sprawl study

To have a clear context of urban sprawl, four broad areas such as resource optimization, environmental aspects, economic effects, and quality of life are necessary. 1. Resource Optimization: Urban sprawl often results in unplanned land use, spreading development over large areas with increased infrastructure costs for utilities, transportation, and services. Understanding urban sprawl helps in managing resources more efficiently (Hamidi *et. al*., 2015). 2. Environmental Aspects: Urban sprawl can cause significant environmental consequences, such as loss of agricultural land, increased pollution, and higher energy consumption due to longer commutes. (Abdel Jawad & Nagy, 2023). Analyzing sprawl helps identify these impacts and develop strategies for mitigation and sustainable development. 3. Economic Effects: Sprawl can increase infrastructure costs and reduced tax revenues per unit of land. It can also lead to economic segregation and decline in property values in certain areas. Understanding the economic implications of sprawl is crucial for land use planning and development policies. (Zhang *et al*., 2022). 4. Quality of Life: Urban sprawl can degrade quality of life by increasing traffic congestion, commute times, and air pollution, as well as reducing green spaces and community cohesion. Studying urban sprawl is necessary to understand its multifaceted impacts on the environment, economy, society, and individual well-being, and to develop strategies for creating more sustainable, equitable, vibrant cities (Tsuyoshi *et al*., 2023).

The last four decades have been characterized by a great deal of socio-economic change in Oman. The rapid transition from rural-based lifestyle patterns to urban-based lifestyle boosted the consumption of natural resources, mainly land, water, and oil (Hamad, 2019). Every city has its own land use limitations, and not all available land can be used for development or residential purposes. This has led to the multi-level housing system over single house system being in fashion. Also, the number of buildings and their heights also comes with restrictions (either via economic or environmental reasons). Population density can be distributed in various forms, and this distribution over a particular area is termed as urban sprawl. As population grows, cities expand laterally beyond their official jurisdiction limits, commonly termed as urban sprawl (Shaw, 2005). There are different types of sprawls: continuous sprawls: which are concentric around the city: leapfrog sprawl, which spreads irregularly and discontinuously; and ribbon sprawl, which grows in a linear manner around the roads and pathways.

Regarding population growth, Oman's population was approximately 4,92,416 in 1955, ranking 149th globally. In 2000, it grew to 23,44,253 and ranked 141st and by 2023, it reached 46,44,384 and moved up to 127th place. This represents a significant increase of 9.43 % from 1955 to 2023 (United Nations data). Al Buraimi's population, a significant portion of Oman's total, grew from 79155 in 2003 to 130,029 in 2023, reflecting big 64.35% increase in just two decades, that signifies urbanization (NCSI, 2024).

This study assesses urban sprawl in the Al Buraimi City, Oman by introducing a novel approach that leverages both spatial and non-spatial data with linear regression model to forecast urban sprawl based on population density, road density and built-up area density. Quantifying and studying urban sprawl at local and regional scales is important to ensure sustainability in urban planning with built- up area being a key parameter (Epstein, 2002). The past research primarily relied on spatial or remotely sensed data to assess urban sprawl in the city. Remote Sensing and Geographical Information System (RS and GIS) offer advanced spatial monitoring and planning capabilities, also helps to understand how urban patterns evolve over a period (Wu *et al*., 2015; Herold *et al*., 2003; Herold *et al*., 2006). RS and GIS prove to be effective for extracting and processing spatial data of varied resolutions for monitoring urban growth (Masser, 2001). This study provides a detailed understanding of urban sprawl, especially in cities with complex urban environments. One of the studies on the nature and pattern of urban expansion of Patna city during the period 1991 to 2008, (Gandhi *et al*., 2012) that the LU change illustrates that the urban expansion is inversely proportional to agricultural land use. Combining both spatial and non-spatial data, urban sprawl pattern can be forecasted.

This research therefore emphasizes the need of sustainable urban planning practices fit to the specific dynamics. Possible s solutions include optimization of land use to prevent urban sprawl, upgrading infrastructure to meet demand and conservation of natural resources such as groundwater and green spaces.

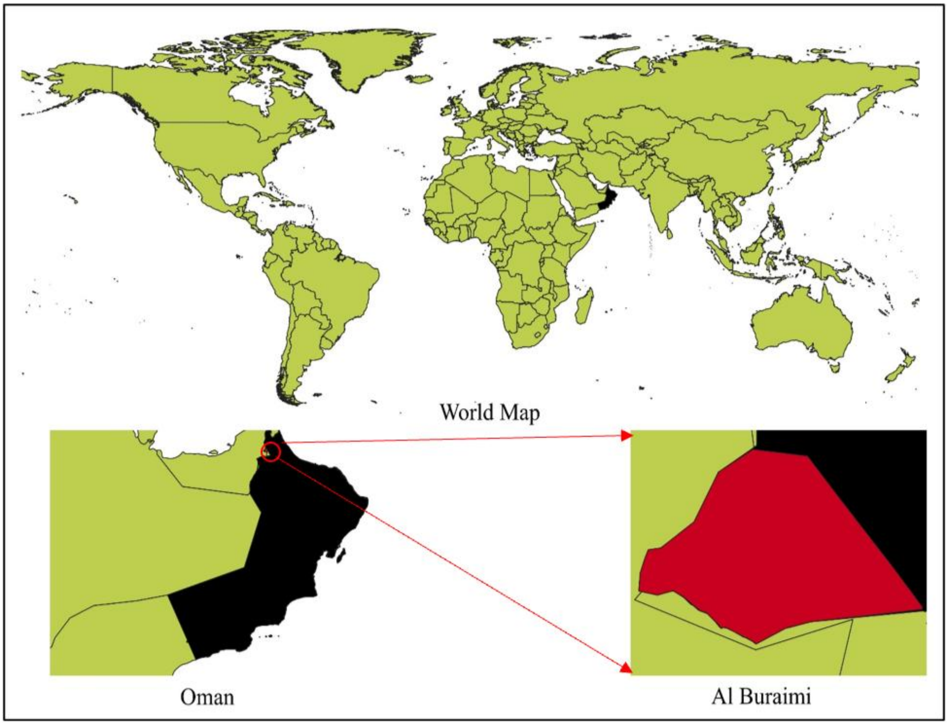
The objectives of this research are to provide a widespread understanding of the potential problem of urban sprawl in Al Buraimi city. The specific objectives include: First, to identify types of urban patterns in the city. The second objective is to examine the reasons for urban sprawl, such as population growth, industrial development, socio-economic factors and educational reasons using quantitative data analysis. The third objective is to assess Land Use (LU) / Land Cover (LC) change using geospatial methods. The fourth objective involves forecasting urban sprawl using statistical methods and the final objective is to evaluate the impact of urban sprawl in the study area and propose remedial measures.

MATERIALS AND METHODS

Study area:

Al-Buraimi (24°15′33″N 55°47′2″E) is a border province in northern Oman, near the border with United Arab Emirates (U.A.E.) city of Al Ain, hence holding a very strategic importance for cross-border trade and cultural exchange. The mainstay of its economy is agricultural, supplemented by the traditional water management system of falaj, as well as retail, logistics and tourism. Al Buraimi souq and heritage landmarks such as Al-Khandaq Fort and Jebel Hafeet make it a culturally and economically vibrant province. The U.A.E. border serves as a catalyst for economic growth but also fuels urban sprawl. The proximity to the UAE has increased cross-border migration, commercial activity and commuting, thus leading to rapid urban expansion that puts pressure on infrastructure and resources. It serves as the capital of the Al Buraimi Governorate and is one of the largest provinces in terms of population (Fig. 1).

Fig.1: Location of Al Buraimi, highlighting the study area and its geographic context



As Oman strives to assert its economic presence through rapid development, it faces challenges that obstruct progress. One major cause of obstacle in growth is urbanization, a circumstance frequent not only across the country but also in our study area, Al Buraimi. The challenges that come with urbanization in Al Buraimi include traffic congestion, random urban sprawl, inefficient land use and demand of energy reducing economic productivity and putting pressure on city's limited resources. These issues explain why, in the context of Al Buraimi, urbanization is currently an obstacle rather than a driver of growth.

The strategic location of Al Buraimi on the Oman -UAE border makes it region with significant cross-boundary economic and cultural exchanges that derive population growth and urbanization. As a result of the growth brought about by proximity to the UAE, there is rapid urban expansion, which has caused an overload on the city's infrastructure. Additionally, the increased demand for housing, resources and services places unsustainable pressure on the city's limited infrastructure further slowing its growth. These dynamics demonstrate how Al Buraimi's strategic position and population growth contribute directly to the urbanization challenges discussed in this study. The pattern of land use practices is changing with urbanization upon agricultural and desert lands, hence creating environmental challenges such as groundwater resources and reduction of green spaces. These factors demonstrate how the strategic location of Al Buraimi, natural resources and economic activities are intertwined with its urbanization dynamics.

Materials

To accomplish the desired objectives, both spatial and non-spatial data were essential. Spatial data refers to information that has a geographic locational attribute, physical location and characteristics of geographic features such as points, lines, and polygons on the Earth's surface. The spatial data used to map and analyze land use/ land cover (LU/LC) pattern in Al Buraimi, allows for a comprehensive understanding of urban sprawl and its impact on region. For instance, it is utilized to track the temporal changes in LU/LC, identifying areas of urban expansion and infrastructure development. By applying these spatial data techniques, the study aims to identify urban expansion and assess their effects on resources management housing and infrastructure. The population density data overlaid on LULLC maps to identify correlations between high density areas and built-up zones, allowing us to how urban sprawl has occurred in relation with population growth. The non-spatial data used in the urban sprawl is study refers to data which were not directly considered for geospatial analysis. In this study, spatial data such as Landsat imageries and Digital Elevation Models (DEMs) were used to create Land Use (LU) / Land Cover (LC) pattern and topographic details of the study area (Table 1). Additionally, high resolution satellite imagery from the Google Earth platform supplemented the spatial data used.

The non spatial data such as population, building density, road length, built-up area was overlaid on spatial data like LU/LC maps to identify the correlation of high-density area with built-up zones. This integration helped to analyze how population growth and urbanization patterns impacted LU and infrastructure development. Table 1 provides a detailed overview of the spatial data such as Landsat imagery Digital Elevation Model (DEM) and non-spatial data inventory used in the study including data, product, year, data format, spatial and temporal resolution.

Table 1: A comprehensive overview of data sets used in the analysis

Type	Products	Year	Data format	Resolution	
Spatial Data				**Spatial**	**Temporal**
Landsat Data: Landsat 9 OLI-2/TIRS-2, Landsat 8 OLI/TIRS, Landsat 7 ETM+	USGS	2003-2023	Raster	30 m	-
Digital Elevation Model	NASA-Earth data	2003-2023	Raster	30 m	-
High resolution satellite data	(Google Earth Pro)	2003-2023	Raster	15 m	
Non-Spatial Data					
Population Data, Building Density Data, Road Length Data, Built-up Area etc.		2003-2023	Statistical	-	-

In the LU/LC maps, the data on spatial pattern Landsat imagery and DEMs have integral parts to understand the urban sprawl in AL Buraimi with detailed temporal land use change information. The present research will make it possible to indicate the pattern of time-to-time urban growth expansion and how the expansions are linked to city infrastructure and environmental stresses. The population density data superimposed over LU/LC maps to pinpoint the highly dense areas of concentration of population growth and its relationship with urban sprawl. It helps to estimate the future urban growth and consequences in terms of resource utilization such as land and water. Further, the data of building density analyzed in respect of the classes of built-up area that define the form of urbanization and relation to infrastructure demand and shortage of housing. DEM data provides topographical insights which help in the identification of areas prone to development pressure, hence informing planning decisions related to sustainable urban growth. These data types work together to provide a comprehensive understanding of urban sprawl and its drivers, supporting the study's goal of proposing solutions for managing urbanization in Al Buraimi.

Methods

Data processing and analysis:

Spatial data is processed using GIS software to create Land use (LU) / Land Cover (LC) map for the study area, derived primarily from Landsat data. However, a fine resolution satellite imagery by providing finer details during the validation process of detected pattern of urban sprawl and in specific classes of LU/LU. Changes in the boundaries were identified and classes verified using historical images from Google Earth Pro, especially those captured between 2003 and 2023. It visually interpreted the images cross checked against the Landsat-based classification for completeness in areas which coarser resolution of the Landsat data could not capture. The incorporation of Google Earth imagery enhanced spatial accuracy and complemented the Landsat data by sharpening the edges of the boundaries for built-up areas, roads and urban features that are crucial to understanding the dynamics of urban sprawl. A supervised classification (maximum likelihood) was performed using semi-automatic plugin where the algorithm is trained on a labeled dataset with known class or categories. For pre-processing Flaash atmospheric correction was applied to remove atmospheric distortions, ensuring the reflectance values represented the true surface properties. The steps included collecting Landsat data, pre-processing and classifying it using semi-automatic classification tool, clipping it to fit the study area and classifying it into five categories. A cross-classification process generated a change matrix for two different time periods. High resolution historical satellite imagery of Google Earth Pro was used to identify sprawl patterns and validation of LU/LC data.

A mathematical model was developed to forecast urban sprawl patterns in Al Buraimi city. Using a linear regression model, predictions for population density, road density and built-up area density were made with 95% confidence interval. The 95% confidence interval in the model applies to the predictions of population density, road density, and built-up area density. It gives the range within which the true values for the said parameters are likely to fall with 95% confidence. That is not applied directly to the sprawl factor (δ), but it does serve as an estimate of the underlying density predictions that go to calculate the sprawl factor. The confidence interval will aid in interpreting the uncertainty of the prediction of those individual parameters and ensures the forecasted values by the model are within a statistically reliable range. These predictions have been used to model urban sprawl in various zones, A to R. Three parameters α, β and γ representing population density function, road density function and built-up density function respectively, were created using equations (1 to 4). These parameters were combined to provide a sprawl factor (δ) of urban sprawl in each area. The sprawl factor (δ) quantifies the percentage extent of urban sprawl in the area ranges from 0 to 100 % using equation 4. The intensity of sprawl with higher values indicates greater chances of urban sprawl. For instance, areas with high population growth, increasing road networks, and expanding built-up zones will exhibit higher (δ) values, signifying a greater likelihood of urban sprawl. (Fig. 2).

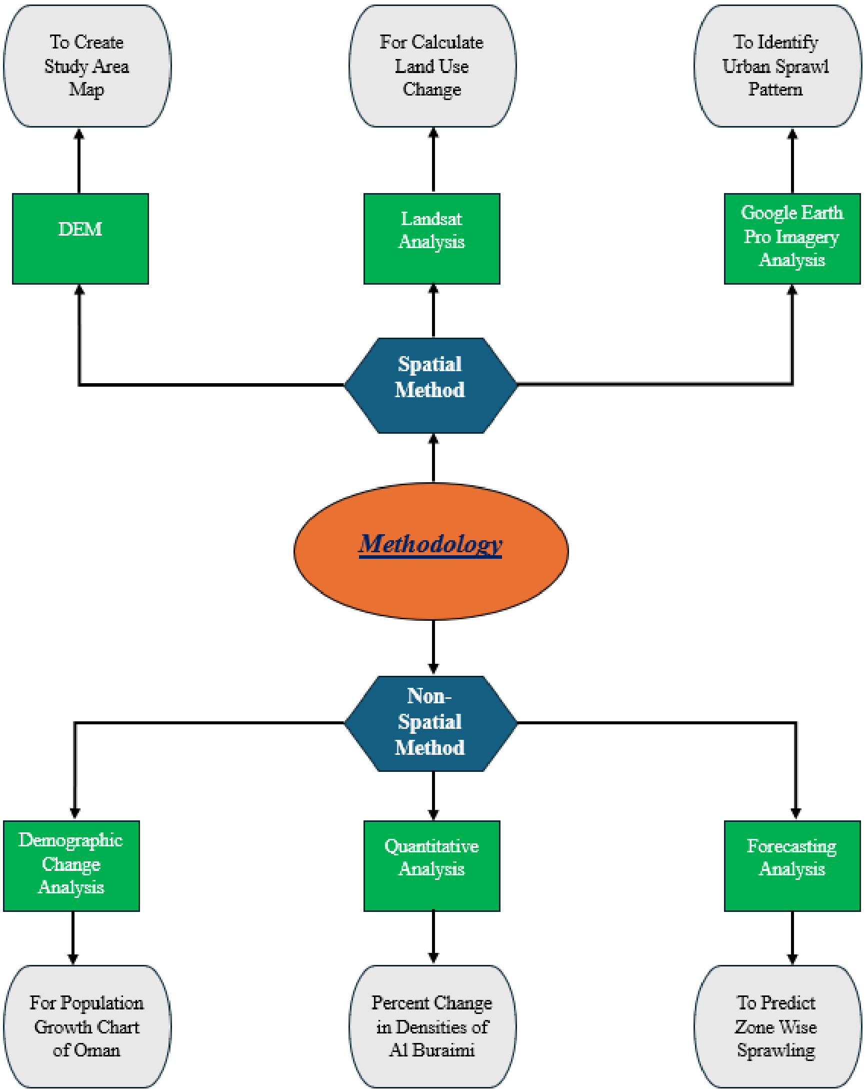
$$\alpha = \frac{Forecasted\ Population\ Density}{Total\ Population\ Density} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$\beta = \frac{Forecasted\ Road\ Density}{Total\ Road\ Density} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

$$\gamma = \frac{Forecatsed\ Built{-}up\ Density}{Total\ Built{-}up\ Density} \quad \ldots\ldots\ldots\ldots\ldots(3)$$

$$\delta = \frac{\alpha+\beta+\gamma}{3} \times 100 \quad \ldots\ldots\ldots\ldots\ldots(4)$$

Fig. 2: Methodology Flow Chart



RESULTS

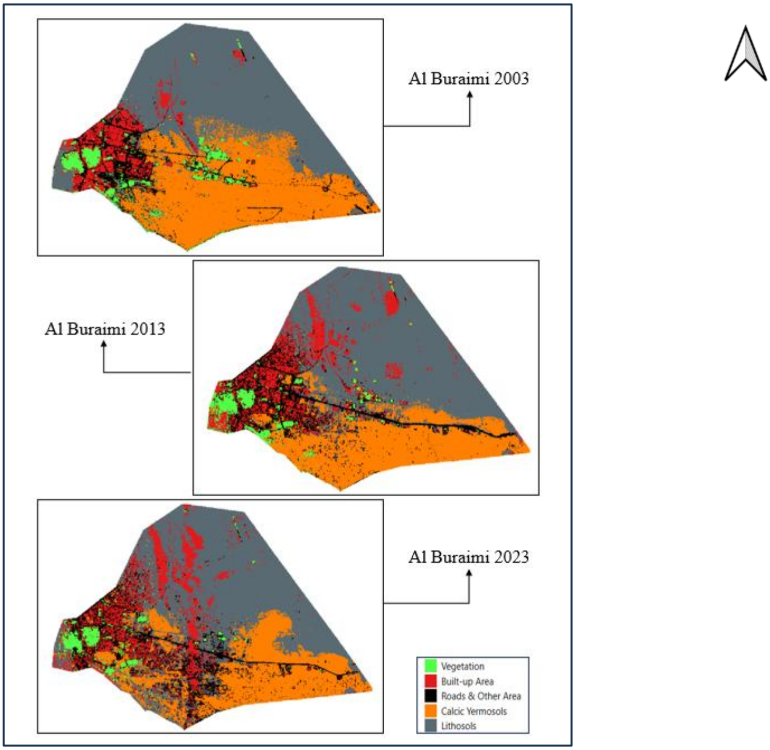
The result section consists of three sets of analyses:1. Land Use (LU)/Land Cover (LC) Analysis. 2. Quantitative Analysis and 3. Forecasting Urban Sprawl.

Land Use (LU) / Land Cover (LC) Analyses

The LU/ LC analysis compares data from three time periods 2003, 2013, and 2023 of Al Buraimi city. The main goal was to identify patterns, trends, and drivers of change using Geographic Information Systems (GIS), Remote Sensing (RS) techniques, and statistical methods. RS data combined with GIS, provides study of urban sprawl (Pandey *et al*., 2012; Harris & Longeley, 2000). LU change analysis shows the spatial representation of urbanization across five categories. Further, LU change matrix method was applied to calculate the percentage change, shows reduction in vegetation areas reduces and increase in built-up areas and road density indicating urbanization.

From the LU/LC results, it is evident that the vegetation area in 2003 was larger compared to 2023, while the built-up area was smaller in 2003 and increased in 2023, suggesting rapid urbanization in the city. (Fig. 3). For detailed analysis, an additional step, called "cross-classification" was included. In this process, LU categories were classified and compared across various time periods using two classification schemes. This method provides a detailed and better understanding of LU has changed over time by considering multiple approaches or classification systems simultaneously (Fig. 4).

Fig. 3: Comparative analysis of Land Use (LU) / Land Cover (LC) classification for Al Buraimi city from 2003 to 2013 with projections for 2023



The cross-classification of LU change analysis include cross-tabulating LU categories from the initial classification to form a new category that combine LU types from different periods. This method generates a "transformation matrix" where each cell represents a unique combination of LU categories. The matrix is then converted into a percentage change matrix to measure and analyze the data. A schematic "percentage change" graph is plotted as a pie chart after processing the data (Fig. 5). The percentage change analysis shows that from 2003-2013 and 2003-2023, vegetation decreased, and the built-up area increased significantly, clearly indicate urbanization (Table 2 and Table 3).

Fig. 4: Land Use (LU) / Land Cover (LC) change conversion among different classes from 2003 to 2013 and projected changes up to 2023

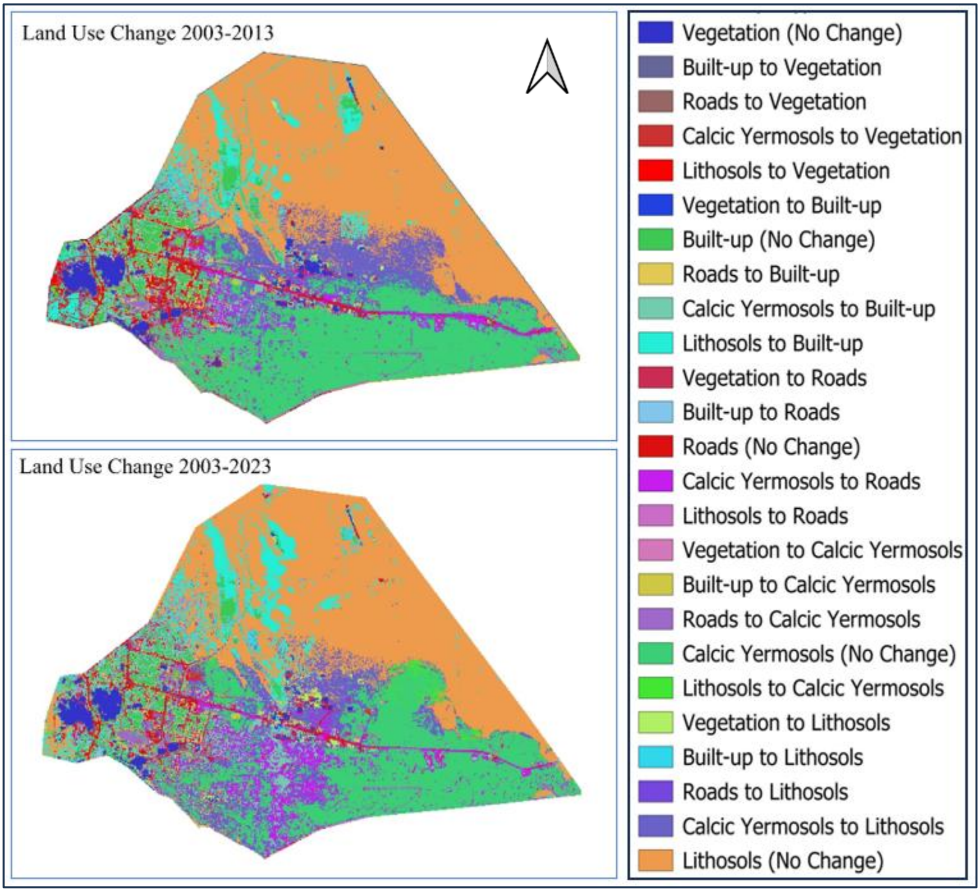


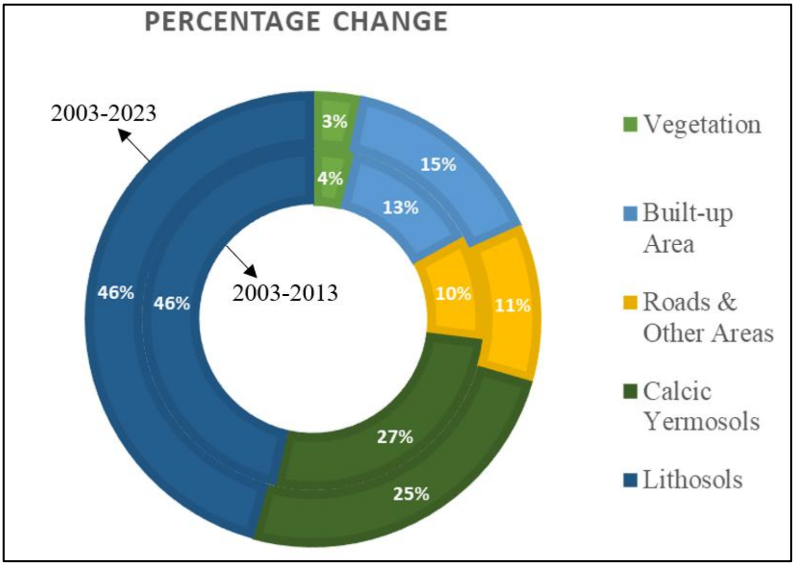
Table 2: Detailed analysis of LU changes in Al Buraimi city from 2003-2013

Referenced \ Classification	Vegetation (m^2)	Built-up Area (m^2)	Roads and Other Areas (m^2)	Calcic Yermosols (m^2)	Lithosols (m^2)
Vegetation	3533400	963900	1062900	711900	567900
Built-up Area	565200	6795900	3337200	122400	480600
Roads & Other Areas	543600	2231100	5348700	2442600	985500
Calcic Yermosols	315900	1627200	4029300	36465300	13973400
Lithosols	1061100	8542800	1441800	1072800	55201500
	3.93%	**13.14%**	**9.92%**	**26.60%**	**46.41%**

Table 3: Detailed analysis of LU changes in Al Buraimi city from 2003-2023

Referenced\ Classification	Vegetation (m^2)	Built-up Area (m^2)	Roads and Other Areas (m^2)	Calcic Yermosols (m^2)	Lithosols (m^2)
Vegetation	2799900	1049400	1102500	504000	1384200
Built-up Area	531900	5790600	3140100	363600	1475100
Roads & Other Areas	708300	2198700	3966300	3003300	1674900
Calcic Yermosols	548100	4302900	7791300	32198400	11570400
Lithosols	570600	9486000	1236600	1982700	54044100
	3.37%	**14.88%**	**11.23%**	**24.80%**	**45.72%**

Fig. 5: Percentage Change in LU data of Al Buraimi; A comparative analysis from 2003-2013 and 2003-2023

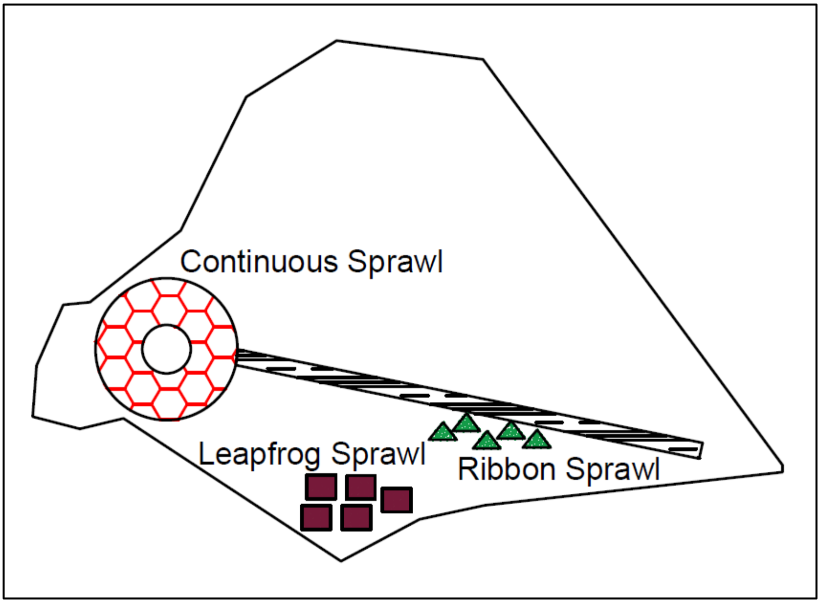


Validation with high resolution Google Earth Image:

To validate the Land Use (LU) / Land Cover (LC) results, high resolution imagery from Google Earth's open access platform, providing historical imagery of the city of Al Buraimi, was utilized. Imagery analysis confirms the results obtained from LU change analysis; revealing clear pockets of urban sprawl.

Three types of sprawl patterns continuous, leapfrog, and ribbon were identified in the study area. Understanding this sprawl patterns is very important as it will helps in adaptive solutions to urbanization. Google Earth Pro image analysis gives significant evidence of urban sprawl in the Al Buraimi city, easily detectable in images from 2003, 2013, and 2023. The imagery showed continuous sprawl in the west part of the city, settlements are concentrated around the former inhabited areas. In the southern part, urban expansion occurred in scattered manner which indicate state of leapfrog sprawling. In the central area of the city, especially around the major roads, pocket settlements have been developed over the years which represents ribbon sprawl (Fig. 6).

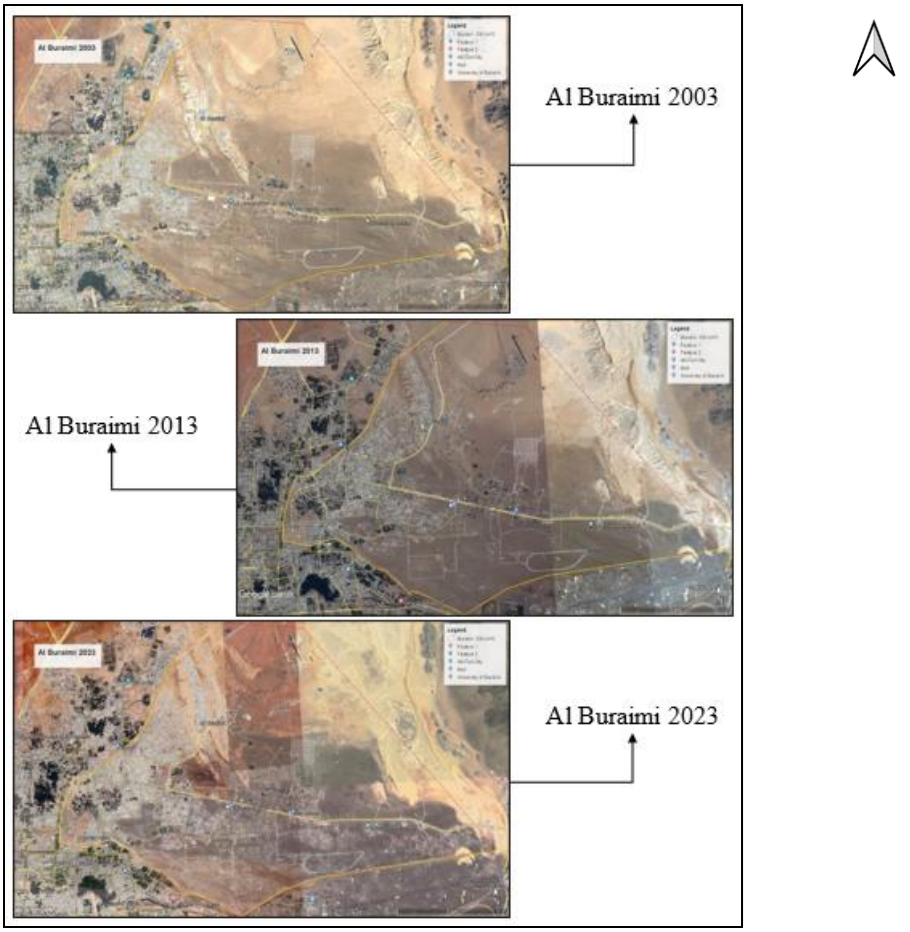
Fig. 6: Types of urban sprawl and their impact area, in Oman



Many factors that drive urbanization, with population growth being predominant in the study area. It is clear in Figure 4 and 5, factors such as population, urban population, average age and density exhibit increasing chronologically. Industrialization emerges as a second factor contributing in urbanization. Data reveals that the western part of Al Burami is densely populated. The specific reason for urbanization in this region is attributed to proximity with Al Ain city of United Arab Emirates (UAE) as well as its topographical considerations.

The figure 7 provides a visual journey of urbanization process in Al Buraimi city by showcasing historical images, highlights distinct urbanization pockets.

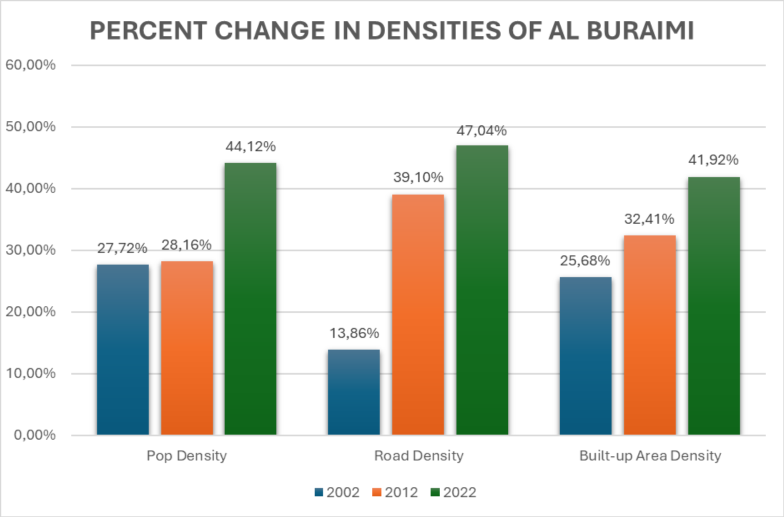
Fig. 7: Evolution of urbanization pockets in Al Buraimi city; analysis of historical images from 2003 to 2013 and projected changes up to 2023



Quantitative analysis:

Quantitative analysis was employed to get evidence of urbanization. This analysis, relies on mathematical and statistical techniques to understand, interpret, and draw conclusions from available data. It involves the calculation and interpretation of numerical data to make decisions or predictions. Three indicators, population density, road density, and built-up area density, were used to get the desired evidence. These indicators were selected strategically due to their direct correlation with urbanization. The percentage change graph illustrates minimal increase in population from 2003-2013, but remarkable changes from 2003-2023 (Fig. 8). Road and building density differences are important markers to rampant urbanization within the study area. Notably, road and built-up area density were found significantly increase by 2023 compared to 2003. Thus, these three parameters exhibit correlations with urbanization, enables to predict saturated and unsaturated regions within study area.

Fig. 8: Percent change analysis in population density, road density, and built-up area density from 2003 to 2023



Forecasting urban sprawl

Urban sprawl forecasting was conducted using a mathematical model to predicts the probability of dispersal within different regions of the study area. The results categorize sprawl into four types: low sprawl (45 %-55 %), medium sprawl (55 %-65 %), high sprawl (65 %-75 %) and very high sprawl (>75 %) (Fig. 9). Low sprawl indicates a less probability of expansion due to higher density, while a very high sprawl suggests more chances of expansion due to lower density. The results shows that areas with high population, road or built-up area density, have a lower chance of sprawling in the future, whereas less dense areas have a higher probability of sprawling (Fig. 10 and Fig. 11).

Fig. 9: Forecasting /Predicted pattern of urban sprawl in Al Buraimi

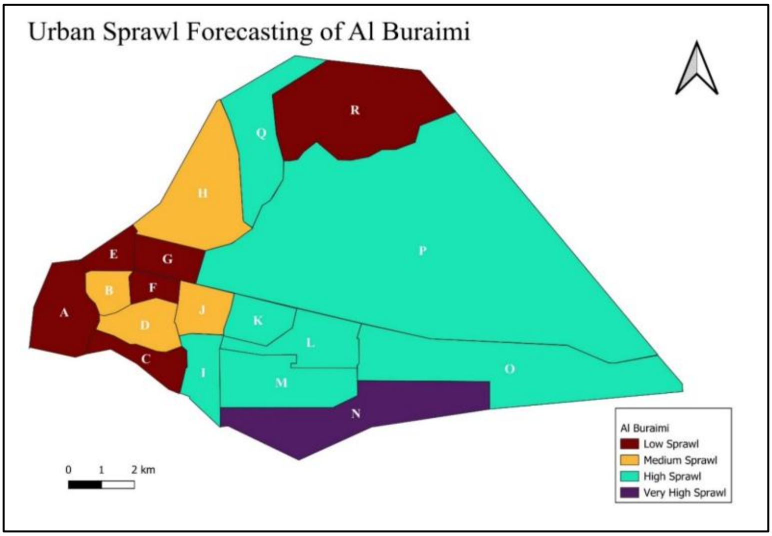
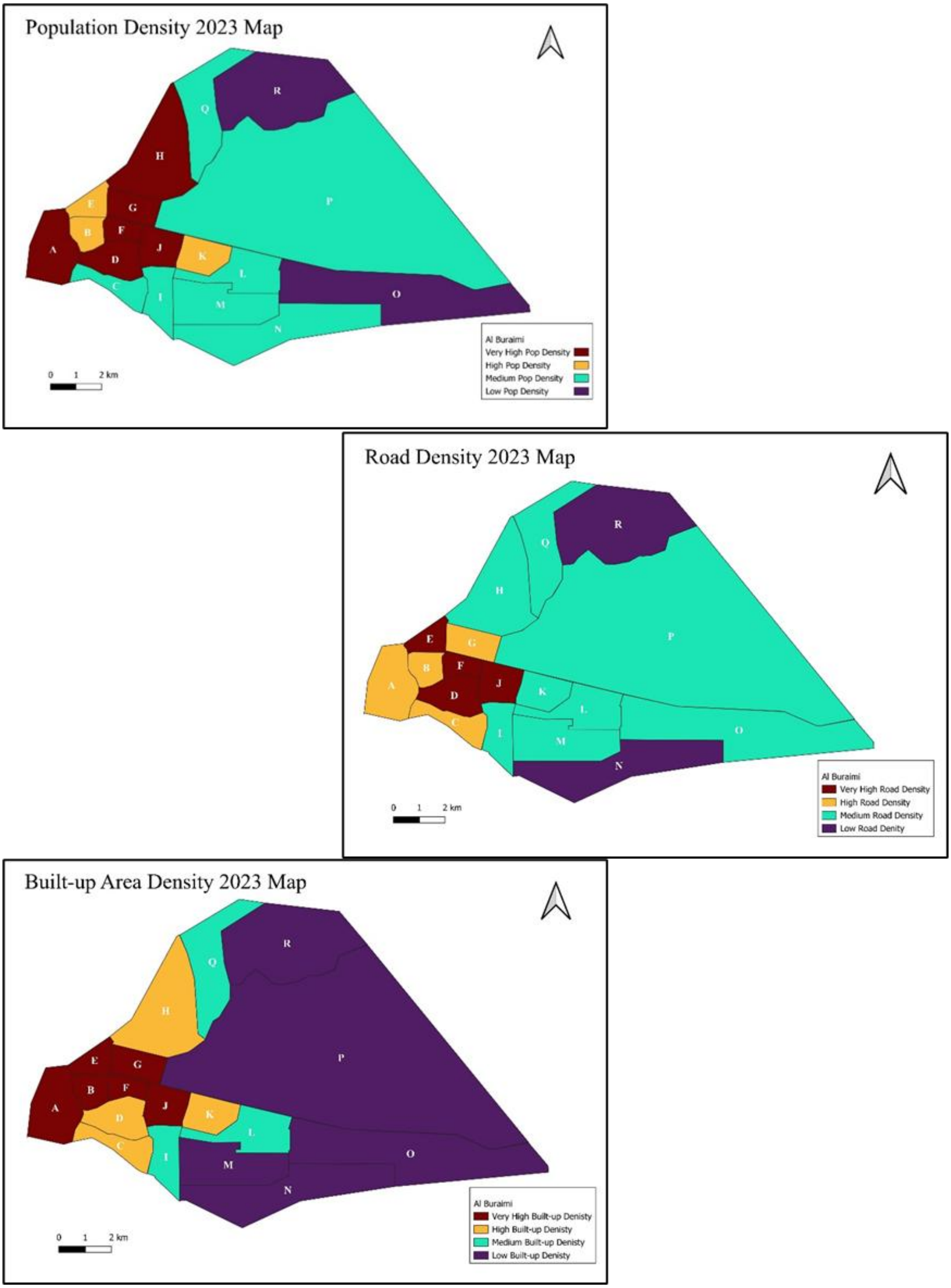


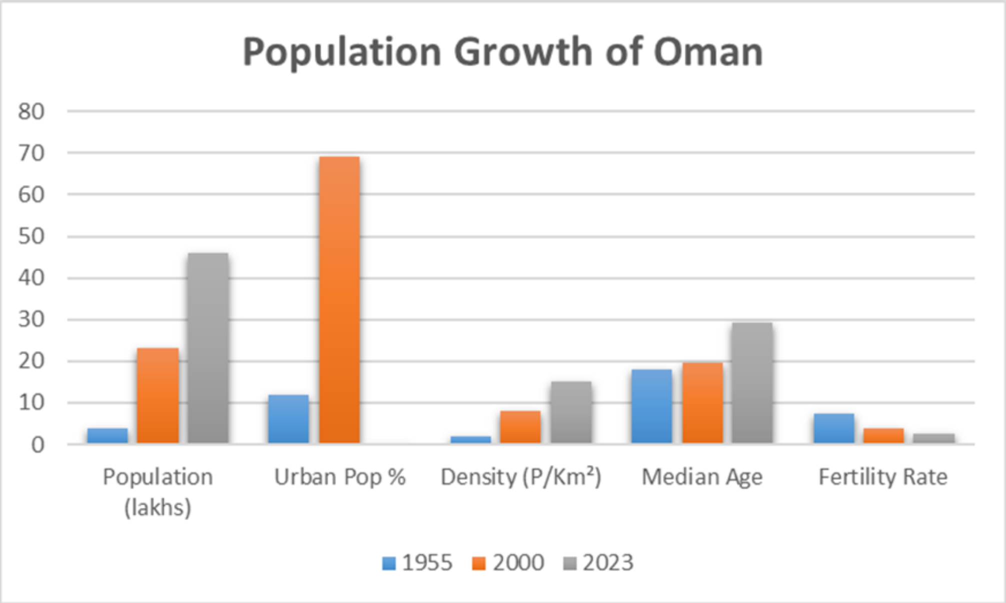
Fig. 10: Maps of population density, road density and built-up area density in Al Buraimi



Validation

As previously discussed, low sprawl indicates that further urbanization is less likely, due to already high road density, population density or built-up area density. And it clearly indicates that the western regions are extremely dense (low sprawl forecast), whereas the eastern areas (center right) and southern areas (center down) reveals sparse condition, high sprawl forecast.

Fig. 11: Population growth chart of Oman



DISCUSSIONS

The aim of this study was to identify and analyze urban sprawl and its patterns in the Al Buraimi city. Both spatial and non-spatial methods were employed to detect urban sprawl. Further, sprawl forecasting was conducted using mathematical model with results validated against available quantitative data. To mitigate urban sprawl in Al Buraimi, following policies recommendations are suggested:

1. Smart Policies: Implement zoning regulations and land-use planning that promote compact, mixed-use development with higher population densities. This encourages the efficient use of land and resources, reduces sprawl, and promotes walkable neighborhoods.
2. Transit-Oriented Development: Invest in public transportation infrastructure and aware public to prefer public transport instead of personal transport. This will reduce traffic congestion and Green House Gas (GHG) emissions. Develop communities around transit hubs to minimize car dependence and encourage sustainable modes of transportation.
3. Preservation of Green Spaces: Protect agricultural lands through land conservation programs and develop urban growth boundaries to prevent further sprawl into undeveloped areas. Impose surcharges on development projects that encroach green spaces.
4. Improve Streets: Design streets to accommodate all users, including pedestrians, cyclists, and public transit riders.

5. Public Participation: Involve residents, stakeholders, and community organizations in the planning and decision-making processes to ensure that development meets the needs and preferences of local communities. These strategies can help the Government of Oman mitigate the negative impacts of urban sprawl and create more sustainable, resilient, and livable cities.

Relevant studies

Several studies on sustainable urban development of cities can provide valuable insights for Al Buraimi city. Some of these studies will be helpful in implementing better future strategies for city like Al Buraimi. Some of these studies are discussed in this section. The costs and negative externalities of urban sprawl have been widely studied and documented (Duncan *et al*., 2013; Frank, 1989; Kunstler, 1993; Burchel *et al*., 2012; Kahn, 2000; Freeman, 2001). However, there are some additional downsides of urbanization. One significant issue is environmental degradation. Urban sprawl leads to increased pollution due to more vehicles use and greater distance between destinations. Evidence of the environmental impacts of sprawl continues to mount. Kirtland *et al*. (1994) reports that the impact of urban land on environmental quality is high due to its spatial expansion which damages ecosystems, contributes to climate change, and reduces air and water quality.

Another issue is the increased Infrastructure costs. Urban areas require more infrastructural development of roads, utilities, and public services. Third, traffic congestion is also a major problem associated with sprawling development. This not only wastes time but also contributes to air pollution and GHG emissions. Sprawl is cited as a factor in air pollution because the car-dependent lifestyles impose results in increased fossil fuel consumption and GHF emissions (Stoel, 1999). Sprawl creates longer commutes, leading to more traffic congestion (Bruckner, 2000; Ewing, 1997; Pedersen *et al*., 2012). Wasserman, 2000) 4. Fourth, the loss of agricultural land, As urban areas expand, valuable agricultural land is often converted into residential or commercial developments, reducing the availability of locally sourced food and increasing reliance on long-distance food transport.

CONCLUSION

Urban sprawl, the central theme of this research, likely emerges as one of the major challenges of the 21st century. It will affect not only the developing but also the developed countries. Quantifying and assessing its pattern, along with futuristic plan would be crucial especially, for the cities like Al Buraimi. The finding reveals three types of sprawl pattern in the study area, continuous, leapfrog, and ribbon, help in adaptive solutions to urbanization.

The key indicators such as population, road, and built-up area densities show significant increase in the last two decades. Based on the forecast results of urban sprawl, 60 to 70 % of the city of Al Burami will undergo a high probability of urban expansion. Urban sprawl in Al Buraimi can be mitigated through long-term planning and effective execution and requires associated public and governmental support. However, this research identifies zones of sprawl along with their types of impact which will help the government in making long-term mitigation plans and execution strategies with key areas.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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