Measuring Land Cover Change Due to Jeddah City, Saudi Arabia Redevelopment Project Using GIS, and Remote Sensing Techniques

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Abstract

Slums are a significant global problem faced by most countries, especially developing ones. These areas lack the provision of essential services, deteriorating infrastructure, and high crime rates, which generally make slums characterized by a low quality of life. These areas can be seen on the outskirts of cities, which consist of unplanned buildings, and for the most part, are unsafe.

In Saudi Arabia, slums can be seen in many cities, and conceivably the most densely populated slums are found in Mecca city, where they cover nearly half of the total urban area. The demographic characteristics of these areas have been identified as mostly consisting of immigrants. Recently, the Saudi Arabia government, under the leadership of the Custodian of the Two Holy Mosques, King Salman bin Abdulaziz, has tended to develop slum areas. Indeed, the southern neighbourhoods of Jeddah have been emptied and cleared of building residue, which will be the focus of this research paper.

Built-up areas in southern neighbourhoods of Jeddah city have increased with total change from 2000 to 2020 by up to 40% (7.13 km2). From 2020 to 2022, a dramatic decrease has been noted in built-up areas of 28.4 % (8.01 km2), while undeveloped areas increased by about 20.3 km2. This decrease in built-up areas has been seen clearly in slum areas, which confirms the progress of the redevelopment project toward the right path.

Keywords: Land Cover, Jeddah City, GIS, Remote Sensing.

الملخص:

تعد العشوائيات مشكلة كبيرة على مستوى العالم تواجهها معظم البلدان، وخاصة النامية منها. تفتقر هذه المناطق إلى توفير الخدمات الأساسية، وتدهور البنية التحتية، وارتفاع معدلات الجريمة، مما يجعل العشوائيات بشكل عام تتسم بتدني جودة الحياة. يمكن رؤية هذه المناطق في ضواحي المدن، والتي تتكون من مباني غير مخططة، وفي معظمها غير آمنة.

يمكن رؤية العشوائيات بالمملكة العربية السعودية في العديد من المدن، ويمكن رؤية العشوائيات الأكثر كثافة سكانية بوضوح في منطقة مكة المكرمة، حيث تغطي العشوائيات ما يقرب من 25 ٪ من إجمالي مساحتها الحضرية، وقد تم تحديد الخصائص الديموغرافية لهذه المناطق على أن معظم سكانها من جنسيات مهاجرة.

في الآونة الاخيرة، تتجه حكومة المملكة العربية السعودية بقيادة خادم الحرمين الشريفين الملك سلمان بن عبد العزيز إلى تطوير المناطق العشوائية, بالفعل تم إخلاء وازالة الردم للأحياء الجنوبية لمدينة جدة وهو ما سيتم التركيز علية في هذه الورقة البحثية .

زادت المساحات المبنية بالأحياء الجنوبية لمدينة جدة في التغيير الكلي من 2000 إلى 2020 بنسبة تصل إلى 40٪ (7.13 كم 2). وفى الفترة من عام 2020 إلى عام 2022، لوحظ انخفاض كبير في الكتلة العمرانية بنسبة 28.4٪ (8.01 كم 2)، بينما زادت الأراضي الفضاء بنسبة 30.2 ٪. وقد شوهد هذا الانخفاض بوضوح في نطاق المناطق العشوائية، مما يؤكد سير مشروع إعادة التطوير نحو المسار الصحيح.

[1] https://whc.unesco.org/fr/list/956/

1.Introduction

Growth is a key feature of all urbanization processes. Growth has resulted in developed land, accelerated erosion, increased traffic, more waste, and a dramatic increase in domestic wastewater. Hence, with rapid urbanization and a rising urban population, the pattern of land use/land cover has been altered, which has led to a series of environmental challenges caused by urbanization. (Arsanjani et al., 2013)

Based on World Bank data, Saudi Arabia is experiencing extreme urban development. Many rural, nomadic, and foreign immigrants are moving to the urban areas of the country. Currently, about 82.1% of the total population lives in urban areas and 17.9% in rural areas. At the regional level, the urbanization rate is above 80% in 6 regions including Eastern Province (93.2%), Riyadh (90.9%), Mecca (87.6%), Northern Border (86. 7%), Tabuk (85.9%), and Jouf (84.5%). The growth in the big cities is very noticeable, but it is not limited to these places.

Saudi Arabia is determined to achieve one of the most rapid urban expansions in the Middle East. This development has caused changes in some environmental components such as land cover patterns (Alqurashi and Kumar, 2014). In the past 8 decades, Saudi Arabian cities have increased in number from 58 in 1936 to 258 in 2004 and most recently to 285 in 2015, spread across 13 regions and 118 administrative districts. Moreover, urbanization is expected to increase to 97.6% by 2030 (Alqurashi et al., 2016).

In 2016, Saudi Arabia embarked on the adoption of an ambitious national vision and development plan for the Kingdom to achieve in 2030. Saudi Vision can be explained as a set of policies, and the presence of urban planning as a field that deals with the physical environment. At the time of looking at the strategic goals, an elaboration of the six main objectives of the Vision directly addresses the urban sector by upgrading the quality of life in Saudi Arabian cities.

According to the Kingdom's long-term demographics, the Kingdom's annual population growth rate is expected to average 2.15%. Most of the population is concentrated in the capital Riyadh, the second cities Jeddah and Dammam, and the holy cities Mecca and Medina.

Jeddah city is one of the most important cities in the Kingdom of Saudi Arabia. Not only for its importance as a modern nation, but also for its historical value, geographical location, and role as a unique pilgrim reception center for the revered cities of Mecca and Al-Madinah. Also, the city has its combination of modernity and history and tradition. This unique combination of culture, history, modernity, economic prosperity, character, and diversity is what makes the city have knowledgeable and contemporary characteristics (Abdu at el., 2002).

The population of Jeddah city Municipality recorded 4,082,184 inhabitants (2016 estimates), with a 3.8% annual population growth rate, this rate is considered higher than the national average. Jeddah city has witnessed a significant increase in population mainly due to migration from suburbs and villages into the city searching for work opportunities and better standards of living.

In the past four decades, Jeddah city has encountered rapid urban expansion, causing land use changes. There are many driving forces that caused the city's spatial temporal changes such as population growth, economic growth, and transportation infrastructure, as well as the topographic nature. Urban development of the city can be distinguished into two types of urban growth: sprawl development and outward expansion (Aljoufie, 2021).

In the current study, multi-temporal Landsat data has been used for detecting the pattern of land cover change, while the GIS technique has been used to analyze and map LC changes during the study period between 2000 to 2022.

1.1. Objectives

This paper aims to study the change in land cover of the Southern neighbourhoods of Jeddah city during the period between 2000 to 2022, as well as the effects of the Redevelopment Project in developing urban areas. The following objectives will be pursued in order to reach the aim above.

* Discuss issues of slums.

* Measuring the change in land cover during the study period.

* Mapping the removed urban areas during the Implementation of Redevelopment Project period between 2020 to 2022.

1.2. Previoous work

The Author reviewed studies dealing with similar topics or objectives , in terms of measuring land cover change, especially built-up cover. Those studies are the following:

Belal and Moghanm, 2011) presented a study for detecting change in land cover from urban growth using remote sensing and GIS techniques. Landsat images were used to estimate the changes during the study period between 1972 and 2005 using GIS integration. The study confirmed that Landsat data is efficient for providing a suitable spatial and multi-temporal resolution for studying changes in the land cover.

(Sinha and Kumar, 2013) presented urban land cover change in five Saudia Arabian cities using remote sensing and GIS techniques. The research emphasized the importance of those techniques in sustainability research. Land cover change (LCC) is used as an essential component of assessing the developing process and using multi-temporal data is valuable for providing a better knowledge of the complex LC change patterns.

(Al qurashi and Kumar, 2014) studied detecting land use land cover (LULC) change in the Saudi Arabian Desert Cities of Makkah and Al-Taif using Landsat satellite data, images and GIS from 1986 to 2013. Maximum likelihood classification methods were used to create and produce LULC maps using post-classification comparison. The results showed a variable distribution of different features of the study area from year to year, especially for vegetation cover.

Another study (Difalla, 2015) mentioned that Jeddah city has undergone urban expansion through the growth of both formal and informal settlements (slums). As a consequence, a major change occurred in the land cover of the city. Therefore, the government needed to intervene and control the urban development process, especially in slum areas through the redevelopment project.

Another study (Rahman, 2016) studying urban sprawl in Al-Khobar, Saudi Arabia by Analysis of Multi-Temporal Remote Sensing Data, measured the impacts of urban sprawl in land use/land cover changes between 1990 and 2013. The researcher used Landsat data (Landsat TM, ETM+, and OLI data), with applying ISODATA classification methods to classify Landsat TM, ETM+, and OLI data measuring changes in the land cover within the study area.

(Liu et al., 2017) discussed the effects of rapid urban expansion and its impacts on change land use/landcover. Research concluded that the rapid increase in urbanization is generating a population demand for speedy, quality, and efficient public services, most importantly housing, piped water, electricity, roads, sewerage, and telephones. As a result, it created a serious challenge for municipal authorities: to meet the increasing demand for services and responsive, proper planning of city extensions, urban centers, and land infills on the one hand and on the other, enabling the private sector to play an increasing role in providing quality urban services, housing, and mass transit.

Another study (Jarah et al., 2019) assured that rapid urbanization, especially unplanned, leads to increased use of water resources, high consumption patterns, and resource-intensive lifestyles. That causes major challenges to environmental protection, pollution, water scarcity, waste management, and quality of life.

2. Methods

2.1. Location of the study area

Jeddah city is the second largest city in Saudi Arabia, which has embarked on a massive slum redevelopment project. Concerning population and area, Jeddah is the second largest city after Riyadh, furthermore; its cultural and economic value is also second only to the holy Mecca city. About 16% of the total urban area of Jeddah city has been classified as slums, occupied by 250,000 inhabitants. Thus, Jeddah's city Municipality has assigned a total budget of 53 billion USD, for the "development" of slums areas. (Difalla, 2015).

Jeddah city lies at 21.71°N latitude, and 39.18°E longitude, while Figure 1 shows the geographic location of it. In this study, the focus will be on the southern part of the city (Figure 1). The prevalent climate of the city is dry or desert under Koppen's climate classification, based on summer temperatures often reaching above 43°C (Aljoufie, 2021).

The Jeddah city mayoralty announced that a total number of 32 random and slum neighborhoods will be razed as part of the Jeddah redevelopment plan, and they will be removed within the scheduled timeline. The process of razing already started in the southern part of Jeddah city, which causes an extreme change in the urban area. The current study focuses on measuring this change in 15 neighborhoods located in the south of Jeddah city, which were already razed by removing their building backfill.

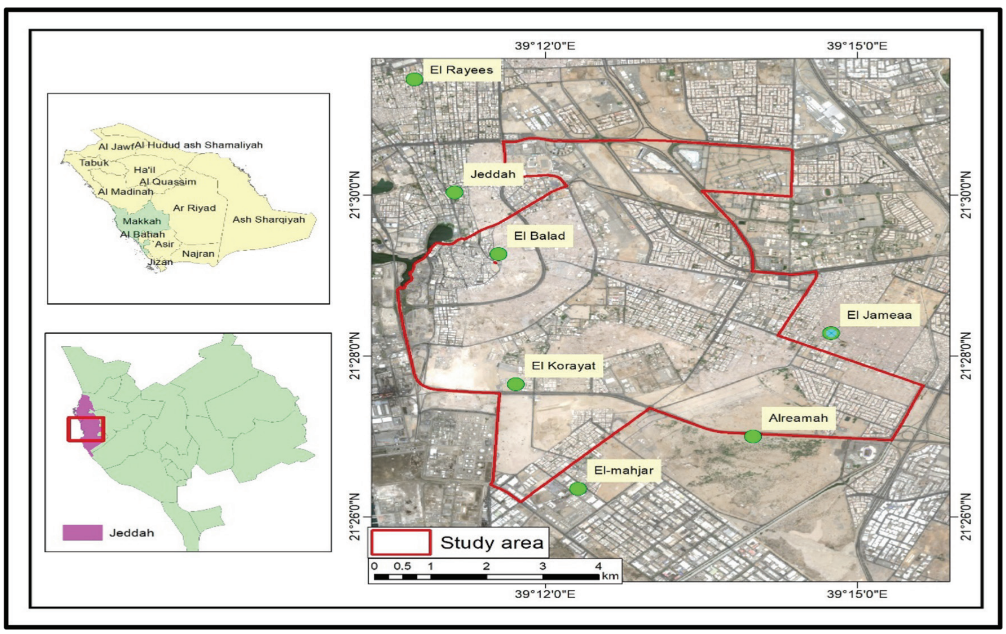

Figure 1. Location of the study area in the Saudi Arabia.
Data source: (Jeddah Municipality, 2016) and Landsat (OLI-TIRS) 2022.

2.2. Data Collection

The data used in this research contained four cloud-free Landsat (OLI-TIRS, ETM) images, path 170 and row 45, which were taken in the years 2000, 2013, 2020, and 2022. The image was chosen at the same seasonal time to get a clear image with zero clouds. All images have been obtained from The United States Geological Survey (USGS) website. The next figure (Figure 2) shows the composite image for both years 2000 and 2022.

2.3. Data analysis

The Landsat data has been analyzed using ERDAS Imagine 2016 software. The visual interpretation of defined band combinations, and NDBI index, was used to identify various signatures in the satellite images, while supervised classifications were applied for land cover mapping. In the end, various maps were developed using ArcGIS version 10.7 software. The visual interpretation of defined band combinations, and NDBI index, was used to identify various signatures in the satellite images, while supervised classifications were applied for land cover mapping.

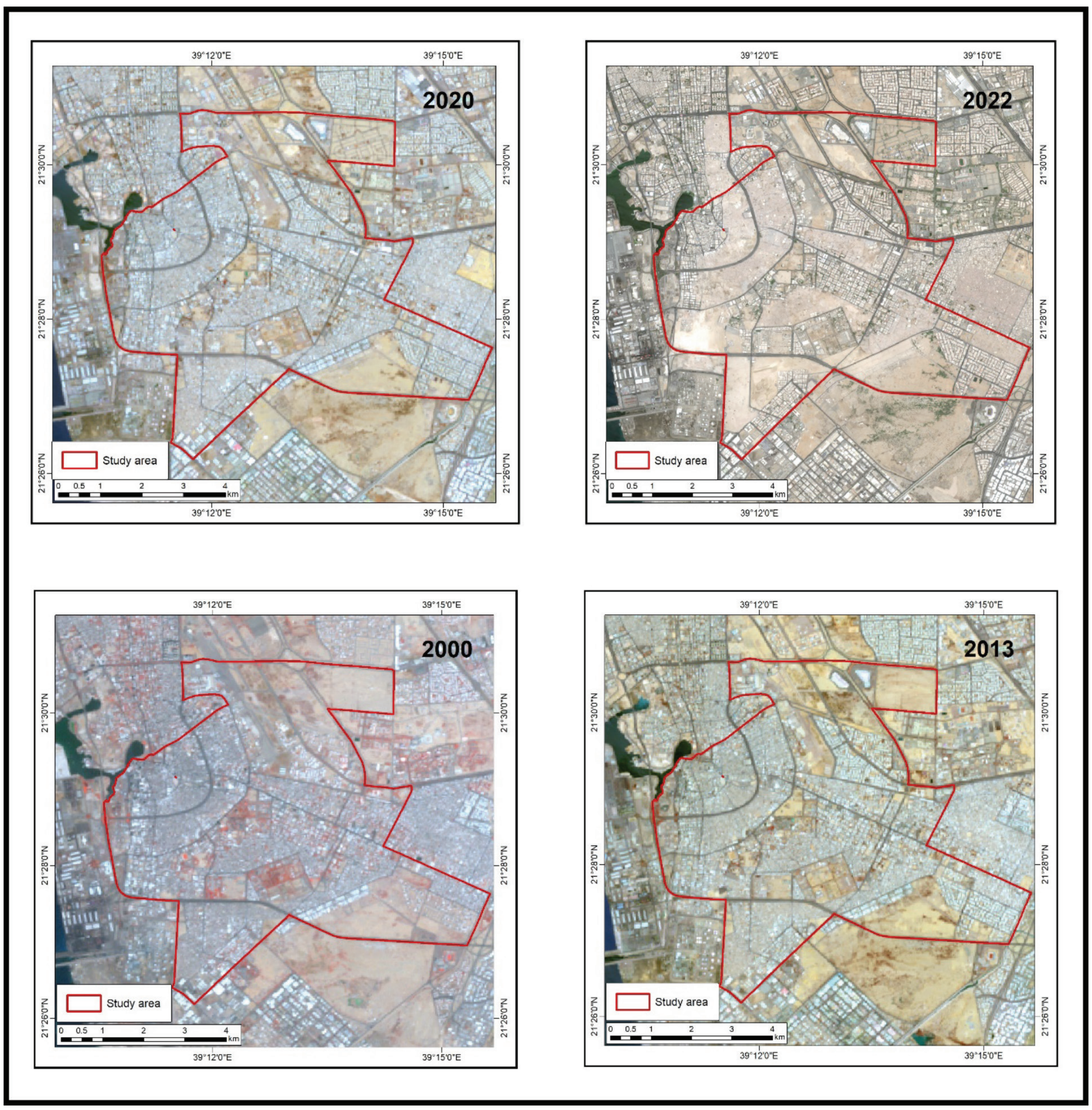

Figure 2: Composite images for years 2000,2013, 2020 and 2022.

Data source: False color images using Landsat images for years 2000, 2013, 2020, and 2022.

2.4. Image classification

Remote sensing and geographic information systems are important tools used for monitoring LC change (Serra et al., 2008). This study aims to monitor the change in land cover of the southern part of Jeddah city during the Saudi Arabia Redevelopment Project by using modern remote sensing techniques and GIS. This study used Landsat 7 and Landsat 8 images to identify the change in land cover of urban areas in the southern neighborhoods of Jeddah city during the period between 2000 to 2022.

This research focuses primarily on urban areas (built-up areas). Normalized Difference Built-up Index (NDBI) index is useful for highlighting and extracting built-up areas for all images (2000-2013-2020 -2022). NDBI uses both NIR and SWIR bands for emphasizing manufactured built-up areas. As shown in Figure 3, the range of NDBI index values is between −1 and 1, where a higher value (greater than zero) indicates a built-up area, and a lower value (less than zero) means an undeveloped area. The index has been produced by applying the following equation:

NDBI = (SWIR – NIR) / (SWIR + NIR)

For landsat 7 data, NDBI = (Band 5 – Band 4) / (Band 5 + Band 4).

For Landsat 8 data, NDBI = (Band 6 – Band 5) / (Band 6 + Band 5).

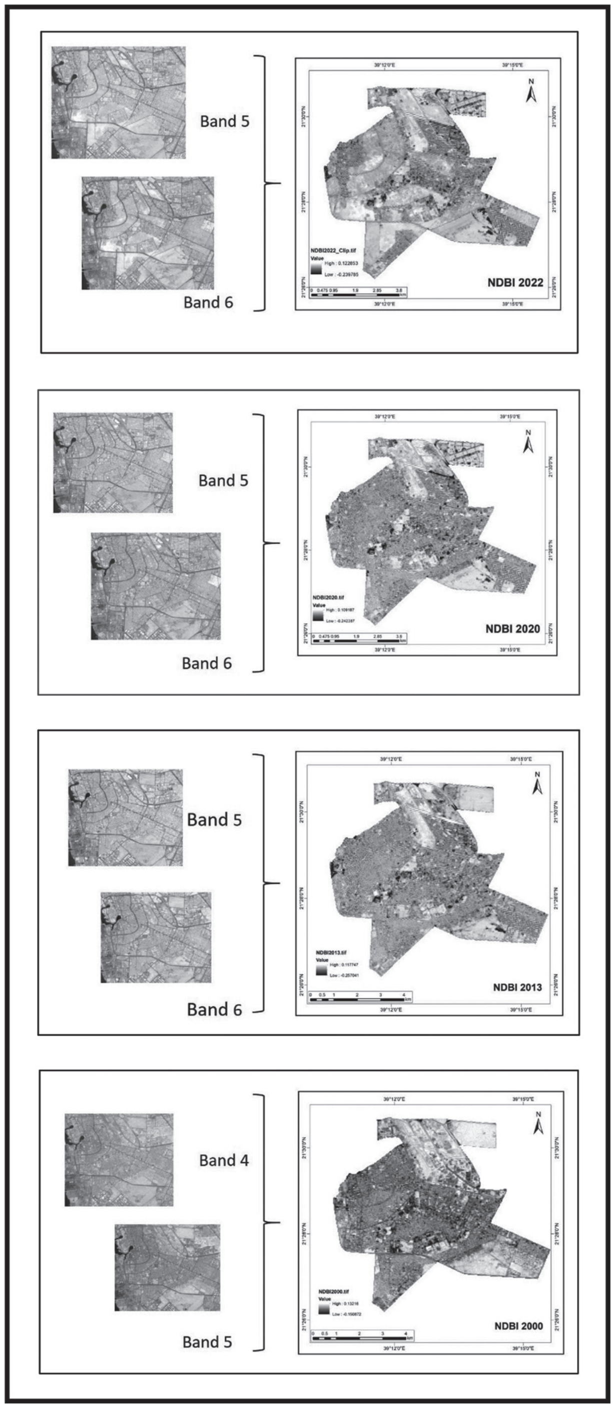

Figure 3: NDBI index for years (2000-2013- 2020 - 2022).

The next step is to use the Maximum Likelihood (ML) Classification applied to the NDBI index for the four years of the study period. Maximum Likelihood is a type of supervised classification algorithm and the most common Pixel-Based Classification, which aims to allocate pixel to the class with the highest likelihood and covariance matrix are the key inputs to the function and can be estimated from training pixels of a particular class (Shoaib et al., 2019 & El-Hames and Alahmadi, 2009).

The study area has been classified into three classes (built-up area, undeveloped area, and water bodies and vegetation cover at the same class). As shown in Figure 4, both vegetation and water bodies have merged because highlighting other classes are more important for achieving the study goal.

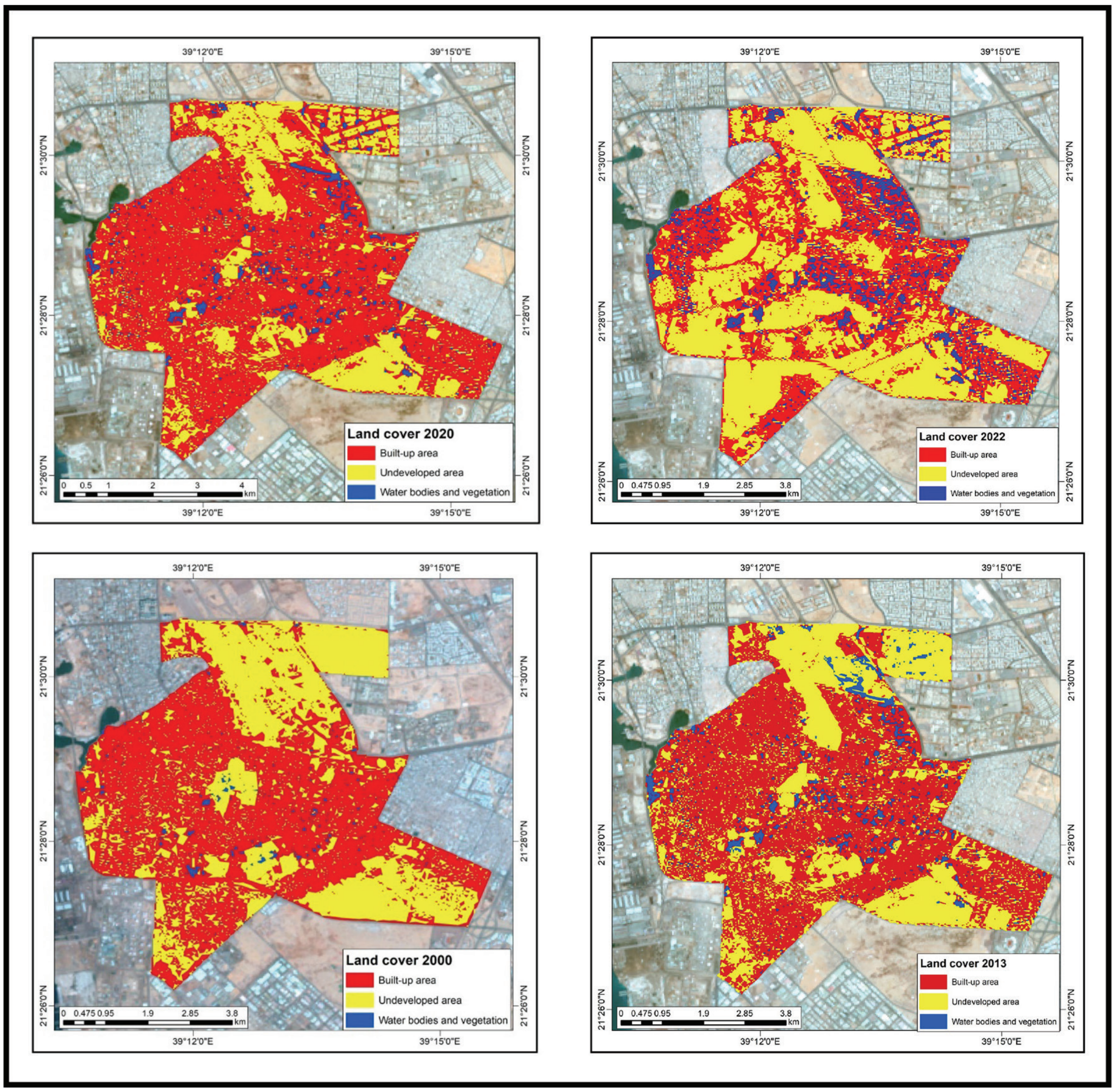

Figure 4: Classified images for the study period (2000 to 2022).

Data source: classifying Landsat images for years (2000,2013,2020, and 2022) and mapping land cover change between years 2020 to 2022.

Figure 4 shows three different classes (vegetation and water bodies, barren soil or undeveloped areas, and built-up areas). This division provides us with a better understanding of the change in the urban agglomeration map during the study period.

3. Results

3.1. Slums and their challenges

Since the inception of slums, there has been no specific definition for understanding the meanings of slums, but there have been attempts to describe the complex contexts, causes, and conditions that represent them. For example, one of the oldest references is shanty towns in (Rome, Paris, and London), characterized by squalid accommodations and destitute inhabitants. (Whittaker, 1993; Geremek, 1987; Stow, 1842 in Neuwirth, 2005).

The phenomenon of slums is very old, where linked to the city's development as a form of advancement and specialization. The dominant characteristics of slum areas are substandard living conditions, unsafe, and poverty (Glaeser, 2013). This definition of a slum shows an area with the following characteristics:

* Insufficient access to essential infrastructure e.g. (safe drinking water, Electricity, sanitation)
* Overcrowding and insecure tenure
* Poor and unsafe structure of buildings

Based on United Nations Habitat (UN-Habitat), slum growth has a serious effect on the process of achieving sustainability in Developing Regions, where the eradication of slums is a part of Sustainable Development Goals (SDG) by 2030 (United Nations, 2014). Thus, removing slums areas and developing unplanned areas takes all the attention off the government, so as not to be an obstacle in achieving the Kingdom's vision 2030. (Abubakar et al.,2017) confirmed about 90% of rapid urbanization growth on a global scale is in developing regions, with a 0.9% annual increase, and this trend is set to continue.

3.2. Measuring the change in land cover

For the study period 2000-2022, changes in scholastic features are shown in Table 1 below, showing the total area covered by these features.

Table 1: change in land cover areas (km^2) between 2000 to 2022.

land cover class	Year			
	2000	2013	2020	2022
Built-up area	21.00	27.04	28.13	20.13
Undeveloped area	17.40	11.88	10.16	16.19
Water bodies and vegetation	1.67	1.13	1.77	3.75

Data source: analyzing land cover change between years 2000 to 2022.

For the study period (2000-2020), the changes in the study area are evidence that the built-up area classes have continuously. From 2000 to 2013, the increase in the total change of built-up areas have been recorded up to as much as 26% (from 21 km2 to 27.04 km2) and this was the largest increase during the study period.

The increase can be noted clearly in Al-Fayhaa neighborhood, and from 2013 to 2020 it was 8.5%, but from 2020 to 2022 a decrease in the total urban area was observed by 28.4%. This is mainly due to some administrative plans that were formed and implemented by the Slum Development and Removal Project in Saudi Arabia and implemented by the Jeddah city Municipality, with Al-Sahafah, Al-Kandara, and Sabil recording the highest scale with more than 90% of their built-up areas declining (removed as slum areas) , while both Al-Fayhaa and Al-Keriyat are devoid of slums.

3.3. Mapping the removed urban areas

There has been a rapid increase in the built-up area of Jeddah city during the development of urban areas between years 2000 to 2020, but the period between 2020 to 2022 has shown a significant decrease in built-up areas.

Table 2 below shows the contrast between the neighborhoods of the study area, including the total built-up areas for 2020 and 2022. It also contains the removed slums areas. It can be seen that the percentage of removed areas ranged from 0 to 98% of the total built-up area. Elsahefa, Kandara and Sabel recorded the highest range with more than 90% of their built-up areas decreased (removed as slum areas), while both Elfayhaa and Elkorayat are free from slums areas. The table shows the contrast between neighborhoods of the study area, whether the total area of the neighborhood, the total built-up areas for each year 2020 and 2022 and removed slums areas.

Figure 5 and Chart 1 show the distribution of removed slums areas among the neighborhoods, which are in the study area, and the following graph shows the total slums area (8.01 km2) neighborhood separately.

Table 2: Distribution of the built-up areas and slums areas among the neighborhoods.

Neighbourhood	Built-up area 2020	Built-up area 2022	Removed area (slums) km2	Removed area (%)
Amariah	0.31	0.08	0.23	73.21
Balad	1.89	1.39	0.50	26.51
Elfahd	3.99	2.24	1.75	43.96
Elhendawya	0.95	0.22	0.74	77.09
Elnazla	2.98	2.13	0.85	28.58
Elsahefa	0.32	0.01	0.31	97.20
Elthar	2.31	1.84	0.47	20.40
Ghalil	1.24	0.67	0.57	45.58
Kandara	0.97	0.09	0.88	90.68
Nazla Sharkeya	1.51	1.28	0.23	15.34
Petromin	0.94	0.57	0.37	39.54
Sabel	0.56	0.01	0.55	98.20
Thalepa	0.77	0.17	0.60	77.86
Elfayhaa	6.31	6.31	0.00	0.00
Elkorayat	0.80	0.80	0.00	0.00

Data source: analyzing land cover change between years 2020 to 2022.

Figure 5. Removed area (slums) from 2020 to 2022.

Data source: analyzing land cover change between years 2020 to 2022.

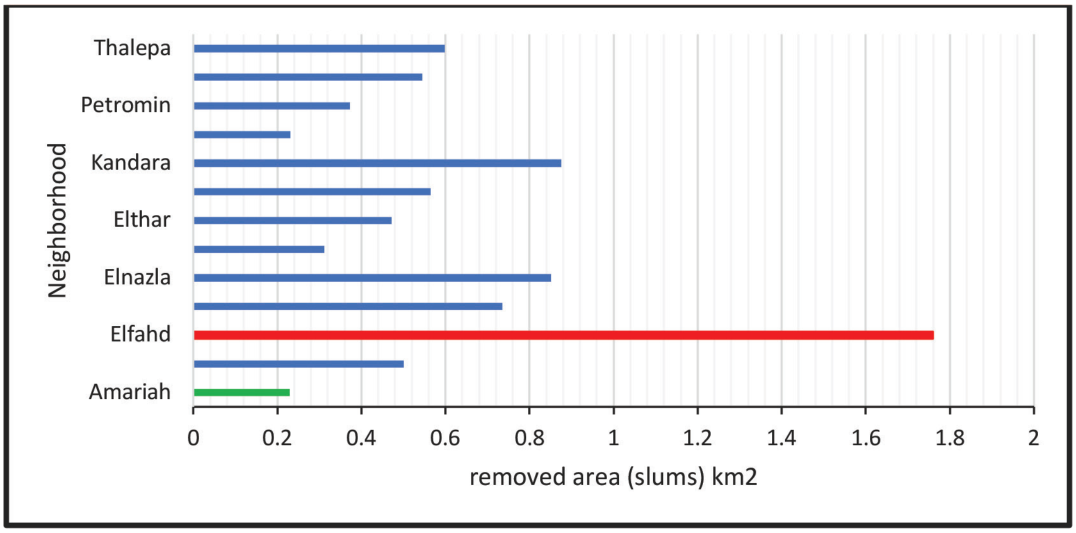

Chart 1. Distribution removed areas (slums) for each neighborhood.

4. Discussion

Jeddah's city slums are a serious problem that have expanded unplanned, covering almost half of the total urban area in Jeddah city, and that is caused by various factors that have grown to a scale beyond control. Slum areas have become undesirable and unsafe places. Accordingly, areas lack essential services and cannot afford an acceptable quality of life for its resident, which means these areas need to be removed. The Municipality of Jeddah city adopted a project to rehabilitate these areas to use redeveloped projects.

This paper investigated the changes in the land cover of southern neighborhoods of Jeddah city between 2000 and 2022.

Integration of GIS technology and remote sensing have proven their efficiency in evaluating project implementation of the Redevelopment Project by Municipality in Jeddah city. This confirms the possibility of using those tools in evaluating the work of other development projects related to urban development.

The study period was chosen between two years (2000 to 2022) to display the significant decrease in built-up areas resulting from the implementation of the Kingdom of Saudi Arabia Development Project, where the direction of change in the land cover was modified after the urban growth from the year 2000 to 2020, then in the last image, lost a large urban area, where classified before as slums areas.

The paper confirmed that the city's urban development project is on the right track. To achieve full benefit and maximize the benefit from the development project, periodic follow-up must be provided to evaluate the implementation of the project using modern geographical techniques to verify the development of an effective plan for the urban area in Jeddah city befitting to the city and its historical, cultural, and tourism value. This will help in the proper re-planning of the urban area, leading to an increase in the planned residential area, an increase in the number of economic establishments, and facilitating the transfer of services to marginalized areas, which will lead to improving and raising the level of services and improving the satisfaction of beneficiaries and the quality of life for the residents of those neighborhoods.

5. Conclusions

Integrating GIS and remote sensing tools are efficient tools for assessing the progress of the Redevelopment Project, thus the use of information in assessing accurate urban policies and their action plans. In the current study, multi-temporal Landsat images have been analyzed to measure and map land cover changes in the south part of Jeddah city from the year 2000 to 2022. The analysis process of satellite images in this research has been conducted using available satellite images using NDBI, unsupervised and supervised classification methods.

The results of the current study indicate that the increase in urban mass continued throughout the study period up to 2020. Still, in the most recent time (2020-2022) there was a decrease in built-up areas associated with the urbanization development project in Jeddah city. The results clearly show that the reduction of built-up areas; classified as slums, is obviously linked to the development of the urban area during the Saudi Arabia Redevelopment project.

In addition, it is evident from Figure 4 that in the early years of the Landsat images, urban areas were experiencing growth, especially within the Fayhaa neighborhood, but this differed in the last images in 2022, where soil arid areas remarkably increased in areas representing slums during the period from 2000 to 2020.

The study presented an extreme change in the built-up area during the Saudi Arabia Redevelopment Project by removing the slum area. The highest area of demolished slums was recorded in Elfahd district, with a total area of 1.76 km^2, while the Amariah district recorded the lowest area, with a total of 0.23 km^2.

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