

Urban Growth Change Analysis of Riyadh, Saudi Arabia: 2005-2015

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Abstract

Expansion of urban areas may have various negative economic impacts on cities such as changes in population density, scattered urban development, and increased water and energy demand. In this study, the capital city of the Kingdom of Saudi Arabia (Riyadh) was studied. Since Saudi Arabia has an oil-based economy, Riyadh has witnessed a fast urban growth rate during the past decade due to rising oil prices. As a result, changes may take place in the Comprehensive Riyadh Strategic Plan (CRSP). A supervised classification method was used in this study to identify urban change from 2005 to 2015. Satellite imagery and Riyadh land use plans served as data sources, and by using a GIS model, built and non-built environments in the city limits were identified. Built environment areas were found to be 38.9% in 2005 and increased to 40.5% in 2015. On the other hand, non-built environment areas decreased from 61.1% in 2005 to 59.5% in 2015. The overall change in built-up area in Riyadh was estimated to be approximately 44% and a total of 38% city expansion was found during the study time period. The study time period included two different phases resulting in scattered urban growth and increased growth rate in the study area.

Introduction

In 1902, Riyadh was a traditional Arabic town with an open space at the center surrounded by markets, houses, and a mosque; all were built out of mud and were surrounded by a wall. At that time, the population was less than 19,000 people in an area of 1 sq km (Middleton, 2009). In 1931, King Abdulaziz Al Saud, the first King of the third Saudi dynasty, declared Riyadh as the capital of modern Saudi Arabia and this was the first phase in the transformation process of Riyadh (Arriyadh Development Authority, 2003b). Riyadh started to grow beyond the wall since then and reached an area of 13 sq km with a population of 83,000 people.

The second phase happened during the oil boom which began in the year

1950. During that phase, the city changed drastically. The wall that surrounded Riyadh for many years was demolished; as a result, the city is open and accessible for everyone – especially people who are looking for job opportunities (Middleton, 2009).

Urbanization of Riyadh was unorganized and not well planned, and that led to many problems. At that time, some authorities started realizing the importance of city codes and ordinances to control the urban development process. Thus, a master plan was developed in 1972. The plan was made by Doxiadis Associates, a Greek architect consultation organization founded in 1952. However, Riyadh growth exceeded planned urban limits and growth rate expectations. Therefore, a second plan was developed from the

previous plan (Doxiadis) and set by SCET International in 1981 (Arriyadh Development Authority, 2003a). This ten-year plan anticipated the population growth to be 1,600,000 in an area of 650 sq km (Middleton, 2009). However, the first plan failed because the growth rate exceeded the expectations as shown in Figure 1.

After the failure of the two master plans, Arriyadh Development Authority (ADA) established a Comprehensive Riyadh Strategic Plan (CRSP) in 2003. This strategic urban plan included all components of city growth, such as urban, environmental, economic, transportation, housing, and infrastructure. This allows authorities to manage the city since the CRSP regulates joint actions, provides services for residents, raises city living standards, and plans for the future.

The CRSP aim was to direct urban growth to a defined area by setting urban growth boundaries (Arriyadh

Development Authority, 2003b). Urban growth boundaries (UGB) consist of a group of areas that are known as urban containment, which includes public lands, defined urban service areas provided by the government, and non-buildable land such as parks, farmlands, and open spaces that surround a town or city.

The importance of implementing UGBs in an urban development process is to direct and limit urban growth to a specific geographic area during a specific time period. One of the main benefits of UGBs is lower development costs because urban growth is directed to a specific area with high density that is provided with public infrastructure and city services such as water, sewer, schools, public transportation, and hospitals; not to mention, rural and agriculture areas located outside UGBs are protected from urbanization. Other benefits include: availability of affordable housing near city services and public transportation, better

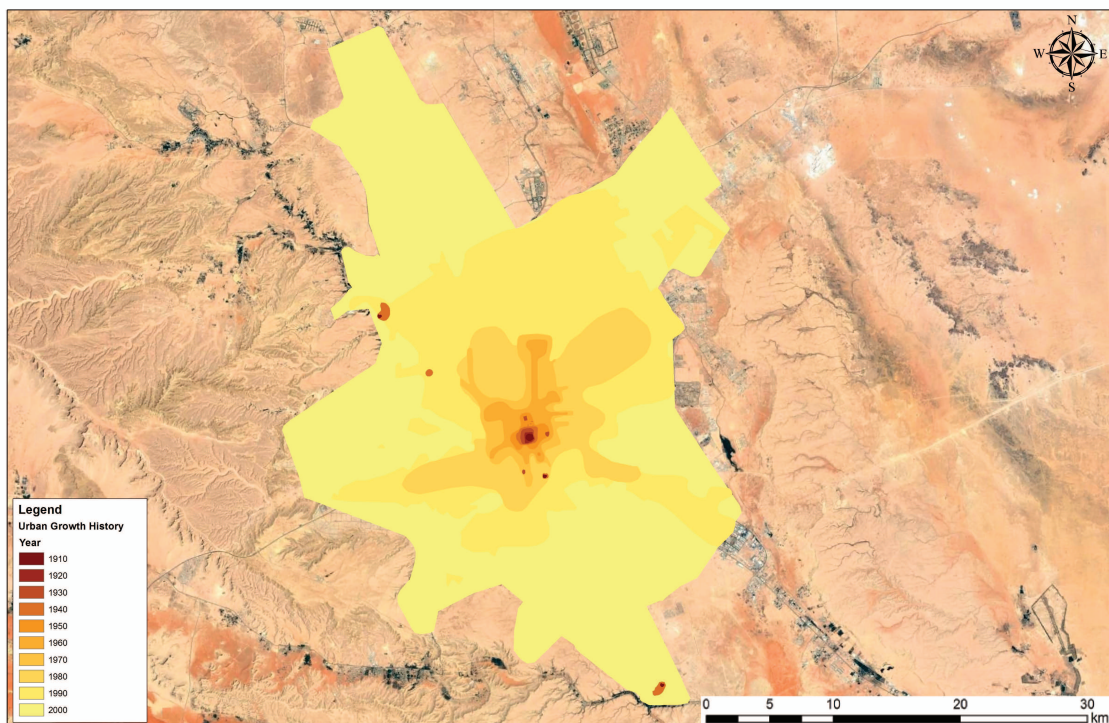


Figure 1. Riyadh urban growth from 1910 to 2000.

job opportunities, better lifestyle, and higher economic production (Conservation Easement Assistance Program, n.d.).

The CRSP included urban growth phases, each with goals to be achieved in a defined geographic area within a specific time limit. The goals aim to reduce scattered urbanization, create a coherent and focused urban growth environment, and regulate the provision of public service and facilities during specific time periods. Four urban growth phases were set in the strategic plan between 2010 and 2030. Each phase has a start time and defined temporary city boundary (Arriyadh Development Authority, 2003b) (Figure 2).

In 2015, a major increase in oil prices occurred. The average price of a barrel of oil was around \$25.9 over a period of 10 years from 1996 to 2005, and it jumped to an average of around \$83.2 over the period from 2006 to 2015

(Organization of the Petroleum Exporting Countries, n.d.). Increases in oil prices had a major effect on Saudi Arabia's economic status and led to numerous changes and developments. One major change is the fast growth rate in Riyadh.

The city experienced many changes between 2005 and 2015 and went through various sets of changes throughout the years (Towson, 2011). Positive and negative impacts occurred, however negative effects are more common especially in developing countries with rapid, uncontrolled urban growth. Consequences of urbanization are evaluated based on their environmental, social, and economic impacts (Bhatt, 2013). The Kingdom of Saudi Arabia is considered as a developing country that experienced a fast and uncontrolled urban growth especially in its large cities such as Riyadh. As a consequence, major undesirable effects are arising every day.

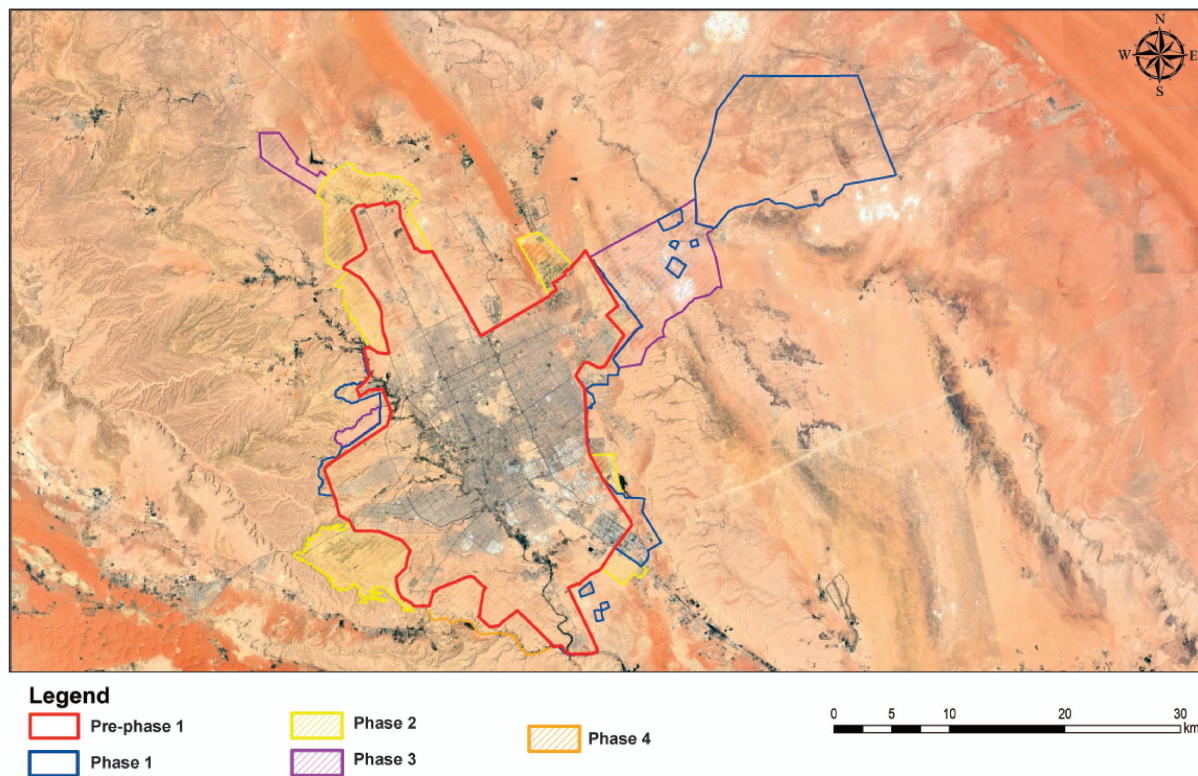


Figure 2. Riyadh urban growth phases. Pre-phase 1 (2005) and phase 1 (2015).

Urban sprawl may harm the environment by increasing temperature and air pollution. Higher localized temperatures are in part due to increases in black or dark surfaces such as rooftops and roads, as well as a decrease in green plants and trees. Negative public and social impacts of sprawl may include increased traffic and motor vehicle accidents, air pollution induced health problems such as breathing diseases, and temperature-related health problems such as heat stroke. Most importantly, sprawl may lead to inflated infrastructure and increased public service costs (Bhatt, 2013).

Gathering data from these changes helped in analyzing the city (Figure 3) and its amenities. Identifying non-built and built areas are significant tools to aid local government, city developers, and residents. This study helps to analyze the growth rate resulting from the economic boom and adapt new urban policies to meet the Riyadh strategic plan. It also will help city officials and utility providers to locate any lack of services such as police, civil defense, mail-post, and schools. In addition, better planning yields better results for future services in the city. Lastly, city residents interested in housing as well as land owners may benefit by understanding future trends and locations of high or low housing supply and demand.

Methods

Study Area

Riyadh, the capital city of the Kingdom of Saudi Arabia is located in the central region at the eastern part of the Arabian Peninsula (Figure 3) with a population of 4.45 million in 2005 and 5.93 million in 2015. The study area is 1750 sq km in 2005 and 2400 sq km in 2015. The latitude of Riyadh is 24° 38 N and 46° 43

E with elevation around 600 m above sea level. The city is bordered by Huraymila, Diriyah, Dhurma and Al- Muzahimiyah provinces to the west, Al-Kharj province to the south, Eastern province to the east and Rimah province to the north. The most important topography of the city is Hanifa valley which runs through the city from the northwest to the southeast with a total length of around 120 km; its depth ranges between 10 m to 100 m and varies in width from 100 m at some regions to approximately 1000 m at others.

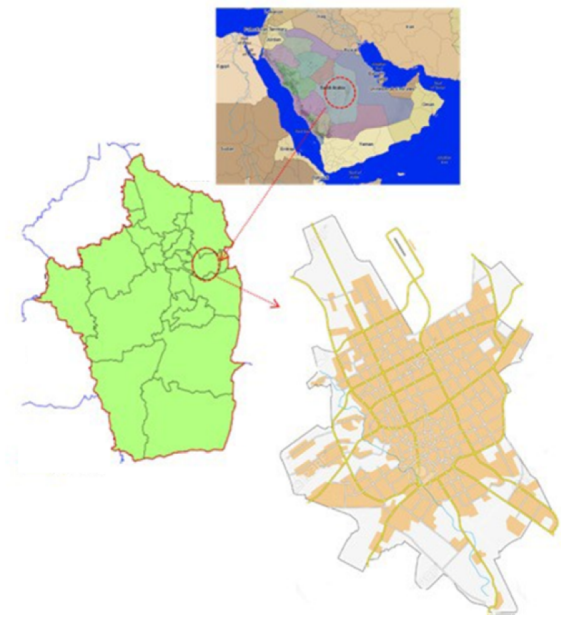


Figure 3. Riyadh city. The area is approximately 2,400 sq km in 2015.

Data Collection

Two types of data were used in this study: satellite imagery and land use plans. Satellite imagery data was collected from the National Remote Sensing Technology Center at King Abudlaziz City for Science and Technology (KACST). It contains Riyadh's images in 2005 and 2015. SPOT-5 satellite image with 2.5 m spatial resolution was used for the year of 2005 (Centre National D'etudes Spatiales, n.d.) and SPOT-7 with 1.5 m spatial resolution

was used for 2015 (Airbus Defence and Space, 2014). Each time period has more than one image to cover the whole study area since the imaging swath for these satellites is 60 km. This high resolution data helped to identify impact on the city during the study period from 2005 to 2015. The extracted raster data assisted in identifying built and non-built areas for the study. Riyadh's land use plans were used to locate city boundaries through urban growth phases. The CRSP defines Riyadh development boundaries and their layers. The urban growth phase map layers are divided into four phases and one pre-phase based on five time periods. Each of these layers has a pre-planned start year for the development process, except for pre-phase 1 since it is considered to be the city boundary before the implementation of the CRSP with no definitive start year identified (Table 1). The vector data was obtained from the GIS department at ADA.

Table 1. Riyadh urban growth phases.

Urban Growth Phase	Year Started	Area (sq km)	Total City Area (sq km)
Pre-phase 1	-	1755.2	1755.2
Phase 1	2010	642.7	2397.9
Phase 2	2015	365.3	2763.3
Phase 3	2020	292.2	3055.4
Phase 4	2025	75.9	3131.4

Projection

All of the data used for analysis in this study were projected using the following:

Projected Coordinate System:
Ain_el_Abd_UTM_Zone_38N WKID:
20438 Authority: EPSG Projection:
Transverse_Mercator False_Easting:
500000.0
False_Northing: 0.0
Central_Meridian: 45.0
Scale_Factor: 0.9996 Latitude_Of_Origin:
0.0 Linear Unit: Meter (1.0)

Geographic Coordinate System:
GCS_Ain_el_Abd_1970 Angular Unit:
Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0) Datum:
D_Ain_el_Abd_1970
Spheroid: International_1924 Semimajor
Axis: 6378388.0
Semiminor Axis: 6356911.946127947
Inverse Flattening: 297.0

Data Preparation

Satellite images gathered were of different sizes and locations within Riyadh. Preparing the images and grouping them into one image was an essential step to start the study. All images were geo-referenced before merging. Subsequently, the satellite images were mosaiced together into one image using ArcGIS (Figure 4). This process was replicated for both time periods. The output was two consolidated satellite images for the years 2005 and 2015 (Figure 5).

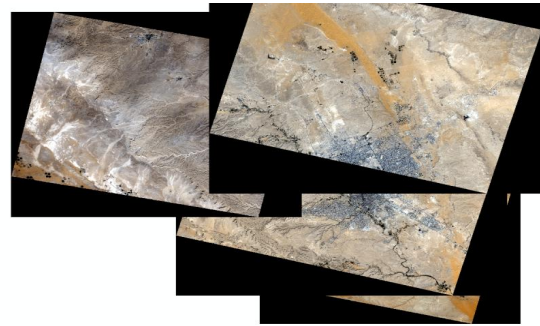


Figure 4. The four satellite images used to cover all study area in 2015.

Excluded Data

Non-buildable lands were excluded from the study area - namely protected areas. It includes green areas and the old airport area (Figure 6). Green areas include: Hanifa valley, national parks, and historical parks. Hanifa valley is located in the west side of the city with an area of around 175 sq km and it has a

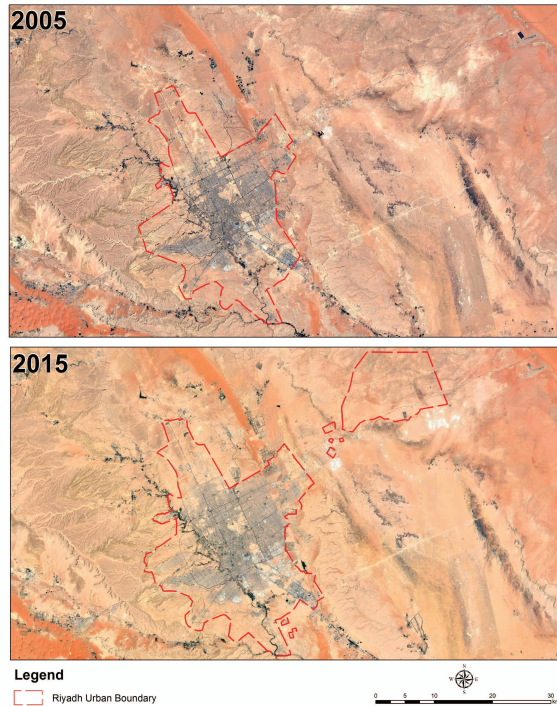


Figure 5. Study area in 2005 and 2015. Orange lines represent city limits.

buffer zone that surrounds the valley to protect it from urbanization. However, the old airport area (15 sq km) is located in the center and it is protected from urbanization.

Procedure

For this study, datasets were processed using three programs: ArcGIS version 10.4 by the Environmental System Research Institute, Inc. (ESRI), Microsoft Office, and Adobe Illustrator.

Satellite Image Classification

A supervised classification method was used. The “Maximum Likelihood Classification” tool was used to identify built-up and non-built-up areas by selecting representative samples such as: buildings, streets, green area, rivers, and

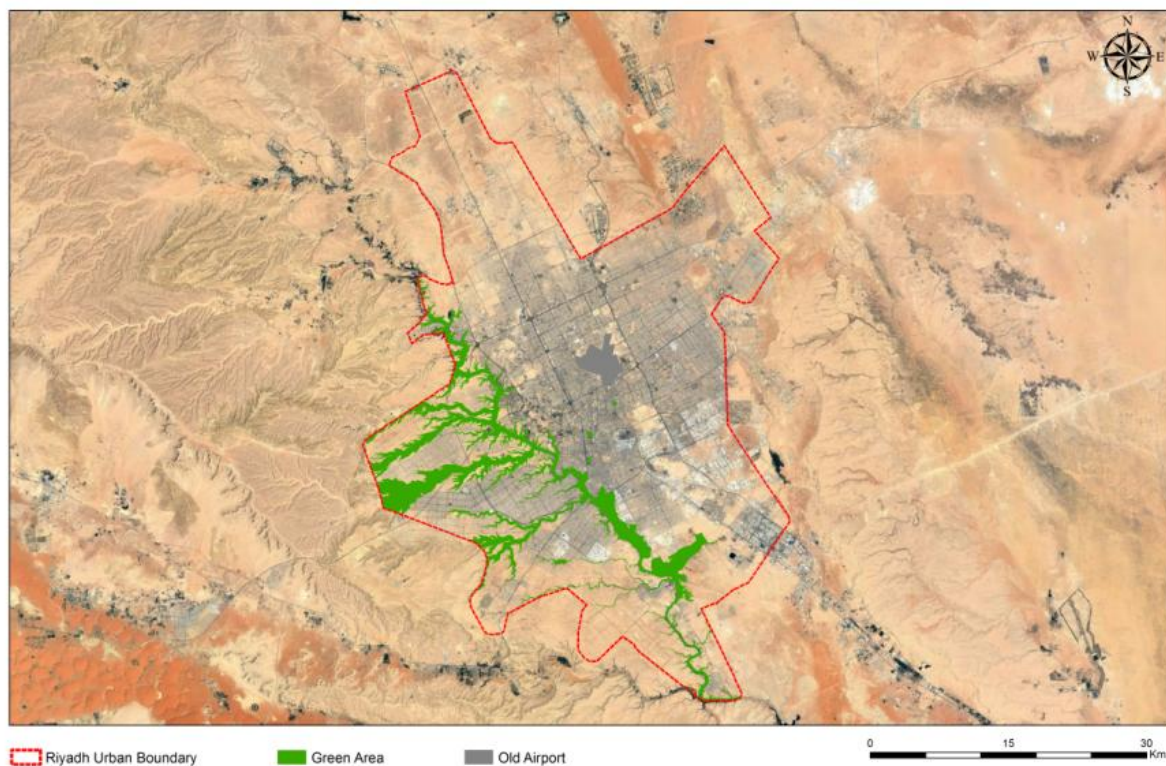


Figure 6. Protected areas including areas represented in green as well as an old airport excluded from the study.

vacant land (GIS Geography, n.d). The raster bands were then classified into two classes: built-up and non built-up. The samples for each class were selected on the map by drawing polygons. Each polygon represented a sample of a case occurrence. Each class was represented by unique color bands (Figure 7). The raster was clipped to exclude the protected areas using the “Extract by Mask” tool. This step was repeated for both images of 2005 and 2015. The output featured two classified raster images clipped to the required study area (Figure 8).



Figure 7. Built areas represented by red polygons and non-built areas represented by yellow.

Calculating Areas

Calculating non-built and built classes was conducted through converting raster data to features. Each raster was converted using the “Raster to Polygon” tool. The output of this process is a polygon feature layer. A field (GRIDCODE) was added to the polygon layer with values of both classes identified while classifying the satellite images. Different values were given for built areas (0) and non-built (1) areas. Calculating the area of two features was more convenient than calculating the area for more than 420,000 features. The “Dissolve” tool was used to create a feature layer with two features – one feature for each class. Calculating the

area for each feature required two procedures – one, adding a new “Area” field and, two, specifying the coordinate system of the data frame to Ain_el_Abd_UTM_Zone_38N. The unit selected to represent the area of each feature was square kilometers. All other layers were added and their areas were calculated similarly (Figure 9).

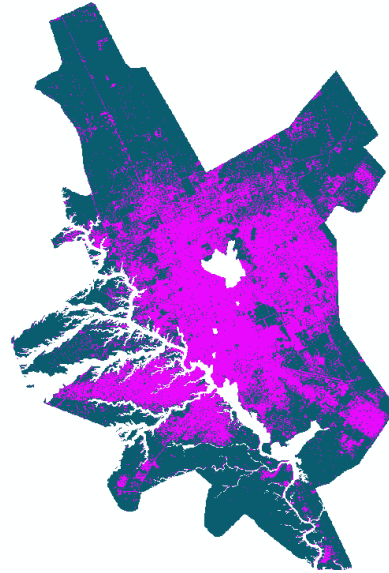


Figure 8. Purple color shows built-up and dark green shows non built-up areas.

Results

The study shows Riyadh experienced an urban growth rate of 44% from the year of 2005 to 2015. In 2005, built areas constituted 38.9% (615.5 sq km) of total city area (1583.9 sq km) (Figure 10), whereas the non-built areas constituted the remaining 61.1% (968.4 sq km). In 2015, phase 1 was added to the study area. Thus, the city area expanded from 1583.9 sq km to 21865.8 sq km. The built-up area increased by 269.8 sq km to reach a total of 885.3 sq km, which constitutes 40.5% of total city study area, including both pre-phase 1 and urban growth phase 1 areas. On the other hand, the non-built-up areas amounted to 59.5% (1300.5 sq km) (Table 2).

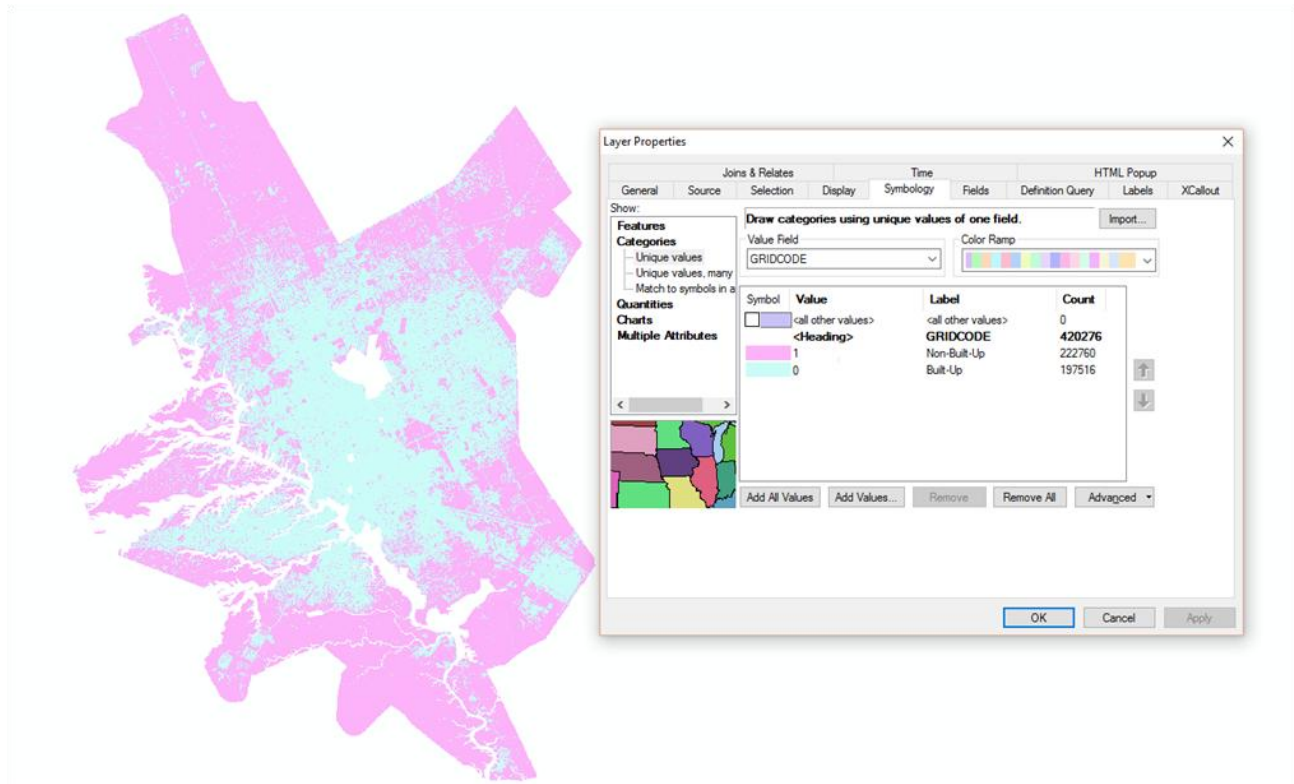


Figure 9. Two features contain all built-up and non built-up areas in 2005. Light blue represents built-up areas and the pink non built-up areas.

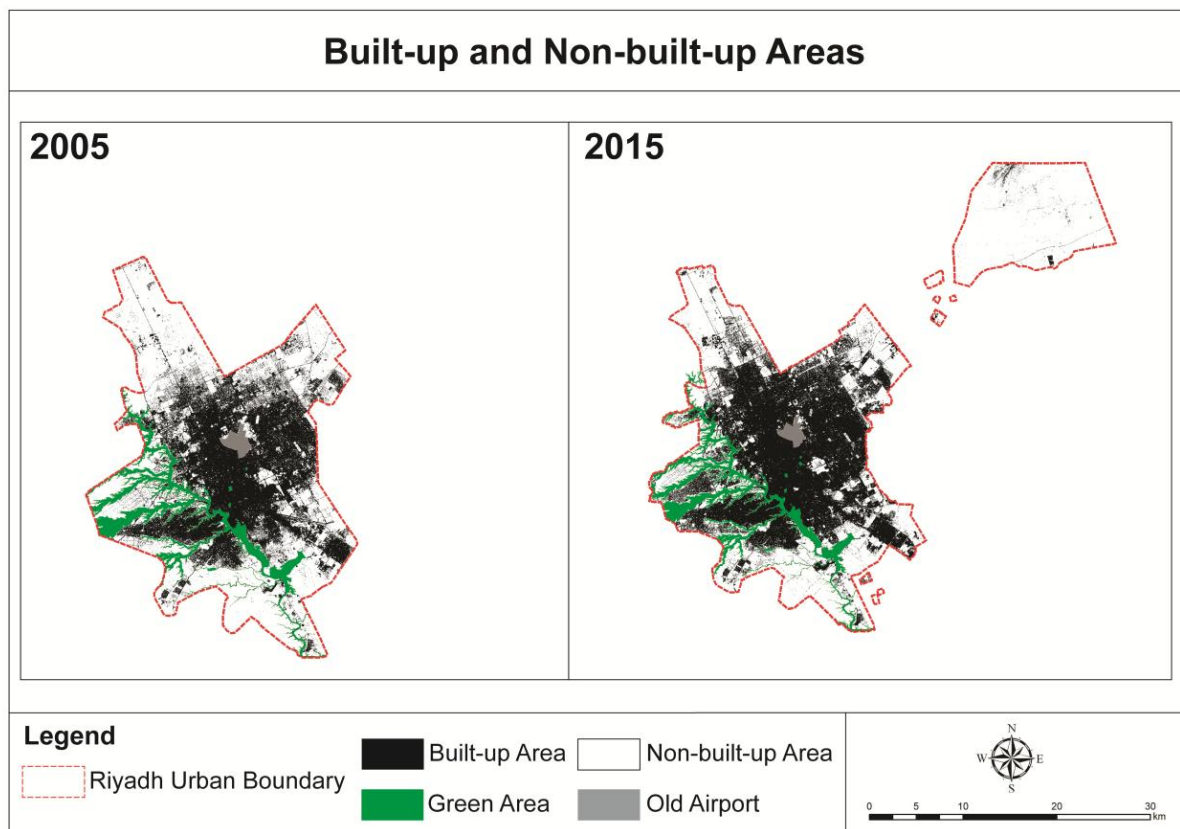


Figure 10. Built-up and non built-up areas for Riyadh city.

Table 2. Built and non-built area distributions in active urban growth phases over the study time period.

Year	Area	Pre-phase 1.		Phase 1		Total	
		sq km	(%)	sq km	(%)	sq km	(%)
2005	Built-up	615.5	38.9	-	-	615.5	38.9
	Non Built-up	968.4	61.1	-	-	968.4	61.1
2015	Built-up	846.2	54.2	39.1	6.3	885.3	40.5
	Non Built-up	737.7	45.8	585.6	93.7	1300.5	59.5
Total		1583.9		624.7		2185.8	

Discussion

The study showed a large change of built areas over the study time period. The built areas increased by 43.8% from 615.5 sq km to 885.3 square kilometers. This major increase reflects the economic and demographic changes that occurred in the city during that time such as the increase in oil prices, urbanization, and population. Out of 43.8%, only 6.4% occurred within urban growth phase 1 city area compared to 37.5% in pre-phase 1 city area. Moreover, the built areas increased from 38.9% in 2005 to 40.5% in 2015. There was no major change observed in the percentages between 2005 and 2015, and that is due to the concurrent increase in overall boundary of the city from 2005 to 2015 by the addition of urban growth phase 1 area.

Pre-planned urban growth phases in the CRSP do not meet the city's need in city expansion and it over estimated the growth. The city boundary is used as a growth management tool to stop urban sprawl.

The boundary of phase 1, for example, expanded the city area by 38% from 1583.9 sq km in 2005 to 2185.8 sq km in 2010. As a result, around 94% of urban growth phase 1 has not been used until now. In 2015, 59.5% of the whole city was found to be a non-built area. This did not differ much from 2005 where the non-built areas were

61.1%. Unorganized and scattered urban growth was a result of Riyadh expansion after setting the new city boundary of phase 1 while the area of Riyadh pre-phase 1 was not fully occupied yet.

Based on the CRSP, a lower growth rate is expected in the future. As a result, future urban growth phases should be smaller in expansion areas. The urban growth phase 1 area was 642.7 sq km, which was almost the double of urban growth phase 2 area (365.3 sq km). It is even smaller in phase 3 (292.2 sq km) and phase 4 (75.9 sq km). However, the non-utilized area of urban growth phase 1 is large enough to consider adjusting upcoming urban growth phases in terms of modifying their areas.

Conclusion

Although a major growth rate was observed over the study time period (43.8%), which reflects a major increase in built-up area in 2015, there was no change in the percentages of built-up and non built-up areas in 2005 and 2015 due to the concurrent increase in non built – up area after the implementation of urban growth phase 1 in 2010. Since the aim of defining city boundaries for each phase of the CRSP is to limit urban growth sprawl and scattered urbanization, adjustment of future phases should be considered in order to save the city from scattered urbanization that will have a negative

impact on residents, utility providers and the general economy.

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