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Observing the dynamics of urban growth of Al-Baha City using GIS (2006–2021)

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ABSTRACT

This study observes and records land cover changes in Al-Baha to track urban growth. The study develops a schematic vision of urban mass's current and future shape and distribution and its growth to achieve sustainable urban development, reduce service and social differences between city areas, and integrate urban and rural areas. The study uses inductive methods to monitor urban developments, population growth, and land use through Al-Baha's structural schemes by extracting digital data from satellite imagery to survey historical land cover changes. The mapping software ArcGIS v10.8 processed these digital data and the final map compositions. Through this urban mass study, the research predicted city growth and development. Capabilities and functions must shape urban and rural-urban communities. The development must also consider the National Urban Development Strategy, the relative importance of rural-urban communities, and their expected functional role in influencing the development of small rural communities adjacent to them to reduce migration from rural areas near the city. The study highlighted changes in city land coverage. Al-Baha expanded from 1982 to 1995. Al-Baha's transformation from village to city accelerated, increasing its area from 31 km^2 to 44 km^2. Many villages beyond 40 were included in the decisions. From 2006–2021, the city's area grew 221%. It increased from 60 km^2 to 133 km^2 in an urban area, indicating false urban growth. The study stressed the importance of geographic information systems (GIS) and remote sensing (RS). The study recommends urban development in suitable areas because agricultural development is not feasible, especially in the northeast. Land use changes should be prevented by planning regulations because these agricultural areas are essential. Helping urban development move away from agricultural areas, especially on the eastern axis, is crucial. Create new urban centers along Al-Baha's western cliff to attract residents and relieve pressure. Limited linear expansion, especially in the northeast, and more expansive urbanization are also significant. Maps should also show when the Al-Baha region's expansionary scope changed and the urban boundaries that had to be reached by a specific time while development plans were efficiently monitored.

1. Introduction

A city is perceived as a social, economic, political, cultural, and urban component that effectively develops and prospers in a specific spatial space while working and interconnecting uniquely to distinguish one city from another [1]. Al-Baha witnessed during the previous decades urban expansion, urban growth, and economic and social growth in all sectors [2]. The government institutes in Saudi Arabia were keen to establish development projects and expand urban development programs such as land grants and financing loans from the fund real estate development [3]. The government is given the modernity of municipal lands' control and management system as many citizens sought to disregard agricultural lands with large areas that exceed their actual needs and prove their ownership [4]. This research was concerned with studying the dynamics of urban growth of the city during the previous periods. Therefore, the research problem lies in the need to study and monitor urban growth and analyze the negative effects of horizontal urban expansion. The motivating factors and the determinants of urban growth are represented in the hills and mountainous areas of the city. The regional plan for the Al-Baha region, where the criteria used to classify villages and rural communities according to their relative importance in their region, were studied. The relative weights of each of these criteria were determined in proportion to the relative importance of rural communities. The structure of the system of rural-urban

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communities and their classification and setting standards for relative weight for classifying villages in Al-Baha were analyzed and categorized into three categories (civilized villages - moderately urbanized villages, less urbanized villages).

Al-Baha is considered one of the cities in Saudi Arabia that, along with other cities, has been negatively impacted by the expansion of urban growth that is excessively damaging to the environment. Since Al-Baha contains agricultural components and natural cover, there is randomness in the land use, which requires accurate and precise knowledge and monitoring of this growth. The development of a large number of farmlands into residential areas has been a source of concern in recent times. This is in addition to the fact that the responsibilities of government agencies concerned with controlling the growth and urban sprawl on agricultural lands in the region overlap with one another. Urban sprawl is considered a significant threat to the forests and green areas, as well as to the tourist nature of these areas, because the region naturally extends in both directions, north and south. Furthermore, increased land encroachment in large areas exceeds the actual need, which is another factor to be concerned about.

The increased land encroachment was in addition to the rise in housing loans that occurred during previous periods, contributing to the housing area's expansion. Additionally, the modernization of land control and management systems contributed. This study aims to provide a clear picture by tracking and monitoring urban growth from the year 2006–2021, primarily because there is a lack of a clear strategy for the region that governs urban growth in a way that ensures the integration of other services, enhances development, and increases the concerted efforts of all parties to achieve balanced growth. The unbalanced urban growth is because the region has not yet developed a strategy that governs it in a way that ensures the integration of other services. In the future, it may be challenging to deal with urban development logically, and it may also be financially costly due to urban development being characterized by its rapid dynamism. Furthermore, the study intends to provide some recommendations that will contribute to activating this urban expansion without causing any harm to the natural resources situated within the city.

The research aims to analyze the stages of urban growth in the city of Al-Baha. The study attempts to monitor the urban mass of Al-Baha in 2006, the urban mass of the city of Al-Baha in 2021, and the motivating factors for urban growth that are specific to it. The research also seeks to develop recommendations to control urban development and expansion. The discussion of urban mass and growth of Al-Baha between 2006 and 2021 is considered the central pillar of the study. The importance of the study lies in discussing the phenomenon of urban growth, which threatens the future of the natural environment in the city of Al-Baha. This research must support and make decisions for decision-makers in the city to identify the reality of urban growth and its development over time, to reduce the undesirable effects of random and irregular urban sprawl.

In the previous years, significant developments in Al-Baha have accelerated urban changes, which created the need for this study. Accordingly, the present study sought to observe the nature of the dynamic urban changes occurring in Al-Baha by determining a geographic information system that is based on analyzing and deducing satellite imagery data to achieve the following objectives:

- Monitoring and recording urban change features in Al-Baha through undertaking a comparative study of the following elements in consecutive periods via Urban expansion and its patterns and the inconsistency of land covers distributions in the Al-Baha.
- Distinguishing the contributing factors to urban land covers development.
- Producing modern digital maps that track changes in urban land cover.
- Witnessing the inconsistency in the land covers distributions in Al-Baha during the study period.

The study pursued answers to the following questions to achieve these objectives:

1. What are the significant changes in the urban morphology of Al-Baha throughout the period between 2006 and 2021?
2. Does any land cover distribution variance occur in Al-Baha between 2006 and 2021?
3. What are the contributing factors to the urban changes and land cover changes in Al-Baha from 2006–2021?

The importance of this study is toward maximizing the need for developmental or planning decision-makers to rely on the spatial technologies embedded in GIS and remote sensing in obtaining, cataloging, and analyzing any piece of information. Furthermore, the study aims to save time and effort and ensure speed and accuracy in providing data so that an urban planning decision is reality-based and built on solid foundations, especially in the case of Al-Baha, which require constant information updates and changes follow-up.

2. Literature review

2.1. City urban growth and its relation to GIS

At all levels of civilization, urbanization is slowly but surely becoming a worldwide issue. Rapid urbanization occurs in all countries, whether they are developing, developed, or destitute. Urban sprawl could be a way to shift from traditional rural to modern developed economies. Urban planning is one of the most common applications of GIS. GIS applications are relevant in all stages, divisions, industries, and urban planning responsibilities. For example, GIS technology is used in urban city expansion to provide city planners with improved information transparency, assess viability projects, and predict environmental impact.

Information is a critical part of city planning and growth. Data from several sources can be stored, managed, and accessed more easily with Desktop GIS. In addition, it provides the same benefit while making it accessible from any device. GIS makes everything very straightforward and easy [5]. The potential of GIS to construct potential urban development scenarios is one of the benefits of employing technology in site appropriateness studies [6]. A practical option in the context of GIS is a spatial or GIS-based procedure for determining the acceptability of a specific area for one particular use. El Garouani et al. (2017) explain an ecological design and policy concept that encourages interconnecting open areas, a multi-modal transport network, and mixed-use construction guided by GIS in urban development. GIS can analyze the real world by layering content and integrating it with its physical position [7]. It can define the population in multi-scale, three spatial dimensions, using a characteristic table detailed description [8]. The Geographic Information System (GIS) is both a repository and an instrument for urban planning. The geo-relational paradigm can collect and connect geographical and literary data in a database-oriented GIS [9]. In providing detailed information, GIS allows planners to be decisive in planning. The essential sources for geographic information system maps. When employed in a GIS system, remote sensing techniques provide the most up-to-date and detailed estimates. In addition, the non-spatial data associated with it is beneficial to urban planners and decision-makers [10]. Information is essential in assessing projects. GIS aids in the management of such databases, which can then be used to advise enterprises on the effectiveness of collection materials, allocation of bioenergy advantages, and cost-benefit analysis.

Further, assessing the project's success is a significant consideration for urban planners to reduce wasting time and resources. To record and analyze the dynamics of urban growth, remote sensing (RS) provides spatial data that may be merged with GIS to create integrated geographic information. When used in conjunction with a GIS, RS can be used to quickly examine the effects of geographical features on urban

sprawl [11]. Remote sensing combined with GIS technology has been shown to produce scientifically valid conclusions and policy suggestions that have aided choice and planners in advancing sustainability, particularly in rapidly increasing urban areas [12]. GIS enables the overlay of various data perceptibly and communicably to multiple stakeholders. As a result, GIS effectively combines, represents, and distributes data to drive the Urban Green Space planning and implementation [13]. Alazzawi (2020) explains that measuring GIS productivity is critical to the organization's overall GIS success [14]. It also greatly aids in the processes of organizational change and strategic planning. GIS has a broad array of applications in structural engineering, including geographic solutions [15]. Karimi et al. (2018) explain that transportation, aquatic ecosystems, building maintenance, urban planning, architecture, and E-business are just a few examples [16].

Furthermore, Khwarahm (2021) suggests that GIS is utilized to visualize the geographical state of a construction area. Apart from assessing the viability of city projects, GIS has implications for the environment [17]. Academics and civil society organizations have used GIS and RS to analyze the impacts of mineral extraction for various reasons outside of the mining sector [18]. These include local socio-economic and ecological risk assessments, regional accumulated and strategic effect assessments, and industry-wide land-use trends analyses.

Urban planning considers the environment. In the last 10–20 years, civil society groups have used GIS, RS, and visualization to evaluate the past, present, and current environment [18] GIS-based sustainable development evaluations are more accurate. A visual representation will help implement a pollution-reduction strategy and achieve environmental sustainability [19]. GIS and GPS are often used to model mining-induced risks and environmental effects [20]. Used technologies include mine development, operation, and environmental conservation [21]. GIS has been used to enable ecological models such soil degradation, land use, hydrological water quality, contaminants, and watersheds [22]. City planners prioritize conservation. Construction enterprises and ecologists can utilize GIS to measure and compare renewable resources [23]. Creating a geographical distribution and arranging new project locations helps city planners minimize sprawl and ensure social and ecosystem sustainability [24]. GIS and remotely sensed data technologies help manage solid waste from generation to disposal [25]. GIS techniques are vital for regulating urban expansion and its impact on ecosystems.

2.2. Urbanization and land use and land cover (LULC)

The land is a significant resource in urban growth and planning, thus considering deploying advanced technologies in planning. Land Use and Land Cover (LULC) modification, transitioning, and Landscape Risk (LR) assessment in earthquake-affected locations are critical for planning and urban resilience (Nath & Singh, 2018). In a user-friendly approach, the GIS allows the reader to view and analyze data to understand better linkages and patterns [26]. Several scholars have used remote sensing, and spatial analysis (GIS) approaches to assess flood hazard consequences on metropolitan areas, infrastructural, farmlands, and land-use changes [27]. Urban expansion should be seen both as an urban land layout or a spatial arrangement of a community at a given moment and as a movement, or how the structural characteristics of urban space change over time [28]. This unanimity causes problems in recognizing administrative boundaries in cities and puts pressure and stress on the natural environment [29]. In ensuring continued urban residence in the coming days, fast-growing urban areas monitoring is essential[30]. In this case, GIS and RS are significant and adequate monitoring tools in urban planning and decision-making [31]. The impact of development analysis is also considerable, with some cities performing better than others in terms of urban growth management.

Urbanization will affect land-use change along urban-rural gradients. It will result in land application concerns such as farmland conversion, natural-to-engineered land cover conversion, and non-contiguous land use [32]. GIS variables suitable land use/land cover analytical methodologies, modeling tools made possible by GIS, and land-use preparations to evaluate inland changes with cheap cost, less time, and greater accuracy [33]. Directly measure, evaluate, and determine the reason for the urban environment's shift in land use and distribution mapping to establish effective plans and tactics for practical and efficient land use management [34]. Spatial processes, geographical models, and sophisticated GIS approaches are utilized to investigate landslide susceptibility patterns, distributions, and orientations and estimate land-use change [35]. GIS and environmental monitoring are widely employed [36]. Through GIS data analysis, land use/land cover and urban expansion have been recovered[37]. Geographic data can reduce time when gathering land use and climatic factors when combined with remotely sensed data.

Urbanization often causes negative land use/land cover changes (LULC). LULC change is a major component of global environmental change, especially in arid and semi-arid nations with scarce land and water [38]. Saudi Arabia has changed dramatically in 30 years due to petrochemical industry growth and population growth [39]. GIS environment approaches are essential for quantitatively and spatially analyzing human impact [40]. GIS can be used as a strategic management tool to develop and operate, revolutionize environmental science processes, and aid environmentally conscious decisions [36]. Urbanization, industrialization, and intensive farming have altered land cover, affecting the environment and biodiversity. [41]. Geographic information systems (GIS) allow for the accurate measurement of different types of LULC, the provision of precise and comprehensive information on present and historical land cover, and the analysis of these changes, as well as the revelation of geographic patterns of urban-suburban development at various times [42]. GIS technologies are combined with other approaches to determine the relevance of criteria and weight elements to improve land suitability analysis.

A region's land use/land cover pattern is influenced by natural, socioeconomic, and human factors over time and space. In four MENA cities with different sizes and growth dynamics, a study was done to quantify patterns of urban expansion and its effects on agricultural land from the 1970 s to 2018. The study used remote sensing data to show the landscape transformation processes in various cities over the last 50 years. The findings indicate that peri-urban green areas have shrunk or shifted due to increased expansion of built-up areas [43].

Land use is a key concern for city and national architects and environmentalists when designing sustainable economic growth. Land-use and land-cover change (LUCC) remote sensing research has a long history and has advanced significantly [29]. GIS and remote sensing provide a cost-effective and precise way to study landscape changes. GIS and Remote Sensing are land-based, so they help create, execute, and assess urban development strategies for long-term sustainability[11]. LULC measures ecosystem health and quality of life. Environmentalists can use frequent edge detection to monitor and assess environmental challenges [31]. LULC dynamics change spatially and temporally due to natural and anthropogenic causes. Remote sensing photos can easily capture land use conditions and provide a data source for current LULC information and changes [30]. Remote sensing is used to monitor land use at various scales. Change detection involves collecting, storing, displaying, and evaluating digital data [34]. LULC changes and urban expansion rates have been exceptional in recent decades due to rural-urban migration and improving economic conditions. Consider urbanization drivers and urban planning improvements.

Rich and poor countries use GIS for planning. Many planning organizations have switched from mapping software to GIS. GIS technology helps city planners with information transparency, development viability assessment, and environmental effect prediction. GIS integration with planning models, visualization, and the Internet will improve urban planning. Rapid urban/built-up expansions caused abrupt reductions in farmland, fallow, and unoccupied land. To mitigate

urbanization's negative effects and ensure the long-term viability of major cities, an innovative urban planning strategy is needed.

2.2.1. Urban growth in cities

Urban morphological change encompasses most city changes over time, such as population composition, total area, and land cover [44]. Therefore, there has been an increase and continuing expansion of geographical studies monitoring this transformation. Urban city growth and land use changes are considered a classification of these studies that track and monitor these changes over time [45]. A significant amount of research has focused on the issue of urban growth in various cities around the world. Gaining insight into land use and cover alterations has become necessary for effectively managing and monitoring natural resources and development, particularly in urban planning. Remote sensing and geographical information systems are established instruments for evaluating land use and land cover alterations, which aid planners in promoting sustainability [46]. One particular study was conducted to identify and forecast changes in land use in Nepal using remote sensing and GIS technology [47]. The study employed remote sensing and geographical information systems to identify and detect land use and land cover in Kathmandu, a city in Nepal that is highly vulnerable to change and is witnessing rapid growth. According to the study, the Kathmandu district experienced a decline of 9.28% in forest cover, 9.80% in agricultural land, and 77% in water bodies over 20 years (1990–2010)[47]. Rapid urbanization is the primary catalyst for these changes, further accelerated by inadequate planning and significant rural-urban migration. A study used Remote Sensing and GIS to examine urban growth monitoring, simulation, and management in coastal cities [48]. The study investigated the urban development of Alexandria by establishing a geographic information system. This system is based on satellite imagery data collected by Landsat between 1986 and 2016. The study aimed to identify the most essential characteristics and the driving factors that actuate, either directly or indirectly, the process of urban growth. The evidence demonstrates that management regulations can assist in controlling and limiting the rapid and unplanned urban expansion occurring at the expense of natural resources [48].

Using geographic information system (GIS) and remote sensing techniques, a study was carried out at the local level of Saudi cities to forecast the growth of urban areas in Riyadh city over thirty years, beginning in 2017 and ending in 2047 [49]. On the other hand, a study uses remote sensing data to investigate the changes in land cover that occurred in Al-Khobar over a decade, from 1990 to 2013 [50]. In addition, a study carried out between 1973 and 2014 was obtained and analyzed to keep track of the changes that occurred in Jeddah spatially and concerning time [51].

Regarding Al-Baha, numerous studies have been published, including one that aimed to observe and forecast changes in land cover and analyze the characteristics and patterns of land cover change from 1975 to 2010. The study assessed land cover change in the Al-Baha region over the past 35 years. It revealed that this change had a notable impact on the forest and shrubland, potentially disrupting the ecosystem and natural balance of the study area [52]. A separate study examines the expansion of the urban regions and alterations in land cover in Al-Baha from 1984 to 2014. The study revealed a 10% reduction in forested areas, primarily attributed to creating recreational facilities in the mountainous regions. Simultaneously, the built-up area experienced a 24% expansion, primarily at the expense of barren lands but also at the expense of woodlands. The quality of the woodlands is also deteriorating, as dieback is occurring, and can be observed in the study area and the southwestern mountains [53].

The unbalanced urban expansion of the city over time, along with the resulting changes, the primary drivers of this expansion, and the subsequent problems it caused resulted in alterations to the land cover, resulting in rise to various issues. The phenomenon reduces forest area, agricultural land, and water bodies, potentially disrupting the ecosystem and the natural balance. These studies examined the alterations in land use and land cover that occurred over time and found notable expansions in specific regions within these cities, indicating significant urban sprawl in recent decades. Hence, implementing more effective governance policies can aid in managing and restraining the area's accelerated and uncontrolled urban growth.

3. Research approach

The research relied on the historical and behavioral approach and the descriptive analytical approach by reviewing the stages of urban development of Al-Baha and linking them to the development plans and the directions of the national vision of the Kingdom 2030. The research focuses on tracking the urban growth of the city land cover and its mechanisms and its negative effects on the surrounding environment and agricultural lands through the analysis of urban sprawl through different stages of time for Al-Baha. This study seeks to survey and record the changes that occurred to the land cover of Al-Baha and the urban changes therein in the period spanning 2006–2021.

This study's approach depended on selecting the appropriate case study and the appropriate data collection tools for this study. Following this, the analytic framework for the case study was utilized to cover the analysis of the collected data. This research was conducted using a case study methodology [54], which relied on a substantial amount of information that can be obtained from various sources. Due to the wide variety of data available for Al-Baha between 2006 and 2021, it was selected as the location for this study. To that end, the study adopts several approaches:

3.1. Deductive approach

A deductive approach is utilized to study Al-Baha city's urban and demographic changes through city charts and governmental reports issued by governmental institutes and academic research.

3.1.1. Spatial analysis approach

The study adopts a spatial analysis approach to extract the digital data supplied by satellite images and use them to record the urban growth of land covers and its change in the studied area. Digital data was processed, and final outputs were designed using ArcGIS v10.8. Area of the study. This study is dedicated to detecting Al-Baha's urban changes with its established administrative borders throughout the extended period between 206 and 2021. Satellite-based digital data have been highly utilized in change detection at regional scales due to their extensive availability and extensive archive. The remaining data from before 2004, which was derived from the Ministry of Municipal and Rural Affairs, shows that the changes that occurred in the urban area of Al-Baha between 2006 and 2021 were not recognized. Using remote sensing and geographic information systems (GIS) together can help generate helpful information about the amount of land changes that have occurred, where they have occurred, and what kinds of changes have occurred. Also, using satellite imagery makes it possible to observe urban change over time. It can be done retrospectively, which has significantly advanced our understanding of urban changes in Al-Baha during the selected period. This is accomplished by delivering information at predetermined time scales. Therefore, all the descriptive information based on satellite imagery and the tabled information for the study area have been analyzed accordingly. This approach allows for a dynamic awareness of the urban system's shortcomings and strengths and the primary concerns that need to be addressed.

3.2. Data processing procedures

Satellite digital data has been processed using software: ArcGIS v10.8. The essential steps in examining, processing, and analyzing the satellite-based digital data are as follows:

3.3. Data collection

The study relied on evaluating the status of the urban mass and its extension from 2006 to 2021. The study adopted a research methodology based on integrating GIS and remote sensing, where satellite imagery for Al-Baha, covering the suggested study period 2006 and 2021, has been obtained from google earth and Esri online imagery. First, the urban mass of the study area for the year 2006 was obtained and monitored via satellite imagery from Google Earth. After that, the urban mass boundaries were studied and determined in 2006. Then, the urban mass was reviewed on the satellite imageries of the study area. The study also relied on monitoring the urban expansion of the study area during the year 2021 on the Esri satellite imagery and reviewing them with the satellite imagery of Google Earth.

3.4. Image processing

The goal of satellite image processing is to determine populated areas and distinguish various land uses during the period represented by said data. The image processing focused on enhancing the imagery by combining them and filling the gap between them. In order to complete the work entrusted with the research, field visits were made to the study area to collect missing data from the site, such as the names of roads, neighborhoods, and the covered land. The study classified the area's land cover into the following covers: urban use, mountains, soil, cliffs, and plants.

4. The study area

Al-Baha region is located in the southwestern part of the Kingdom of

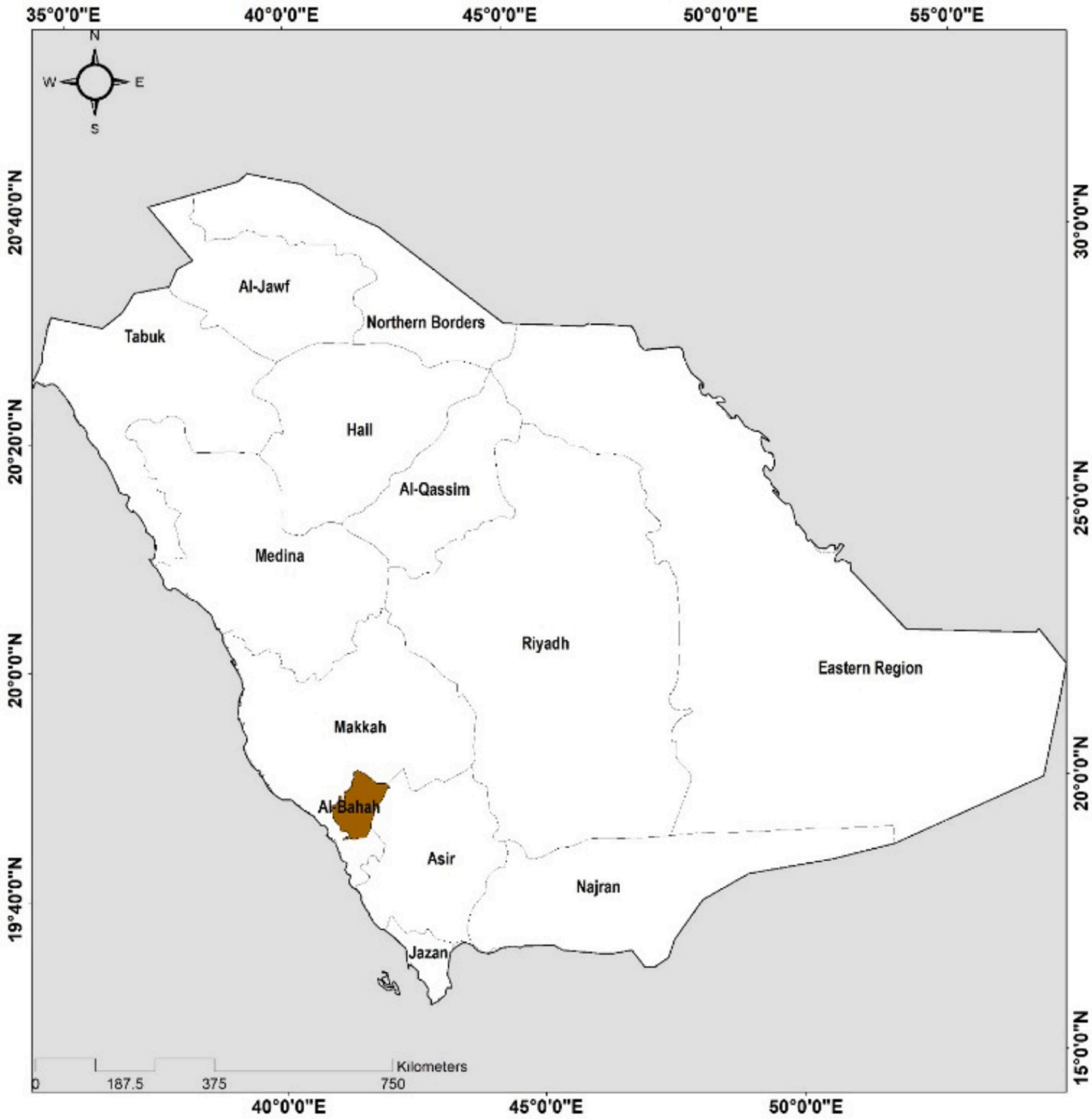

Fig. 1. Al-Baha region is located in southwest Saudi Arabia.

Saudi Arabia (Fig. 1), 180 km south of Taif and about 410 km north of the city of Abha. The Makkah region surrounds the Al-Baha region except in the southeast, bordered by the Asir region. Al-Baha region is considered one of the smallest regions in the Kingdom in terms of area, approximately 36,000 km^2 [55]. Al-Baha region constitutes 1.6% of the total area of Saudi Arabia and consists of nine main governorates: Al-Baha, Baljurashi, Al-Mandaq, Al-Makhwah, Qilwah, Al-Aqeeq, Ghamed Al-Zinad, Al-Hajrah and Al-Qura [56]. In total, there are three distinct geographical sectors in the Al-Baha region. These three sectors are represented in the mountainous Sarah sector, the Badia sector, the semi-desert part, and the coastal sector of Tihama. The area is separated by a huge rocky cliff, which is the extension of the Sarah Mountain range, where it descends more than 2500 m in a west direction towards the Tihama sector [2]. The area east of Al-Shafa is divided into two parts: the mountainous Sarah and the Badia. The topography of the Al-Baha region is exposed hills consisting of rocks with gradual slopes cut by narrow valleys [55]. The climate of the Al Baha region is moderate and pleasant in summer and cold in winter. Its mountainous nature characterizes Al-Baha, between 1500 and 2500 m above sea level, along with the Sarah Mountain range [55]. The importance of Al-Baha comes from its strategic location as the meeting point of the main roads linking the main cities in the region [2].

By comparing the classification of satellite imagery of the studied area between 2006 and 2021, a qualitative and quantitative change was detected in land use. The study argues that the change was limited to a rise in particular land use, such as transforming some agricultural land or mountain areas into urban areas and roads. Change also occurred in terms of a decrease, such as empty lands transformed into roads, buildings, or city facilities. Al-Baha went through rapid changes, resulting in land cover changes throughout the past 15 years. Through tracing the most noticeable changes on the land cover of the map Al-Baha, the study notices a rapid rise in urban use in Al-Baha. It is primarily related to many factors such as political, economic, social, geographic, and cultural factors. For instance, the result of the process of urbanizing the countryside adjacent to the city became a part of it by an administrative decision. Therefore, it is essential to understand the historical development of urban growth in Al-Baha to develop a comprehensive view of the factors that directly affect the city's expansion and control.

5. Result and discussion

Since the present is an expansion of the past, the survey studied and observed the change that occurred in the land cover of Al-Baha in the period crossing 2006–2021, concentrating on the examples of land use and factors impacting it. Through the directed characterization of satellite imagery, the study arrived at the outcomes:

5.1. The historical development of horizontal urban growth in Al-Baha

The study of urban development in different historical periods is necessary to understand the geography of the present time because it sheds light on the current urban locality and answers many questions about its interactions, structure, and growth [57]. Moreover, it gives a great picture of what the city was like in different periods [58]. Urban growth is defined as the state of the city's extension and its overlap with its surrounding neighborhoods throughout its history [59]. Several factors that determine its size and trends affect the city's growth. Various elements influence the city, including physical, social, economic, environmental, and governance. For example, migration, agricultural growth, forest patterns, and sprawl are all socio-economic factors that contribute to urban growth [60]. Perhaps the most important of them is the economic factor, which takes many forms, the current and future material capabilities determine the plans for its development and the periods required to implement those plans—knowing that the impact of those capabilities would lead to a stumble in the city's urban growth [61].

5.2. Origin and development of Al-Baha

Al Baha is a newly emerging city. Al-Baha is one of the new Saudi cities that appeared on the Kingdom's map after 1974. It did not exist as a city before that date when the capital of the Al-Baha administrative region was the city of Baljurashi. Al-Baha was one of the villages of this region. Hence, it owes more to the administrative definition than the functional one. Al-Baha is a group of villages. In the period after World War I, the village of Al-Zafeer was the administrative center of what was then known as Bilad Ghamed. Upon establishing the Saudi government, Ghamid and Zahran became administered as a unit in 1925. The Saudi authorities moved the seat of the local government to Baljurashi, a town located 14 km south of Al-Zafeer [55].

5.3. The geographical location of the study area and its spatial relations

Al-Baha is the capital of the Al-Baha Administrative Region. Al-Baha is one of the fourteen administrative regions that make up Saudi Arabia. Al-Baha is the smallest administrative area in Saudi Arabia and the least populated [2]. Its area is about 10,690 km^2, representing about 0.04% of the area of Saudi Arabia, which is about 25.2 million km^2 [62].

The main administrative area of Al-Baha is part of the southwestern region in western Saudi Arabia, known as the Sarawat Mountains. This area is characterized by the presence of the Al-Shafa line, which represents the western boundary of the rocky crystalline Arabian Shield. It also represents at the same time the water division line in the Sarawat Mountains. In addition to that, this line divides the central administrative area of Al-Baha into two parts, one east, which is the mountainous Sarah sector, and the other west, which is the arid Tihama sector. Furthermore, the city of Al-Baha is in the middle of that part of the Al-Shafa line that penetrates the central administrative area of Al-Baha.

Al-Baha city consists of 47 villages, the largest of which are Al-Baha and Al-Zafeer [63]. With this statement, one of the government reports on the development of the Al-Baha region began, and in the report's acknowledgment of the village of Al-Baha city, there is some truth to it. However, the concept of the city is still not unified by most of the official authorities [64]. Instead, the identification of the Saudi city is still an area of controversy until recently. Al-Baha city is a city in which agriculture prevails, and it is the dominant function in the city because it has no functional specialization. Al-Baha is also considered a city of trade and agriculture, but it is certain that the city, in the concept of 1982, consisting of villages - neighborhoods - Al-Baha, Al-Zafeer, and Al-Zarqa, has become the commercial heart of a larger area, which is what is known as the city's master plan area [65]. This area, in particular, gained importance among those in charge of managing the city's affairs as the city's borders until 1995 [64].

5.4. First: The historical development of the horizontal urban growth

Urban growth generally takes on two main dimensions. The first dimension is the horizontal urban growth, while the vertical urban growth represents the second dimension [66]. Cities grow and expand due to many individuals, collective, and governmental decisions [67]. There are many geographical and non-geographical factors behind this, and no city is without these physical and nonphysical factors [68]. By comparing the historical periods of the city's growth, the impact of urban growth controls becomes apparent, strongly linked to each location's geographical characteristics and future extension [69]. Therefore, horizontal urban growth is one of the dimensions of urban growth that draws attention when comparing more than a different period of time to a study area or more than one city [66]. The study follows this growth in stages, and from here, it studies urban growth by studying the development of urban spaces and urban buildings in the city.

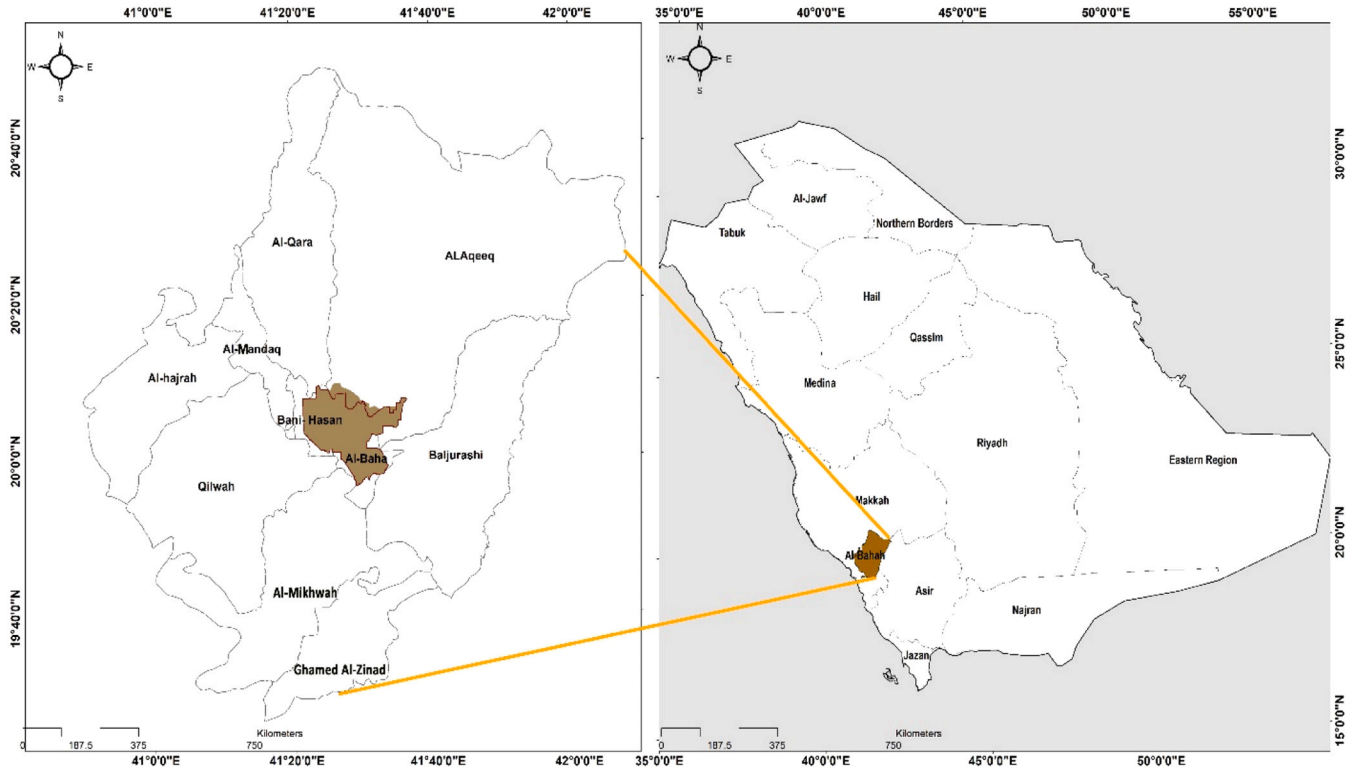

Fig. 2. The city of Al-Baha is located in a middle area between Belad Ghamid and Zahran.

5.5. *The evolution of urban growth (2006–2021)*

The study is mainly based on tracking the urban growth in Al-Baha from 2006 to 2021. Al-Baha has gone through several stages of urban development and growth trends during the past years. According to the comprehensive development plan for the Al-Baha region, the city of Al-

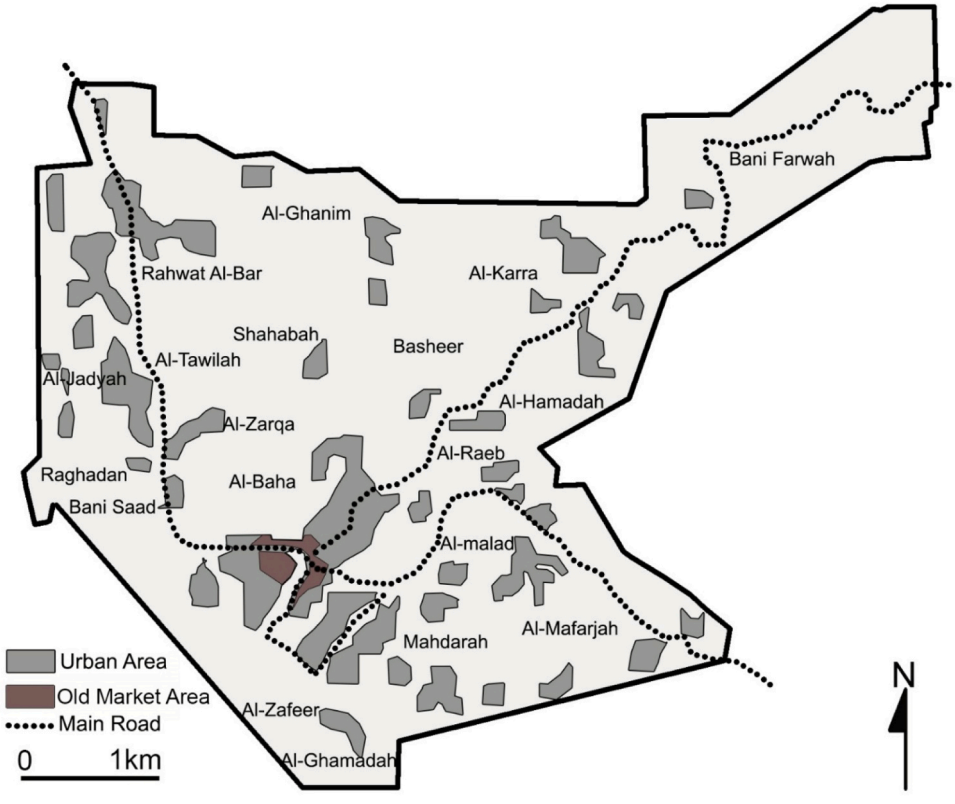

Fig. 3. The scattering of urban mass of Al-Baha during 1985. It was redrawn by the author from the comprehensive development plan of Al-Baha [70].

Baha in 1964 was what is now represented by the old market area, which is part of the old village of Al-Baha (Fig. 3) [70]. Then the city developed towards the east and south of the current old market area, or the so-called central Al-Baha, and expanded in the north direction, which was limited by the presence of Al-Baher mountain. The Al-Baha also expanded to the west, which was limited by a mountain west of the Raghadan area, reaching its area in 1987 about ten times 1964 [70]. Then the expansion of Al-Baha increased to the south and east until its area reached about 3060 ha in 1982 [70]. After the city became within the limits of 1982, it represented a small part of a larger area, which is the city's indicative plan area, which amounted to 327.5 km^2. In 2005, the expansion represented part of the indicative plan for 2025, which amounted to 988 km^2. The following Table (1) shows the development of the urban mass of Al-Baha and its trends from 2006 to 2021.

The urban mass area of the study area increased in 2020 to about 50 times what it was in 1982, with a change rate of (433%), and by adding an urban area of 102 km^2, equivalent to 10202 ha. The city witnessed, between the years 2006 and 2021, which is 15 years, the most significant horizontal urban expansion of the urban mass. The urban mass area of the city has nearly doubled to about five times, and the urban addition amounted to 73 km^2, equivalent to 7267 ha, with an annual addition rate of 32.3 ha/year.

5.6. The first phase: prior to 2006

The total area of the urban mass of Al-Baha reached about 60 km^2, which is equivalent to 45% of the current urban area of the city. During this period, the urban area of Al-Baha was confined to the neighborhoods located around the old market area of the city, which is the old city. To some new extensions, the city began to appear after that time, besides the emergence of some random extensions in the city of Al-Baha in many different directions characterized by flat land areas. The signs of urbanization appeared in the random extensions of the city during this stage (Fig. 4).

The last phase during the period 2006 until 2021:

The total built-up area at the end of 2021 amounted to 133 km^2. An increase of 221% over urbanization in 2021 has occurred. The actual increase during this phase amounted to 73 km^2, with an annual increase of 4.9 km^2 and an annual growth rate close to 32.3%. However, as a result of the fact that the annual growth rate of urbanization was less than the annual growth rate of the population during the recent period, the urban density rate of the city increased to 91 people / km^2, and the per capita urban area decreased to about 25.1 km^2 compared to the previous phase (Fig. 5).

In the last phase, between 2006 and 2021, urbanization moved with King Fahad Road, the most developed axis due to flat land, and Al-Baha University has attracted urbanization powerfully. It also went with (King Abdulaziz Road) and with (King Fahd Road), which are the most axes The primary growth from the other axis (Fig. 5). However, the mountainous nature of the city of Al-Baha determined the form of urban growth, so urbanization began to grow in the form of longitudinal radial axes emerging from the city center with the axes of regional roads and the airport road. Urbanization continued to complete the urban spaces with modern plans for the suburbs, such as schemes and some neighborhoods in the city. However, the construction in the northeast direction was more than in any direction. It occurs due to the proximity to Al Baha University and some vital services that help to attract urbanization in this direction.

The study results of the urban development were similar to the previous results prior to 2006 for several reasons. First, they depended on the exact data for these periods from the Ministry of Municipal and Rural Affairs and based on modern satellite images in monitoring the urban growth of Al-Baha. However, the results differed for the years 2006 and 2021. The study results showed that the urban area of Al-Baha for the year 2006 was about 5995 ha, and the block area for the year 2021 was about 13262 ha.

5.7. Second: the spatial dimensions of urban growth in Al-Baha

The spatial dimensions of urban growth are intended to analyze the movement of urbanization on the ground in a particular area during a specific period [71]. The study of the spatial dimensions of the phenomenon of urban expansion is an original geographical goal, as the spatial change does not appear in its proper form unless it is tracked on the ground [72]. Moreover, analyzing the spatial elements can be responsible for urban expansion, how the form of expansion changed by tracking it in different periods, how urbanization expanded and reached its current form, and which axes are more attractive to urban expansion [73].

5.7.1. Urban growth trends

Urban growth trends are essential to indicate the spatial factors that stimulate urban growth in specific directions and reduce and limit urban growth in other directions[74]. The study of urban mass growth trends also seeks to determine which direction is of greater importance than the other directions and which is more to explain the spatial difference of urban growth. These factors measure urban growth in different directions [75]. The urban growth trends also vary, and the urban spaces and distances they occupy in the city vary. It is also possible to determine the trends of attractive and repulsive growth of urbanization in the city through Table 2 and Fig. 6, which show urban growth in various directions in various periods.

It is clear from studying the stages of urban development in Al-Baha that the urban growth was not parallel or equal due to several factors. Most of the urban expansion operations in the city are in the northern and northeastern directions, as well as the southern direction, which includes the southern and southwestern directions. This development of urban expansion results from a group of urban growth stimuli, foremost of which is the direction of the prevailing winds. The role of the prevailing wind direction and its role in expansion has been explained so that the newer sector seeks to be in the future of these winds fresh and pure, leaving the old sector in the wind's corridor with its pollution, accumulation of waste, and atmospheric secretions [76].

Al Baha city formed a three-way growth pattern as it grew in three directions. This is due to inhibiting factors that freeze and limit growth in other directions and push it in these directions. As shown in Table 2,

Table 1
The development of the urban area and the urban expansion in Al-Baha from 1982 to 2021. It is prepared by the researcher based on data extracted from satellite images for the years from 2006 to 2021. Moreover, the rest of the data before 2004 was based on the Ministry of Municipal and Rural Affairs data [70].

Duration	Interval	Urban Area			Urban Expansion		Urban Expansion Rate	Growth Trend
	Year	Km^2	Hectare	Change %	Km^2	Hectare	Hectare/Year	
1982	0	31	3060	0	0	0	0	Random direction on the sides of the principal axes.
1982–1987	5	33	3275	107	2	215	43	Random direction on the sides of the principal axes.
1987–1995	8	44	4420	135	11	1145	143	Random direction on the sides of the principal axes.
1995–2006	11	60	5995	136	16	1575	143	Random direction on the sides of the principal axes.
2006–2021	15	133	13262	221	73	7267	484	Random direction on the sides of the principal axes.
Total	39	301	30012	981				

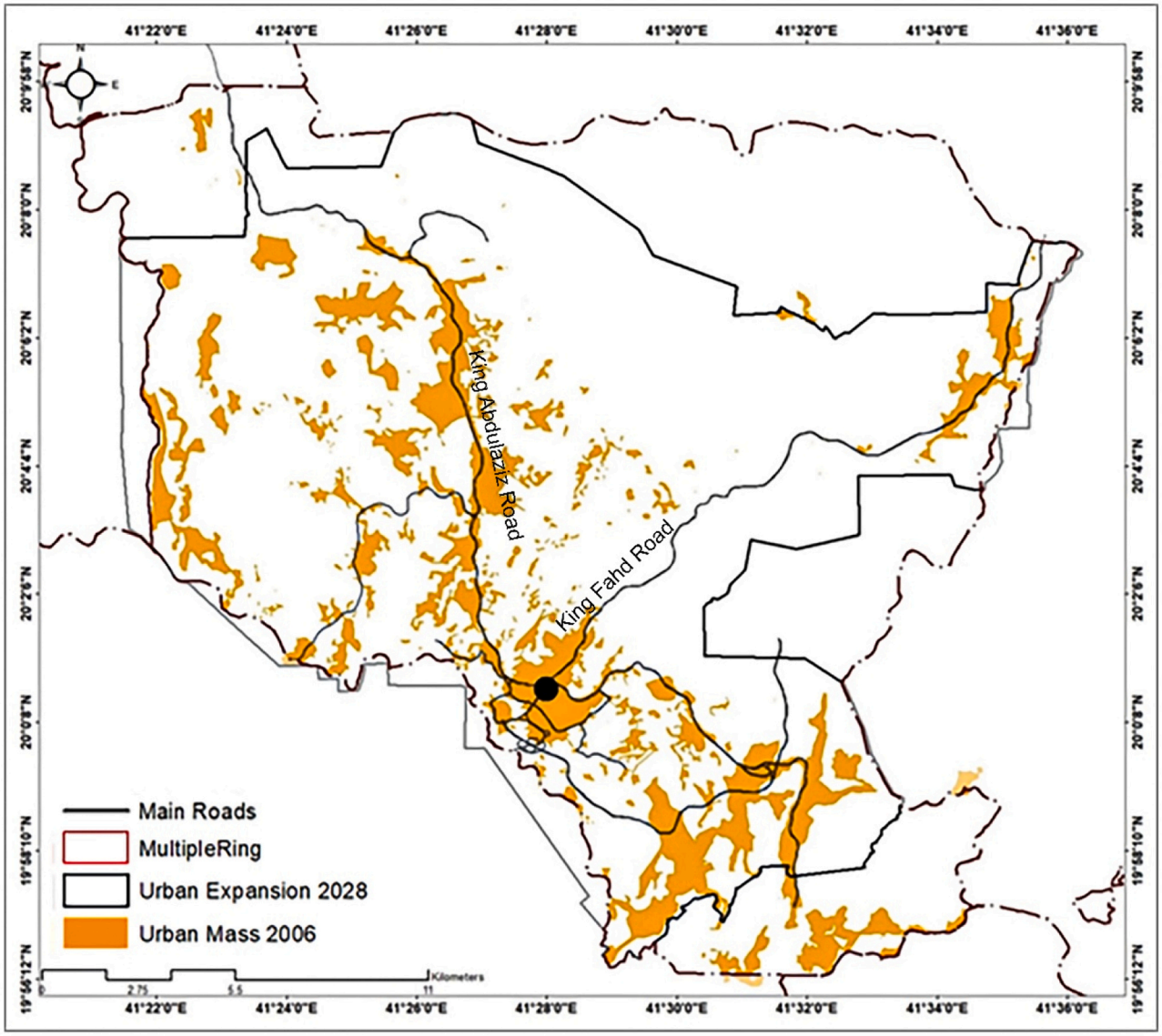

Fig. 4. The development of the urban mass of Al-Baha prior to 2006.

most of the urban growth and expansion operations during the period 2006–2021 are within the northern, eastern, southeastern, western, and southwestern directions of the urban mass of the city. As a result, the added area is more than 88%. Therefore, in this case, the urban growth is considered more than three-quarters of the added area of the city.

Many factors stimulate urban growth, as shown in (Fig. 7). The King Abdul Aziz Road heading from the southeast of Al-Baha city to the northwest is one of the most important motivating factors, as it is the regional road that connects the Asir region through Al Baha city and towards the Taif Governorate of the Makkah region. The King Abdulaziz Road also links King Fahd Hospital, located in the city's west, to the entire city. King Fahd Road, linked to King Abdulaziz Road, which runs from the city center towards the east, is considered one of the second most important factors stimulating urban growth. King Fahd Road connects the city to Al Baha University and King Saud Airport, located east of the city, to King Abdulaziz Road. Many of the city's most important administrative and social services are based on these roads, which go to the north, northwest, west, southwest, and south, passing through the city's areas.

Urbanization extended around the central neighborhoods in the center of Al-Baha, but from 2006-to 2021, it took three main axes. First, urbanization extended to the north and northwest with the extension of King Abdulaziz Road. Moreover, it spread to more than 20 km north of the city center and the market area. Second, the relatively flat lands helped urban expansion toward the east. The flat land on King Fahd Road has been considered the most critical motivation for the growth of the urban mass in this direction as the planning of the built-up block in the city's neighborhoods became in King Fahd Road towards the airport. Finally, urbanization moved to the east, more than 15 km from the city center (Fig. 8).

5.8. *The controlling elements of urban changes*

The most critical elements that control urban changes in the city are location, topography, population, urban growth, roads, transportation, land use patterns, services and utilities, land prices, and government policies [77]. In this context, all stages of urban development were studied, analyzed, and evaluated from the plans prepared for the city of Al-Baha by the government institutes. The study and analysis were conducted using the quantitative statistical method and the GIS program to analyze the pattern of distribution and variance at the level of the city, the municipality, the municipal sectors, and the highways of Al-Baha.

The urban development is characterized by its spread throughout the city of Al-Baha, especially in the flat areas, because it is directly affected

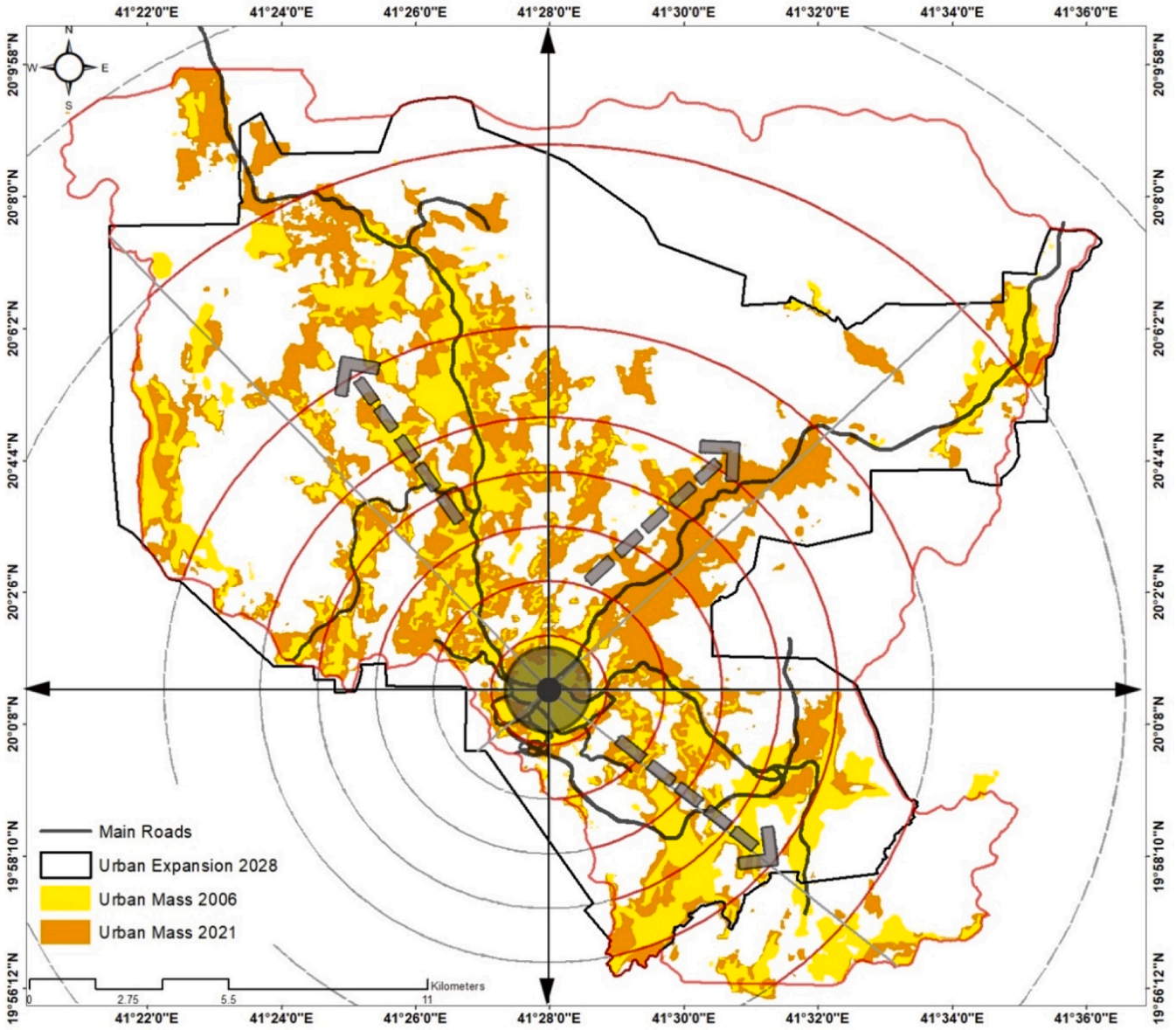

Fig. 5. The urban area at the city level during the period 2006–2021.

Table 2
The growth direction and its area in Al-Baha during 2006–2021, based on satellite imageries using ArcGis v10.8.

Growth Direction	2006		2021	
	Area	%	Area	%
North	308.54	5.6	1725.4	1725.4
Northeast	396.27	7.1	1314.6	1314.6
East	1045.85	18.9	1728.5	1728.5
Southeast	981.87	17.7	1554.2	1554.2
South	84.5	1.5	136.8	136.8
Southwest	70.59	1.3	114.3	114.3
West	925.25	16.7	2022.3	2022.3
Northwest	1734.89	31.3	4665.9	4665.9
Total Area	5547.76	100	13262	100

by natural and human factors. It shows the areas of exclusion and attraction of urbanization in the city as follows:

- Natural expulsion areas are represented in natural factors such as the plot location, high areas, and steep areas. For example, the plot of land is in the torrential stream, and areas with hard rocks that cost vast amounts of money to settle are considered natural expulsion areas.
- Human expulsion areas are represented in lands near factories, far from the city center, with a high price, lack or scarcity of services, distance from main roads, low construction rate, lack of built plots, and the change of the city's plan for land uses.

The urban expansion in Al-Baha is uncontrolled, as it has been subjected to many changes in development projects. The freedom to build without planning controls resulted in an urban stumbling block that led to a loose and random urban growth, surrounded by many vacant spaces. It leads to the loss of the urban fabric of the city. There is evident overcrowding in the neighborhoods located in the city center and scarce space. More than three-fifths of Al-Baha residents live in neighborhoods with random and spontaneous growth. This is because the planned areas are reduced with this high population accumulation. However, there are still many undeveloped areas, which means that the residents of these neighborhoods live in buildings with vertical growth due to the small built area.

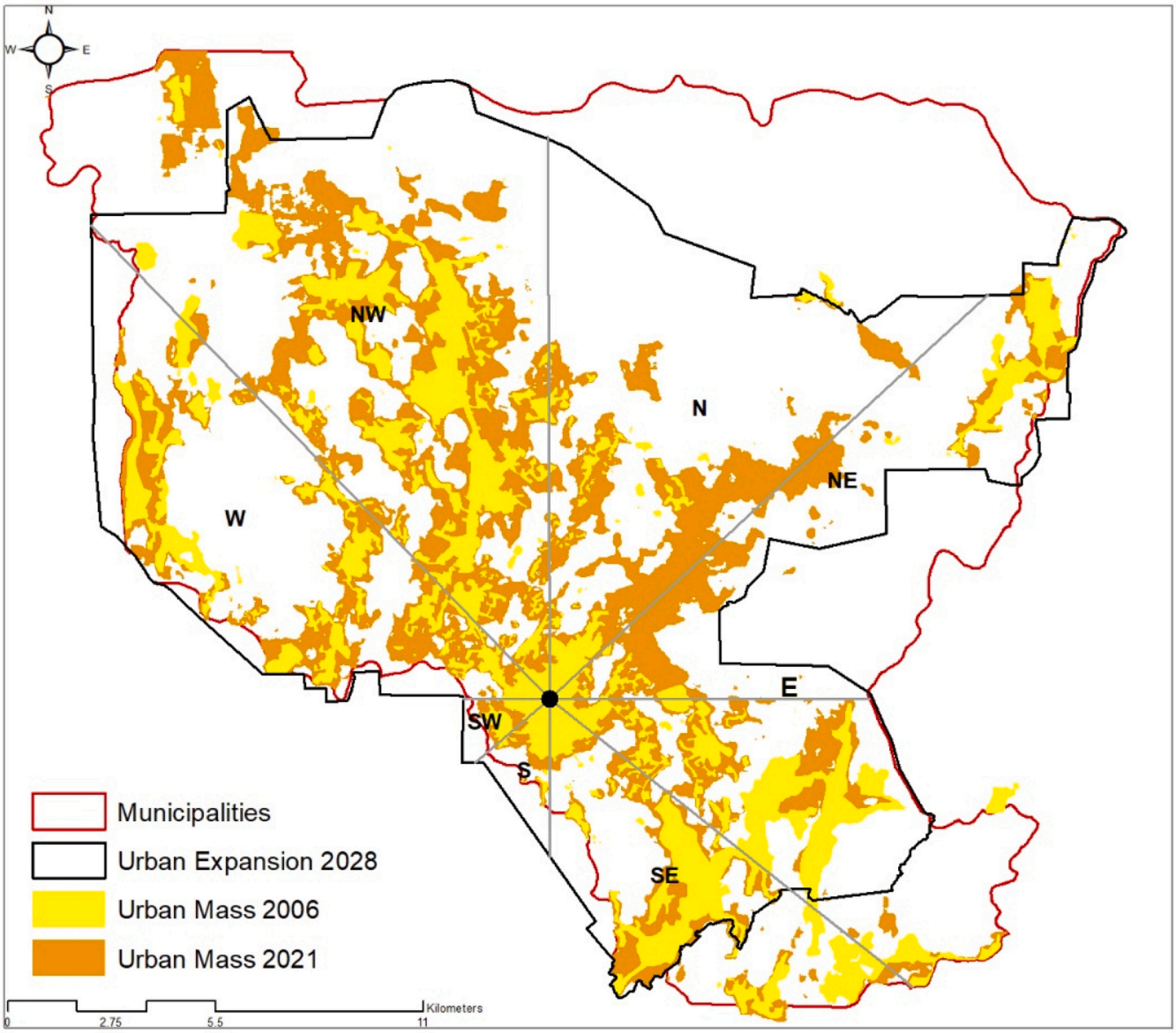

Fig. 6. The development of the urban mass of Al-Baha from 2006 to 2021.

The annual urban addition is more transparent and more expressive than the urban addition at the period level, reflecting real growth. Between 2006 and 2021 is considered the most urban growth period, as the urban addition amounted to about 7267 ha, equivalent to 73 km^2 (Fig. 9). It occurred due to reasons that were previously identified. Between 1995 and 2006, the urban area has a rate of 1575 ha, equivalent to 16 km^2. Whereas, between 1987 and 1995, the urban addition amounted to 1145 ha, equivalent to 11 km^2. The period between 1982 and 1987 came as the least added urban spaces among all times. This period is the lowest in terms of the rate of addition, as the lowest was recorded at about 215 ha, equivalent to 2 km^2 (Table 1).

5.9. Human factors influencing urban growth

The roads in the city are considered the most man-maid elements affected by natural phenomena. The main roads extend in the Al-Baha region in the northwest and southeast direction. This axis is part of the regional road extending from Taif through Al-Baha then Abha and ending with the city of Jizan, which is about 870 km. The main axis branches off from it in the city center area, by a secondary road in the north-east direction toward the airport, with a length of 45 km. Both axes pass through the main valleys in the study area, as shown in Fig. 9. The physical geography of the city area has led to the high cost of road construction and limits of the city's urban growth. The urban growth flourished on the hills and has been associated with the construction of roads. As a result, the roads are more closely interconnected than any other city that does not resemble it in its natural conditions.

Due to the rugged terrain of Al-Baha and the resulting difficulty in movement and poor communication, this area has remained somewhat isolated from the rest of the Kingdom prior to modern road construction. It had only some mountain tracks used for movement on the backs of animals. As for the movement of residents from Al-Baha to Al-Mikhwah Governorate, located at the bottom of the Sarah Highlands, it was a complicated matter. Moving to Al-Mikhwah is closer to climbing mountains than moving. While travel from Al Baha to the city of Taif until 1947 was on foot. The construction of the road network in the study area made it possible to live far from the central business district, perhaps for distances of up to 20 km. As most of the city's national residents and some residents own private cars, the distance factor was neglected when looking for housing. On the other hand, the construction

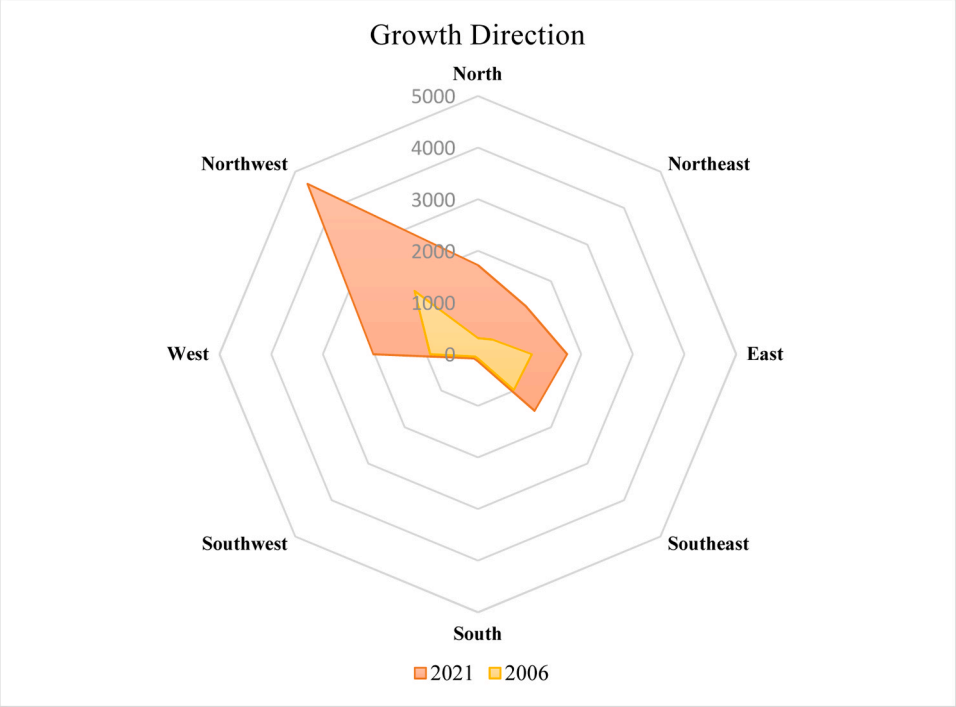

Fig. 7. The growth direction is toward the northwest of the city.

of the road network has attracted the city's central business district to housing by non-citizens, and it has become undesirable for housing by its original residents. The migration of local people led to urbanization spread along the roads and away from the city center boundaries.

5.10. City growth axis

Several factors, namely control the urban growth process of Al-Baha city:

1. The city is located on the edge of a mountain cliff, and its development is impossible to the west.
2. The city's hilly location does not allow it to expand and extend except through the valleys in the hills of its area or on the slopes of some of these hills, even though they are primarily agricultural areas.
3. Highways are part of the Abha-Taif regional road and the Al-Baha Airport Road.

The city's urban expansion to the west is considered impossible, and therefore it occupied the valleys of the city area as a first stage, and then some parts of the hills followed that. The geographical factor affecting the urban growth process of the city now is the roads. Just as roads are the component of the urban type, they have also contributed to the formation of the social pattern in the city. It is considered the transformation of the main road that the area's people used to use in their movements in the past, specifically Wadi Raghadan, into a part of the regional road Taif - Abha. In addition to the construction of a road linking the city center with the airport, the city's connection to Tehama via the Aqabat Al-Baha Road led the urban expansion toward the direction of Tehama, which came through the expansion of paved roads. These roads began to extend to the north on the sides of the regional road linking the city of Taif and towards the northeast on the sides of the airport.

As mentioned previously, the city's urban areas gather around the main road in its area. The city is the nucleus - the central business district now - in the middle of it is the intersection of the airport road with the regional road Taif - Abha, and to the north, on both sides of the last road, there is a major urban complex, Raghadan, which consists of eight villages, the largest of which are: Bani Saad and Al-Tawila. To the north of the previous settlement, there is another community, the Rahwa area, consisting of ten villages, the largest of which are Al-Jadiyah and Bal Ala.

On Taif – Abha Road, to the south of the central business district, there is a third urban cluster: Al-Malad, Wadi Al-Ali, and Al-Mafarjah. As for the airport road, Al-Baha, there are two urban gatherings, the least of which is the Al-Hamda and Al-Ra'eb. Here the urban structure is in line with the nature of the agricultural area listed on the banks of the valley. The second urban cluster is the cluster of Al-Sawad, Bashir, Bani Farwa, and Al-Kara. It is clear from the above that the urban growth in the Al-Baha city guide plan is a strip growth on the sides of the main road, especially on both sides of the regional road Taif - Abha, where it is noted that nine villages extend on one strip.

It can be said that the natural geographical obstacles to the growth of the original city. It is responsible for the development of the city and the expansion of its urban scope to resort to what can be called the process of rural urbanization. Due to the inevitability of the city's urban development and in response to its functions, the city has become multifunctional by adding administrative, recreational, and educational functions to its dominant function, which is agriculture. In light of the pressure of the natural geographical factors and their limitation on the growth process, as they provide a small amount of land suitable for this growth, the city has spread its border network to the neighboring countryside to swallow up more than 40 villages and include them in its urban scope in response to the planning requirements that the city needs. Hence, the process of urbanizing the countryside adjacent to the city became a part of it by an administrative decision. Therefore, it can be said that the human geographical factors have met the natural geographical obstacles to the city's growth. The growth process of rural areas developed with time to fill the rural gaps of the urban entity of Al-Baha. Mainly since human geographic factors help accelerate the process of rural-urban transformation and the imbalance of the rural balance for the urban share. Among these factors are the attractions to the city and the push factors out of the countryside.

People move from the countryside to the city in a process known as

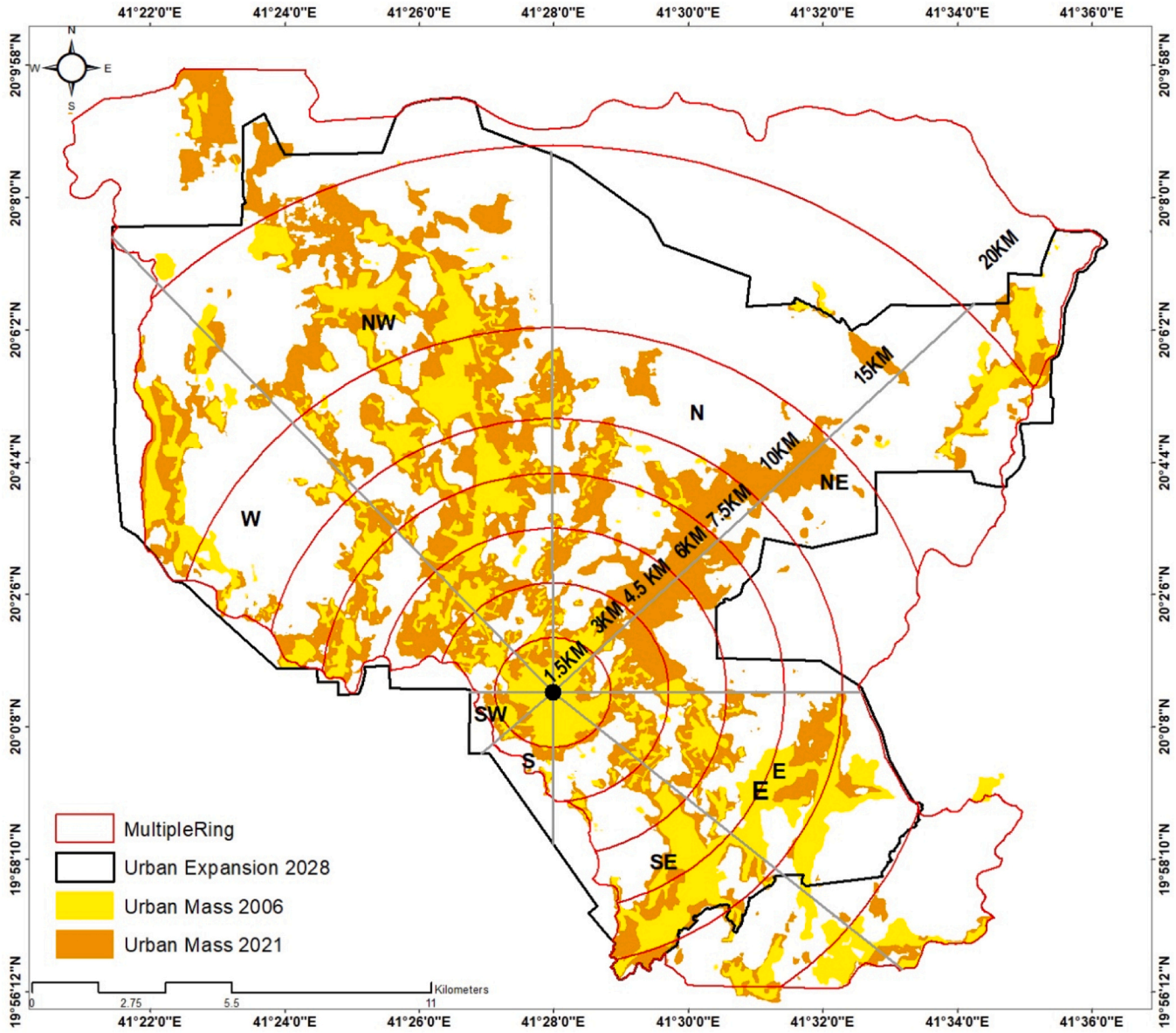

Fig. 8. Urban growth trends and distance from the city center of Al-Baha for the years 2006–2021.

urbanization. The main reason for this process is to obtain a better standard of living. In addition, there are many attractions in the city. The following are the most prominent:

Attractions to the city:

- The city provides job opportunities as one of the city's main attractions. As a result of the economic growth in the city, the demand for labor has risen significantly.
- The city provides the living conditions for the city's residents.
- Higher labor wages compared to rural areas.
- Many different industries are available in the city.
- The city has educational institutions that offer various courses, skills, and diverse topics.
- The city provides better health and education care than the countryside.
- The city has the availability of various urban facilities.

Push factors to leave the countryside (abandonment of agricultural land by some farmers):

Many factors affect and push the population to leave the countryside for the city. However, essential factors are as follows:

- The lack of job opportunities leads to a high rate of poverty which forces residents to look for better jobs offers.
- There is limited access to infrastructure and public services that drive people to move to better living standards.
- The migration of the rural population moves to the city to improve their standard of living.
- Facilitations in construction operations such as material loans and land grants to citizens attract more citizens to the city.
- Part of the rural workforce has shifted to civilian jobs in the city.
- The city has expanded education, tourism, and government services, leading to urbanization.
- The rapid development and growth of the road network in the Al-Baha region attract more residents to move out of the rural area.
- All the above are the factors that will lead to the growth of the city's urban area in the future.

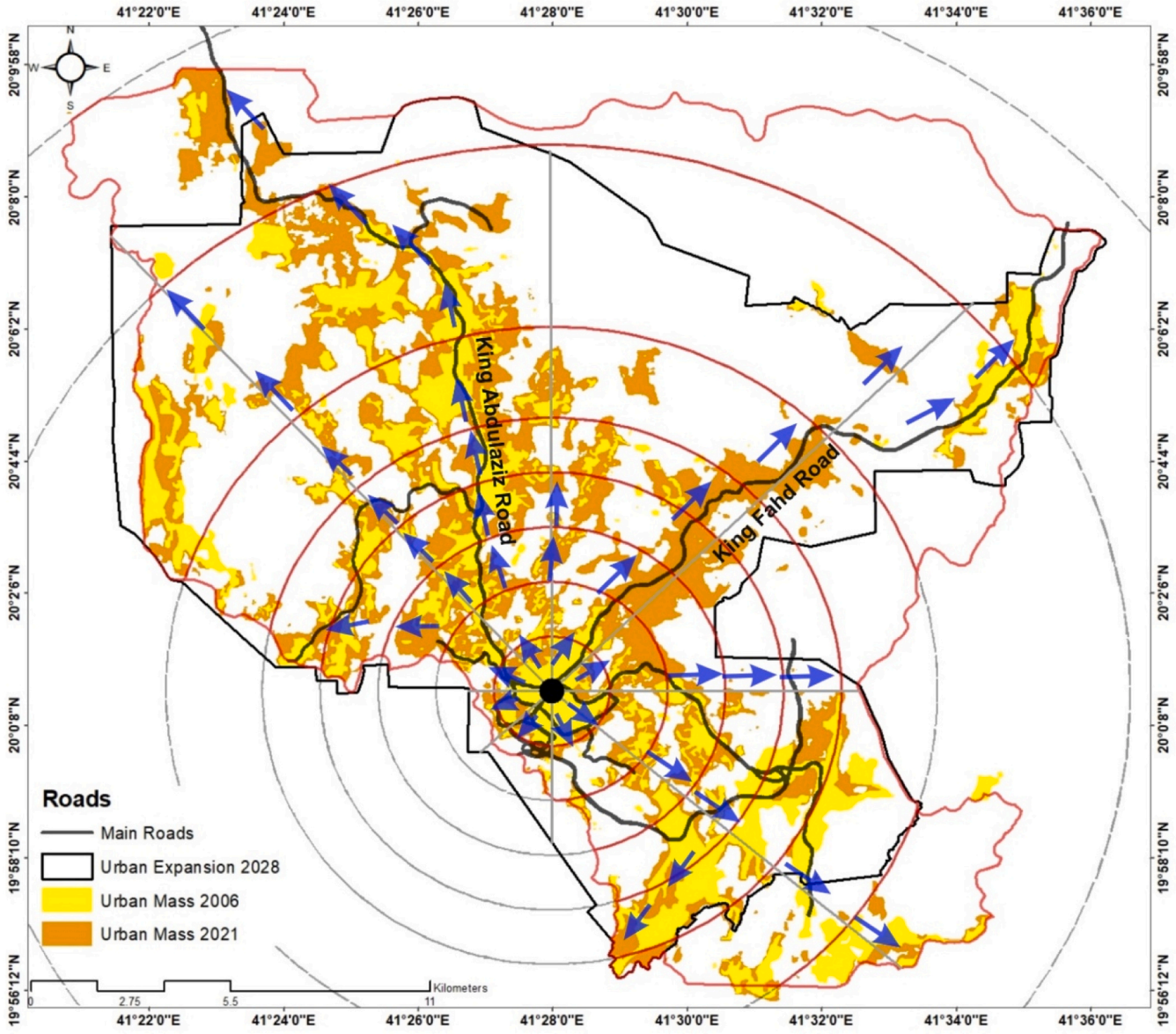

Fig. 9. Urban development stages and growth trends at the city level during the period 2006–2021.

6. Conclusion

This study has taken considerable interest in understanding the dynamics of urban expansion and its patterns and the inconsistency of land cover distributions in the Al-Baha. The study tracks changes in urban land cover and observes the inconsistency in the land cover distributions in Al-Baha during the study period. The area of Al-Baha city grew initially due to the acceleration of the transformation of Al-Baha from a village to a city. After being a village until 1974, Al-Baha became a city in Saudi Arabia. It is now a built-up group of neighboring villages that exceeds about 40 villages according to the administrative definition rather than the functional definition. Al-Baha has a large, unoccupied area on steep slopes. Given its topography, much of the land within the boundaries is unsuitable for urban development. Current urban growth is shaped by steep topography and agricultural land morphology. Al-Baha's morphology is linked to its urban growth, not city status. As a result, the city's area grew by 221% from 2006 to 2021. It increased in urban areas from 60 km^2 to 133 km^2, which means false urban growth.

Therefore, it is not natural urban growth, as it is closer to an unnatural increase than to a natural increase in the demographic sense of what can be called urban borrowing. Hence, the city's urban growth is considered an artificial growth that cannot be said to have come in response to normal geographical conditions. On the contrary, it has been found that human geographical controls have overcome their natural counterparts that limit the city's growth by choosing some rural-urban areas adjacent to the city despite their scattering, distance, and small area and counting these centers as parts of it. The nearby countryside was artificially urbanized, indicating adapting human geographical factors affecting city growth to natural geographical factors. Many factors aided artificial urbanization. Farmers abandon farms for city jobs. The city's road network expanded economic, tourism, and educational activity, and supportive government facilities helped urbanize. Thus, Al-Baha's urban growth came in response to the requirements of its new functions at the expense of its neighboring countryside.

The study additionally detected that the city's natural obstacles have caused it to encroach on rural areas. Since terraced agricultural lands follow the natural topography of mountains and valleys, they attract more urban expansion due to the apparent loss of abundant farmlands and the ease of converting them to residential use. This research concluded that many factors increase urban growth and random and

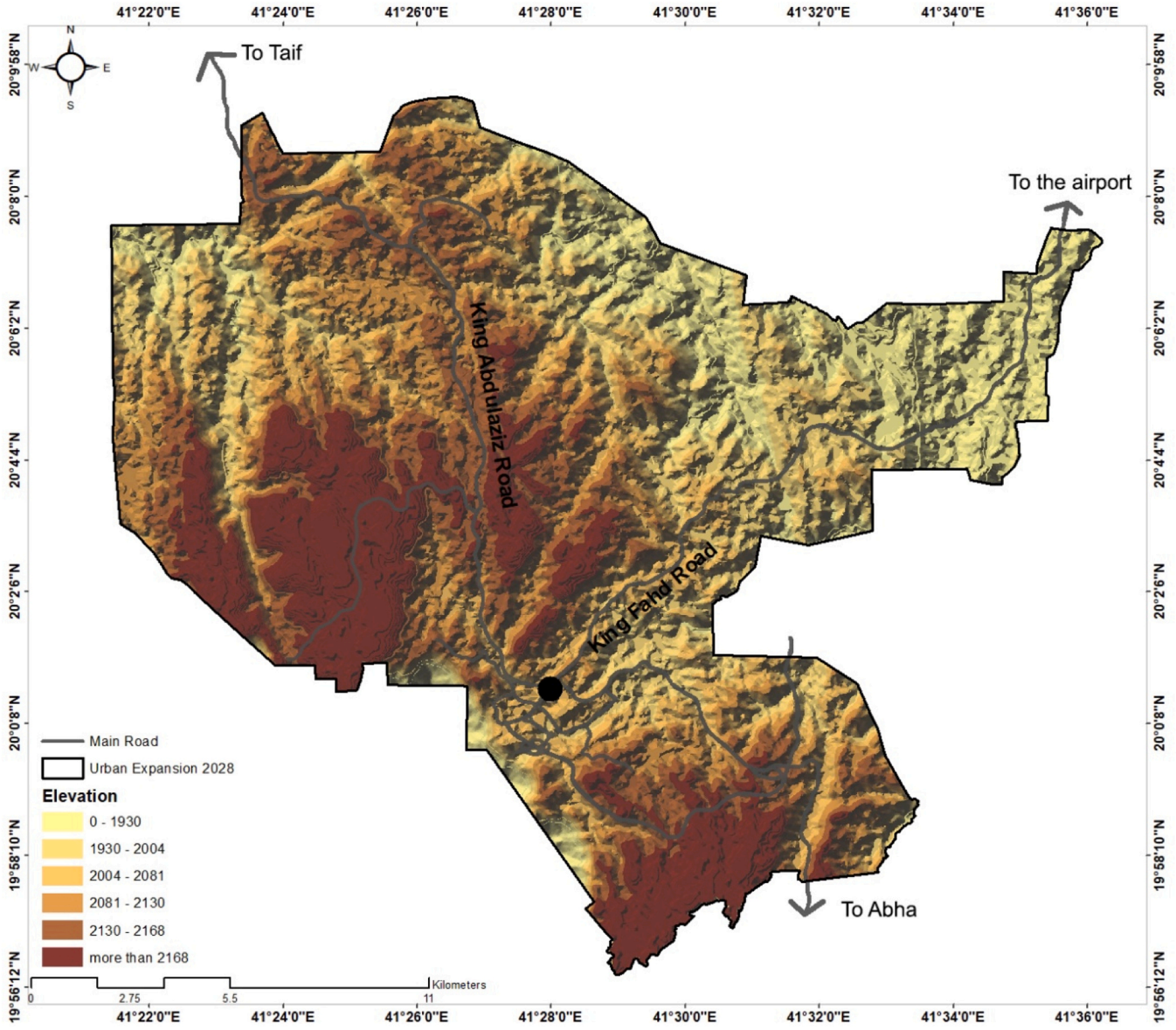

Fig. 10. The regional road extends from Taif through Al-Baha then to Abha, whereas a secondary road extends in the northeast direction toward the airport.

irregular urban sprawl at the expense of the natural environment, agricultural areas, and rural villages surrounding the city. Accordingly, dealing with the issue of urban sprawl must be based on strategic foundations and principles that consider the analysis of locations and trends of development and the population's future needs.

7. Recommendation

Based on the research's findings, the study suggests that in addition to working to create a comprehensive plan for the region that supports the best possible use of the natural resources and the potential to find a balance in the region's urban growth, corrective strategies for the present and future should be considered by the environment. The study advises that planning suitable areas should be the focus of urban development, as agricultural development is not feasible in these areas, particularly in the northeastern regions. It is advisable to create an urban scale for rural areas comparable to cities and offer plans for current and future urban growth improvements to protect open spaces and developable agricultural lands. Because of the significance of these agricultural areas in the region, planning regulations should be developed that help prevent the modification of agricultural land uses and changing their use. The study suggests defining borders that preserve natural forests, particularly those that encircle and are adjacent to urban areas, such as Shahba and Raghadan forests, and designating them as protected areas. It is essential to encourage urban development and direct it to locations suitable for urban development and not suitable for agricultural development, especially on the eastern axis of the region. It is suitable to create new urban centers capable of drawing residents and easing the pressure in the west of Al-Baha city center along the western cliff.

Moreover, it is essential to restrict the prevalence of the linear expansion pattern, particularly in the northeast, and promote and incentivize expansion across a broader range of areas by areas suited for urbanization. In addition, a main axis should connect the urban growth in the northeastern and northwest regions to facilitate linking between them. It is advisable to slow down the urbanization occurring in the western areas of Al-Baha; the ring road connecting the southeastern and eastern regions should be stimulated. Additionally, it is urged to work toward creating maps that highlight times when the Al-Baha region's expansionary scope changed noticeably and the urban boundaries that

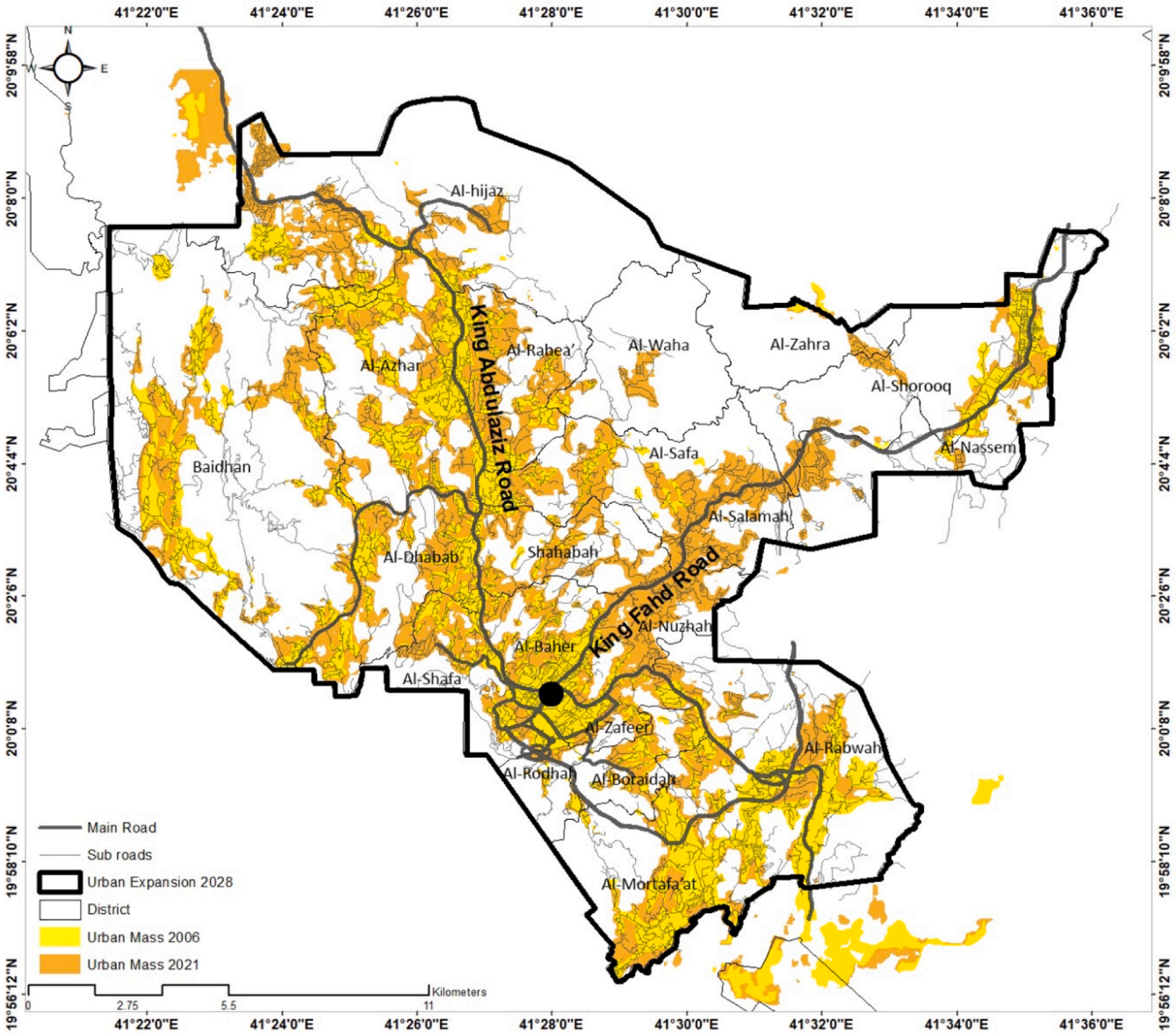

Fig. 11. The city has spread its border network to the neighboring countryside to swallow up more than 40 villages and includes them in its urban scope in response to the planning requirements that the city needs.

had to be reached in a certain period while being closely watched over by development plans and their effectiveness.

Declaration of Competing Interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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References

[1] M. Jayne, D. Bell, City of Quarters: Urban Villages in the Contemporary City, Routledge, 2017.
[2] U. N. HABITAT, "Cities Prosperity (Al-Baha) Report," 2020. Accessed: Apr. 16, 2022. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Funhabitat.org%2Fsites%2Fdefault%2Ffiles%2F2020%2F04%2Fcpi_profile_for_al_baha_2019.pdf&clen=1226931&chunk=true.
[3] F.A. Mubarak, Urban growth boundary policy and residential suburbanization: Riyadh, Saudi Arabia, Habitat Int. vol. 28 (4) (2004) 567–591.
[4] S. Al-Hathloul, M.A. Mughal, Urban growth management-the Saudi experience, Habitat Int. vol. 28 (4) (2004) 609–623.
[5] D. Kumar, Appl. GIS RS Urban Plan. (2021), https://doi.org/10.13140/RG.2.2.28603.75041.
[6] J.A. Parry, S.A. Ganaie, M.S. Bhat, GIS based land suitability analysis using AHP model for urban services planning in Srinagar and Jammu urban centers of J&K, India, J. Urban Manag. vol. 7 (2) (2018) 46–56.
[7] A. el Garouani, D.J. Mulla, S. el Garouani, J. Knight, Analysis of urban growth and sprawl from remote sensing data: case of Fez, Morocco, Int. J. Sustain. Built Environ. vol. 6 (1) (2017) 160–169.

[8] S. Yamamura, L. Fan, Y. Suzuki, Assessment of urban energy performance through integration of BIM and GIS for smart city planning, Procedia Eng. vol. 180 (2017) 1462–1472.
[9] X. Li, A.G.O. Yeh, Cellular automata modelling for urban planning in fast-growth regions. Handbook of Planning Support Science, Edward Elgar Publishing, 2020.
[10] M. Marzouk, A. Othman, Planning utility infrastructure requirements for smart cities using the integration between BIM and GIS, Sustain Cities Soc. vol. 57 (2020) 102120.
[11] M. Daoudi, A.J. Niang, Effects of geomorphological characteristics on urban expansion of Jeddah city-Western Saudi Arabia: a GIS and Remote Sensing Data-Based Study (1965–2020), J. Taibah Univ. Sci. vol. 15 (1) (2021) 1217–1231.
[12] S.W. Wang, B.M. Gebru, M. Lamchin, R.B. Kayastha, W.-K. Lee, Land use and land cover change detection and prediction in the Kathmandu District of Nepal using remote sensing and GIS, Sustainability vol. 12 (9) (2020) 3925.
[13] S. Lahoti, M. Kefi, A. Lahoti, O. Saito, Mapping methodology of public urban green spaces using GIS: An example of Nagpur City, India, Sustainability vol. 11 (7) (2019) 2166.
[14] F.R.Y. Alazzawi, Priority challenges and critical success factors for GIS in Al-Mansour Municipality, Int. J. Psychosoc. Rehabil. vol. 24 (02) (2020).
[15] M. Hiloidhari, et al., Emerging role of Geographical Information System (GIS), Life Cycle Assessment (LCA) and spatial LCA (GIS-LCA) in sustainable bioenergy planning, Bioresour. Technol. vol. 242 (2017) 218–226.
[16] H. Karimi, J. Jafarnezhad, J. Khaledi, P. Ahmadi, Monitoring and prediction of land use/land cover changes using CA-Markov model: a case study of Ravansar County in Iran, Arab. J. Geosci. vol. 11 (19) (2018) 1–9.
[17] N.R. Khwarahm, Spatial modeling of land use and land cover change in Sulaimani, Iraq, using multitemporal satellite data, Environ. Monit. Assess. vol. 193 (3) (2021) 1–18.
[18] T.T. Werner, A. Bebbington, G. Gregory, Assessing impacts of mining: Recent contributions from GIS and remote sensing, Extr. Ind. Soc. vol. 6 (3) (2019) 993–1012.
[19] H.M. Alshuwaikhat, I.R. Abubakar, Y.A. Aina, Y.A. Adenle, M. Umair, The development of a GIS-based model for campus environmental sustainability assessment, Sustainability vol. 9 (3) (2017) 439.
[20] G. Li, S. Sun, C. Fang, The varying driving forces of urban expansion in China: Insights from a spatial-temporal analysis, Land. Urban Plan vol. 174 (2018) 63–77.
[21] M. Zarubin, L. Statsenko, P. Spiridonov, V. Zarubina, N. Melkoumian, O. Salykova, A GIS software module for environmental impact assessment of the open pit mining projects for small mining operators in Kazakhstan, Sustainability vol. 13 (12) (2021) 6971.
[22] H. Shahumyan, R. Moeckel, Integration of land use, land cover, transportation, and environmental impact models: expanding scenario analysis with multiple modules, Environ. Plan B Urban Anal. City Sci. vol. 44 (3) (2017) 531–552.
[23] F.C. Prinsloo, Development of a GIS-based decision support tool for environmental impact assessment and due-diligence analyses of planned agricultural floating solar systems, Univ. South Afr. vol. 1 (2019) 1–121.
[24] B. Alharthi, T.A. El-Damaty, Study the urban expansion of Taif City using remote sensing and gis techniques for decision support system, Adv. Remote Sens. vol. 11 (1) (2022) 1–15.
[25] J. Lella, V.R. Mandla, X. Zhu, Solid waste collection/transport optimization and vegetation land cover estimation using Geographic Information System (GIS): a case study of a proposed smart-city, Sustain Cities Soc. vol. 35 (2017) 336–349.
[26] S. Singh, S.N. Behera, Development of GIS-based optimization method for selection of transportation routes in municipal solid waste management. Advances in Waste Management, Springer, 2019, pp. 319–331.
[27] A. Abdelkarim, A.F.D. Gaber, A.M. Youssef, B. Pradhan, Flood hazard assessment of the urban area of Tabuk City, Kingdom of Saudi Arabia by integrating spatial-based hydrologic and hydrodynamic modeling, Sensors vol. 19 (5) (2019) 1024.
[28] C.M. Viana, S. Oliveira, S.C. Oliveira, J. Rocha, Land use/land cover change detection and urban sprawl analysis. Spatial modeling in GIS and R for earth and environmental sciences, Elsevier, 2019, pp. 621–651.
[29] P.A. Bhat, M. ul Shafiq, A.A. Mir, P. Ahmed, Urban sprawl and its impact on landuse/land cover dynamics of Dehradun City, India, Int. J. Sustain. Built Environ. vol. 6 (2) (2017) 513–521.
[30] C. Liping, S. Yujun, S. Saeed, Monitoring and predicting land use and land cover changes using remote sensing and GIS techniques—A case study of a hilly area, Jiangle, China, PLoS One vol. 13 (7) (2018) e0200493.
[31] A. Bose, I.R. Chowdhury, Monitoring and modeling of spatio-temporal urban expansion and land-use/land-cover change using markov chain model: a case study in Siliguri Metropolitan area, West Bengal, India, Model Earth Syst. Environ. vol. 6 (4) (2020) 2235–2249.
[32] H. Cao, et al., Urban expansion and its impact on the land use pattern in Xishuangbanna since the reform and opening up of China, Remote Sens. vol. 9 (2) (2017) 137.
[33] M.H.A. Ghurah, et al., Assessment of urban growth and sprawl using GIS and remote sensing techniques in South Ghor region, Al-Karak, Jordan, Int. J. Eng. Technol. (UAE) vol. 7 (3.1) (2018) 5–11.
[34] A. Berila, F. Isufi, Two decades (2000–2020) Measuring urban sprawl using GIS, RS and landscape metrics: a case study of municipality of Prishtina (Kosovo), J. Ecol. Eng. vol. 22 (6) (2021).
[35] S. Mansour, M. Al-Belushi, T. Al-Awadhi, Monitoring land use and land cover changes in the mountainous cities of Oman using GIS and CA-Markov modelling techniques, Land Use Policy vol. 91 (2020) 104414.
[36] B. Rimal, L. Zhang, H. Keshtkar, N. Wang, Y. Lin, Monitoring and modeling of spatiotemporal urban expansion and land-use/land-cover change using integrated Markov chain cellular automata model, ISPRS Int. J. Geoinf. vol. 6 (9) (2017) 288.
[37] M.K. Jat, M. Choudhary, A. Saxena, Urban growth assessment and prediction using RS, GIS and SLEUTH model for a heterogeneous urban fringe, Egypt. J. Remote Sens. Space Sci. vol. 20 (2) (2017) 223–241.
[38] J. Bahrawi, H. Ewea, A. Kamis, M. Elhag, Potential flood risk due to urbanization expansion in arid environments, Saudi Arabia, Nat. Hazards vol. 104 (1) (2020) 795–809.
[39] A.M. Almadini, A.A. Hassaballa, Depicting changes in land surface cover at Al-Hassa oasis of Saudi Arabia using remote sensing and GIS techniques, PLoS One vol. 14 (11) (2019) e0221115.
[40] A.K. Abd El Aal, M. Kamel, S.H. Alyami, Environmental analysis of land use and land change of Najran city: GIS and remote sensing, Arab J. Sci. Eng. vol. 45 (10) (2020) 8803–8816.
[41] A.F. Alqurashi, L. Kumar, An assessment of the impact of urbanization and land use changes in the fast-growing cities of Saudi Arabia, Geocarto Int. vol. 34 (1) (2019) 78–97.
[42] B. Wiatkowska, J. Słodczyk, A. Stokowska, Spatial-temporal land use and land cover changes in urban areas using remote sensing images and GIS analysis: the case study of Opole, Poland, Geoscience vol. 11 (8) (2021) 312.
[43] P. Riad, S. Graefe, H. Hussein, A. Buerkert, Landscape transformation processes in two large and two small cities in Egypt and Jordan over the last five decades using remote sensing data, Land. Urban Plan. vol. 197 (2020) 103766.
[44] T. Ünlü, Managing the urban change: a morphological perspective for planning, ICONARP Int. J. Archit. Plan. vol. 7 (2019) 55–72.
[45] Y. Wu, S. Li, S. Yu, Monitoring urban expansion and its effects on land use and land cover changes in Guangzhou city, China, Environ. Monit. Assess. vol. 188 (1) (2016) 15.
[46] A. Alqahtany, GIS-based assessment of land use for predicting increase in settlements in Al Ahsa Metropolitan Area, Saudi Arabia for the year 2032, Alex. Eng. J. vol. 62 (2023) 269–277.
[47] S.W. Wang, B.M. Gebru, M. Lamchin, R.B. Kayastha, W.-K. Lee, Land use and land cover change detection and prediction in the Kathmandu district of Nepal using remote sensing and GIS, Sustainability vol. 12 (9) (2020) 3925.
[48] M.A.M. Elmorshdy, "Urban growth monitoring, simulation and management from coastal cities management perspective using Cellular Automata, Remote Sensing and GIS: a case study of Alexandria governorate, Egypt", 2019.
[49] H.A. Altuwaijri, M.H. Alotaibi, A.M. Almudlaj, F.M. Almalki, Predicting urban growth of Arriyadh city, capital of the Kingdom of Saudi Arabia, using Markov cellular automata in TerrSet geospatial system, Arab. J. Geosci. vol. 12 (2019) 1–15.
[50] M.T. Rahman, Detection of land use/land cover changes and urban sprawl in Al-Khobar, Saudi Arabia: an analysis of multi-temporal remote sensing data, ISPRS Int J. Geoinf. vol. 5 (2) (2016) 15.
[51] M. Almazroui, A. Mashat, M.E. Assiri, M.J. Butt, Application of landsat data for urban growth monitoring in Jeddah, Earth Syst. Environ. vol. 1 (2017) 1–11.
[52] S.H. Mahmoud, A.A. Alazba, Land cover change dynamics mapping and predictions using EO data and a GIS-cellular automata model: the case of Al-Baha region, Kingdom of Saudi Arabia, Arab. J. Geosci. vol. 9 (2016) 1–20.
[53] P. Pellikka, A.Y. Alshaikh, Remote sensing of the decrease of juniper woodlands in the mountains of Southwestern Saudi Arabia—reasons and consequences, Arab. J. Geosci. vol. 9 (2016) 1–12.
[54] J.W. Creswell, J.D. Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, Sage Publications, 2017.
[55] MOMRA, "Al-Baha City Profile", Riyadh, 2019.
[56] A.-B. Province, "Al-Baha Province", Al-Baha Province. Accessed: Apr. 12, 2022. [Online]. Available: ⟨https://shorturl.ae/XSmrM⟩.
[57] M. Herold, H. Couclelis, K.C. Clarke, The role of spatial metrics in the analysis and modeling of urban land use change, Comput. Environ. Urban Syst. vol. 29 (4) (2005) 369–399.
[58] J. Xiao, et al., Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing, Land. Urban Plan. vol. 75 (1–2) (2006) 69–80.
[59] M. Aljoufie, M. Zuidgeest, M. Brussel, M. van Maarseveen, Spatial–temporal analysis of urban growth and transportation in Jeddah City, Saudi Arabia, Cities vol. 31 (2013) 57–68.
[60] A. Siddiqui, A. Siddiqui, S. Maithani, A.K. Jha, P. Kumar, S.K. Srivastav, Urban growth dynamics of an Indian metropolitan using CA Markov and Logistic Regression, Egypt. J. Remote Sens. Space Sci. vol. 21 (3) (2018) 229–236.
[61] M. Wolff, T. Wiechmann, Urban growth and decline: Europe's shrinking cities in a comparative perspective 1990–2010, Eur. Urban Reg. Stud. vol. 25 (2) (2018) 122–139.
[62] M.S. El-Hawagry, M.R. Sharaf, H.M. al Dhafer, H.H. Fadl, A.S. Aldawood, Addenda to the insect fauna of Al-Baha Province, Kingdom of Saudi Arabia with zoogeographical notes, J. Nat. Hist. vol. 50 (19–20) (2016) 1209–1236.
[63] H. Aljasir, In Sarat Ghamid and Zahran, vol. 2, Dar Al-Yamamah, Riyhadh, 1977.
[64] A. Abdula'al, Saudi Cities: Land Use and Functions, vol. 1, Nahda Al-Sharq Library, Cairo, 1996.
[65] G. bin Jreais, The written saying in the History of the South, Al-Baha and Asir, 5th ed., vol. 1, King Fahd Library, Riyadh, 2014.
[66] W. Zhang, W. Li, C. Zhang, W.B. Ouimet, Detecting horizontal and vertical urban growth from medium resolution imagery and its relationships with major socioeconomic factors, Int J. Remote Sens vol. 38 (12) (2017) 3704–3734.
[67] I. Zambon, A. Colantoni, L. Salvati, Horizontal vs vertical growth: Understanding latent patterns of urban expansion in large metropolitan regions, Sci. Total Environ. vol. 654 (2019) 778–785.

[68] T.K. Bradshaw, B. Muller, Impacts of rapid urban growth on farmland conversion: application of new regional land use policy models and geographical information systems 1, Rural Socio vol. 63 (1) (1998) 1–25.
[69] N. Bihamta, A. Soffianian, S. Fakheran, M. Gholamalifard, Using the SLEUTH urban growth model to simulate future urban expansion of the Isfahan metropolitan area, Iran, J. Indian Soc. Remote Sens. vol. 43 (2) (2015) 407–414.
[70] MOMRA, "The Comprehensive Development Plan_ Al-Baha Region", Riyadh, Jan. 1985.
[71] J. Cheng, Modelling Spatial and Temporal Urban Growth, Utrecht University Utrecht, The Netherlands, 2003.
[72] Y.D. Wei, R. Ewing, Urban Expansion, Sprawl and Inequality, in: Landscape and urban planning, vol. 177, Elsevier, 2018, pp. 259–265.
[73] S.H. Otuoze, D.V.L. Hunt, I. Jefferson, Predictive modeling of transport infrastructure space for urban growth phenomena in developing countries' cities: a case study of Kano—Nigeria, Sustainability vol. 13 (1) (2020) 308.
[74] A. Schneider, K.C. Seto, D.R. Webster, Urban growth in Chengdu, Western China: application of remote sensing to assess planning and policy outcomes, Environ. Plan. B Plann Des. vol. 32 (3) (2005) 323–345.
[75] F.S. Taiema, M.S. Ramadan, Monitoring urban growth directions using geomatics techniques, a case study Zagazig city-Egypt, Egypt. J. Remote Sens. Space Sci. vol. 24 (3) (2021) 1083–1092.
[76] S. Chang, Q. Jiang, Y. Zhao, Integrating CFD and GIS into the development of urban ventilation corridors: a case study in Changchun City, China, Sustainability vol. 10 (6) (2018) 1814.
[77] B. Bhatta, Analysis of Urban Growth and Sprawl from Remote Sensing Data, Springer Science & Business Media, 2010.