# Dynamic Spatial Monitoring for Urbanization Area Sprawl and Land-Use Using Multi-Spectral and Temporal Remotely Sensed Satellite Images

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# Abstract

Spatio-temporal analysis for Urban Growth patterns is vital for city management and planning. Nowadays, AL-Hilla city is challenged lack of reliable urban datasets for urban sprawl management and planning. It suffered from a massive fragmentation of agricultural lands and orchards after 2003 and their transformation and conversion into residential lands, and that's leads to a decrease in the plantation and vegetation lands, which affects the climate, increase temperatures, winds, and dust storms in the two past decades, especially in the summer and drought seasons. This study focuses on assessing, monitoring, and estimating the urbanization growth and detection of the changes in Land-Cover using different temporal, spectral, and spatial different satellite images. A supervised image classification technique, the Mahalanobis Distance (MD) was adopted. Three different maps of Land-Use/Land-Cover were generated for the period of 2002, 2011, and 2022, and were employed to assess and analyze the vegetation land degradation and urban sprawl quantitatively, and visually. A confusion Matrix was adopted to perform the accuracy assessment. A statistical comparison was conducted to calculate the changes between the land categories. It is found, over the past 20 years, urbanization increased rapidly in AL-Hilla city by 20.31km$^2$, from 33.40 km$^2$ in 2002 to about 73.97 km$^2$ in 2022. An average annual increasing rate during the period from 2002 to 2011 was recorded at about 6.7%. However, urban area sprawl was higher for the next decade during the period from 2011 to 2022, with the increased rate of average annual recorded at about 3.8%. Urban area growth of AL-Hilla city increased three times from 2002 to 2022 and that is about 27.98% of the total area of AL-Hilla city. In general, this urban growth leads to the Urbanization sprawl, and expansion into other Lands classes; Water area, Soil area, and Vegetation area.


# Introduction

Urbanization is the spatiotemporal analysis that has an important role in social, economic, and environmental fields. Urban sprawl is a spatiotemporal process and analysis that involve various types of urban sprawl[1–4]. In addition, urban sprawl results from the combined effects of both natural parameters and anthropogenic[5]. The anthropogenic parameters mainly mean; population growth, economic increase, and urbanization development. However, natural parameters refer to spatial-heterogeneity; Topography and Soil properties[6–7]. In many cities, urban sprawl has a negative effect on agricultural and vegetation lands, and also on the city's greenery[8]. The urban expansion also will cause landscape transformation, conversion, land degradation, and agricultural lands fragmentation[9–11].

Iraq is one of the countries around the world that suffered from the negative impacts of urban expansion. Currently, urban area in AL-Hilla city is facing challenges and lacks reliable datasets for urban monitoring, management, and planning. in AL-Hilla city there is a massive conversion and fragmentation of plantation and agricultural lands such as orchards after 2003, and convert into urban lands, which caused desertification, negative impacts on the climate, high temperatures, and dust storms become increasingly persistent in the last 20 years, especially in the summer season. Many studies[12–14], report

and pointed out that landscape conversion and transformation are resulting of urban sprawl. The urban sprawl has serious environmental issues that threaten the sustainable development of the agricultural lands and the city. The landscape's conversion, and transformations under the impact of urban growth in different and multi-directional [15–16].

The dynamic urban sprawl process depends on many factors such as land topography, manmade lands and the city demography, population, and economy[17]. The urban sprawl causes a change in natural lands, which is included rocks, soil, and vegetation to manmade lands, which are composed of asphalt, concrete, and metals[15,17,18]. Another big problem of urban sprawl is lands conversion and transformation into developed manmade land use[19]. While the natural landscape conversion and transformation, the surrounding lands and human resources will be under the effect of the urban sprawl, which causes changes in human life quality in two directions; positively and \ or negatively.

Currently, Remote Sensing is a powerful technique and tool for viewing, processing, detecting, monitoring, analyzing, mapping, and estimating urban growth. Remote Sensing adopts for management, and monitoring the changes in urban areas on different angles[1,20–23]. Nowadays, remote sensing is known as an important source of datasets for urban area modeling, based on its highly spectral, spatial and temporal datasets[24]. In Addition, remote sensing datasets are very various and verity to be very useful for different applications and projects because of it can provide datasets in real-time data with a synoptic view, and repetitive coverage for the same study area, a database needs to create the changes of urban area in any\or specific particular area[25]. A geographic Information System (GIS) is a system of decision support, which can facilitate and ease urban management and planning. GIS modeling become a powerful tool for the urban sprawl research field. Some studies on urban expansion use the GIS is a computerized tool for getting a full understanding of the urban sprawl effects on the environment. The GIS shows the spatial patterns of urban expansion by measuring distance of any new urban expansion and growth area from town center and road as reported by Gar-On Yeh and Xia[26]. Because the urban growth and development is irreversible, the GIS can simulate the future lands development[27–30]. The satellite datasets, remote sensing, and GIS are the most relevant approaches and technologies to meet the needs of urban growth in a good and effective manner[23].

In the last 20 years, AL-Hilla original structure, and spatial organization have changed dramatically, and thus AL-Hilla city is segmented into different areas and regions, each involving some particular activities. AL-Hilla's population has dramatically increased from 2000. the increasing of population records three times between 2003 and 2022[31]. AL-Hilla lands have changed based on the activities of human beings[25]. This study is aimed to create Land Use/Land Cover changes detection and temporal maps for AL-Hilla city and the rapid urban growth over the last 20 years from 2002 to 2022.

Finally, this article starts by introducing urban sprawl. Section (2) provides details of the study area, and the processing and analysis of the used datasets, image corrections, and classification. Section (3)

contains the results of the land use/land cover classes processing and analyzing, and analysis of the urban growth. Section (4) concludes the study.

# Materials And Methods

For this study, three satellite images of the QuickBird-2, WorldView-2, and Sentinel-2 were adopted to be tested, and examined to conduct this study, and to show the effectiveness of adopting and using the multi-sensor datasets that have a variety of resolutions in order to detect the change detection of Land Use and Land Cover then to detect and monitor the Urban Expansion in AL-Hilla city. There are many phases to complete performing this research, it starts with, (a) Pre-processing stage to remove geometric and radiometric errors and noise, (b) the processing step is determining the study area by clipping and sub-setting the images, (c) then the satellite images resampling, (d) Fieldwork to collect the ground control points, (f) the training and testing samples are selecting. However, for the post-processing step, (g) the Mahalanobis distance as a supervised image classification approach was employed for creating the Land Use/Land Cover thematic maps. Then, (h) validate all the obtained results by applying the confusion matrix approach. (i) the change detection was performed by making a statistical comparison between all of the results of each classified image from 2002 to 2022, (g) finally, the Urban growth analysis was performed to calculate the annual urban growth percentage rate in AL-Hilla city.

### Study Area Description

The study area of this research is located in the central part of AL-Hilla city, its location has a latitude about of (32°32'07.93"N - 32°23'31.52"N), and a longitude about of (44°22'50.30"E- 44°29'42.41"E), with elevation to the mean sea level about of (112) ft and that equal to about (34m). The study area is far around 100km to the south of Baghdad city. The AL-Hilla city is located in Babylon province, Iraq, and it is the center of Babylon province. It has surrounded by other governorates boundaries such as Baghdad province, Karbala province, Anbar province, Najaf province, Wassit province, and AL-Qadissiya province. Euphrates river goes through the study area, and it is one of the two biggest rivers in the republic of Iraq, and this river is divided into two branches, (1) the AL- Hindiyah, and (2) the AL-Hilla branch which is located in the south of the Musayib city[31]. Al-Hilla has a population of around (970000) people regarding to the registration that was conducted in 2018, Fig. 1 illustrates the study area description.

AL-Hilla' economy is depended on agriculture, and it has tens of hundreds of squares kilometers covered by agricultural areas, which provides the city markets with different fruits, vegetation, and plantations. Moreover, it has hundreds of archeological locations and ancient sites such as the ancient city of Babil. These historical and ancient's locations have frequent tourist attractions to enjoy and study these sites. Another site that increases the economic side of AL-Hilla city is having the many private and government universities near and inside the study area. AL-Hilla city has a dry season, and temperatures in some seasons is over 50°C in summer, and the average temperatures in AL-Hilla city are ranging 14-24° C. However, rainfall is so limited to occur between November to April in the winter season, with annual precipitation reaches to 4.49inches[32].

### Errors and Noise Removal

The high spatial and spectral resolution of QuickBird-2, WorldView-2, and Sentinel-2 satellite images were employed for monitoring, detecting, and deriving the Land Use/Land Cover maps and the urban expansion and growth of the study area for the years 2002, 2011, and 2022 respectively. All the adopted satellite images were cloud Free, and all these datasets were captured in June. The Sentinel-2 image was downloaded from the website of the [European Space Agency by using the followed link: https://scihub.copernicus.eu/dhus/#/home]. The images included the visible (V), and near-infrared (NIR) bands. Table I shows the specifications of the used satellite images.

**Table 1.** specifications of the adopted Datasets.

| Satellite | Date | Spatial resolution | Spectral resolution (m) | Projection |
|---|---|---|---|---|
| QuickBird-2 | June, 2002 | 5 bands | 01m x 01m | UTM Zone 38N |
| WorldView-2 | June, 2011 | 8 bands | 0.6m x 0.6m | UTM Zone 38N |
| Sentinel-2 | June, 2022 | 13 bands | 10m x 10m | UTM Zone 38N |

Different digital image techniques were applied to make the satellite images ready for the next analysis steps to perform detecting and monitoring of the changes in land use/cover and urbanization area expansion. These stages such as, imagery geometric and radiometric corrections, and image subsetting to extract the study area. All the remote satellite images were corrected geometrically and radiometrically. The geometric correction was conducted by collecting 14 ground control points (GCPs) from the Fieldwork in the study area, and then using these GCPs to correct the QuickBird-2 satellite image, this image is considered as a reference (Master) scene to other used images of 2011, and 2022. Fig. 2 and Table 2 show the location of the collected GCPs from the study area. Geometric rectification process is a critical process to produce a corrected thematic map of different Land class changes and urban expansion and growth over the period of time. The 2011 WordView-2 and 2022 Sentinel-2 images had been already rectified, and geo-referenced to the map projection (Universal Transverse Mercator) within Zone 38N, WGS84 ellipsoid as a datum. These images were used as slave scenes. In this study, image-to-image approach has been used for performing images registration, a polynomial first-degree equation was utilized in images transformation. Then, it is calculated Root-Mean-Square-Error was less than 0.5 m, revealing an excellent image rectification. The nearest neighbor approach was adopted for resampling[32]. A Histogram-matching was employed to improve the output image's visual appearance, and brightness[33].

**Table 2.** the description of the collected GCPs

| No. | Latitude | Longitude |
|---|---|---|
| 1 | 32°28'33.03"N | 44°28'08.35"E |
| 2 | 32°31'10.73"N | 44°27'27.05"E |
| 3 | 32°31'42.42"N | 44°25'34.94"E |
| 4 | 32°31'18.48"N | 44°23'58.57"E |
| 5 | 32°29'29.98"N | 44°23'43.18"E |
| 6 | 32°28'05.89"N | 44°23'23.08"E |
| 7 | 32°26'52.05"N | 44°23'22.64"E |
| 8 | 32°26'40.34"N | 44°28'17.70"E |
| 9 | 32°24'03.89"N | 44°23'27.86"E |
| 10 | 32°24'33.34"N | 44°29'04.27"E |
| 11 | 32°25'52.53"N | 44°25'44.55"E |
| 12 | 32°27'10.51"N | 44°26'27.56"E |
| 13 | 32°28'28.91"N | 44°25'22.34"E |
| 14 | 32°30'10.38"N | 44°25'56.98"E |

### Image Processing and Classification

The selection of the involved bands in the next stages of processing and analysis of the applied satellite system images was performed to provide good visual information regarding to urban areas, and it was for QuickBird-2 and WorldView-2 bands (1, 3, and 4) bands, (2, 4, and 7) bands, and their equivalent Sentinel-2 (2, 4, and 8) bands. Then, color combinations were made to each image of the QuickBird-2 (2002), WorldView-2 (2011), and Sentinel-2 (2022) for better purposes of analysis. The selection of color combination of the three satellite systems, QuickBird-2, WorldView-2, and Sentinel-2 bands were made to use the three main spectral-regions information of the adopted satellite system images (visible, and near-infrared).

To map and estimate the urban expansion, and changes that occurred AL-Hilla city during the period of time between 2002-2022, nine bands from the three datasets (the thermal bands were not involved) were individually applied for the purpose of the supervised classification. The Mahalanobis Distance method was selected to classify all the images, Envi software was adopted for performing the Land Use/Land Cover estimating from the multi-temporal satellite images. For image classification, five categories were selected in this research: (1) Roads, (2) Vegetation, (3) Water Bodies, (4) Soil Area, and (5) Urban Area. These five classes are detailed in Table 3.

**Table 3.** the considered classes, and their definitions in this study.

| Class number | Class name | Description |
|---|---|---|
| 1 | Roads | Asphalt Roads |
| 2 | Vegetation | Orchards, field crops, deciduous, and evergreen plantations, and shrubs. |
| 3 | Urban Area | Industrial and commercial, buildings, residential areas and houses, and all types of transportation facilities such as airports, and parking lots |
| 4 | Water Bodies | All types of water bodies, rivers, lakes, and other |
| 5 | Soil | Desert and sand area |

The Land Use/Land Cover spectral confusion of the five classes has similar spectral responses, the major classification in-accuracy is caused regarding to the applying classification methods[34-36]. The on-screen digitizing, and visual interpretation were adopted to solve the spectral confusion for the Land Use/Land Cover classes. Two major types of the spectral-confusion can find in this research: (a) Urban Area/Soil Area classes and (b) Vegetation/ Soils classes.

# Results And Discussion

Figs. 3 - 5 show the images of 2002, 2011, and 2022 of the QuickBird-2, WorldView-2, and Sentinel-2 satellite systems respectively, after performing, (1) the subset of all the satellite images to obtain the study area, (2) removing both of geometric and radiometric errors, (3) images rectification process between the reference image (QuickBird-2) and the slave images (WorldView-2 and Sentinel-2).

### Change Detection and Urban Sprawl Monitoring

The figs. (6–8) indicate the applied outcomes of the classified images of QuickBird-2 satellite 2002, WorldView-2 satellite 2011, and Sentinel-2 satellite 2022, respectively. By adopting Envi software, a random sampling technique was used to collect training and testing sites from all the processed satellite images. The training sites were used in the Mahalanobis classifier in order to classify the three satellite images of QuickBird 2002, WorldView-2 of 2011, and Sentinel-2 of 2022 to detect the Land Use/ Land Cover change throughout the period of 2002 – 2011, and 2011- 2022. All testing samples were collected. These were checked using in situ checking and through the visual interpretation of the high-resolution image got in the fieldwork during July 2022. The testing sites were utilized to evaluate the accuracy of all the obtained results generated by image classification. The results showed an overall accuracy of about 85.94%, 89.82%, and 93.67% for 2002, 2011, and 2022 images, respectively. The classified maps' accuracies showed results of more than 85%, and that gives a good manner about the image processing approaches that were adopted in conducting this study.

Also, the results illustrate the values of kappa coefficients, which were about 0.84, 0.86, and, 0.90 for 2002, 2011, and 2022 images, respectively. Figs. 9 and 10 indicate all the overall-accuracies and kappa-coefficient values of the classified images by the Mahalanobis distance classifier for all the applied satellite images of 2002, 2011, and 2022.

There are five major categories of interesting regions in AL-Hilla city: Roads, water bodies, urban area, vegetation, and soil were distributed in 2002, 2011, and 2022, all the obtained results are illustrated in Table 4.

**Table4.** indicates changes as extracted from the study area images.

| Class Name | 2002Area ($km^2$) / (%) | | 2011 Area ($km^2$) / (%) | | 2022 Area ($km^2$) / (%) | | % of Increase or Decrease Since 2002 |
|---|---|---|---|---|---|---|---|
| Roads | 16.81 | 11.59 | 19.29 | 13.30 | 28.09 | 19.37 | + 07.78 |
| Urban Area | 16.59 | 11.44 | 34.37 | 23.70 | 45.88 | 31.64 | + 20.20 |
| Water Bodies | 07.93 | 05.47 | 04.29 | 02.96 | 02.42 | 01.67 | - 03.80 |
| Vegetation | 51.21 | 35.35 | 43.15 | 29.76 | 28.59 | 19.72 | - 15.63 |
| Soil Area | 52.42 | 36.15 | 43.90 | 30.28 | 40.02 | 27.60 | - 08.55 |

The statistical comparison was utilized in this study to detect the changes in the patterns of the study area[38]. This method involves comparing multi-temporal produced classified Land Use/Land Cover maps from multi-temporal images over the period 2002 to 2011 and 2011 to 2022. In Figs. (6–8), the spatial urban sprawl is quite visible. The urbanization area increased dramatically and was distributed in the center part of AL-Hilla in 2002. The urbanization area category spread and is as revealed in the 2022 thematic map. The statistical comparison of categories indicates, that there is a notable urban expansion in the last 20 years between 2002 to 2022. Moreover, the outcomes show a substantial increase in two categories, Roads and Urban Area categories, and both of them together represent the urban area. For the last two decades, the urbanization region has rapidly increased in AL-Hilla as indicated in Fig. 11 and Table 4. It increased by 29.29 $km^2$, from 16.59 $km^2$ in 2002 to 45.88 $km^2$ in 2022. However, Fig. 11 shows the total urbanization areas of both residential areas and roads in 2002 was 33.40 $Km^2$ and it increased in 2022 to be about 73.97 $km^2$. It increased rapidly from 2002 to 2002 by about 40.57 $Km^2$. Table 5 shows the value of the average annual increasing rate of about 2.06%. The average annual rate of the 2022 urban region was about 1.91 times more than the size of the urban region in 2002. There are several phases to analyzing the urbanization in AL-Hilla city for the time from 2002 to 2022. In the first nine years of the study (2002–2011), the urban region sprawl was significantly high. In this time, the results of the Wars from 1980-2003, more than 600,000 persons returned to Babylon province, Iraq from surrounding country boundaries, and almost all of the coming people settled in urbanization regions, particularly in

AL-Hilla city and surrounding areas. Those coming people built private houses, on their own lands or go through fragmented lands of orchards and agricultural lands, consequently, many new houses and buildings were constructed in that area. The urbanization area (roads and urban area) class has increased from 2002 to 2011 by more than 12.26% of the total area of AL-Hilla city. Figs. 6, 7, and 11 illustrate the burgeoning of the city's spatial urban expansion, and its dramatic growth, which happened in the study area in different directions between (2002 and 2011). Moreover, in the case of considering the area of the roads is one side of the urban area. Therefore, the total area of both roads and urban area together will be increased for the period 2002 to 2011 was 33.40Km$^2$ to 53.66 Km$^2$ and that was equivalent to 37% of the total area of the AL-Hilla city as illustrated in Fig. 11.

Figs. 6–8, the second 10 years of this study area is (2011–2022), Although AL-Hilla city has hundreds of thousands of Syrian and Iraqi local refugees between 2013 and 2018, urban expansion rapidly accelerate at stabilized development rate. The Expansion of the Urban areas happened in approximately the first period (2002–2022), which shows a little growth in the rate after 2011, that was simply because of the Iraqi local refugees and Syrian refugees, those who ran away from the ISIS invasion, were settled inside and \ or near to AL-Hilla city. In the quantitative side, the urban regions and road classes together increased by 20.31 km$^2$, from 53.66 km$^2$ in 2011 to reach about 73.97 km$^2$ in 2022, and that will be equivalent to 51.01% of the AL-Hilla city (Fig. 11 and Table 4). The Urban patterns expansion, and changes in other study area categories occur in the northwestern, and northeastern parts as well as, the southwestern, and southeastern parts of AL-Hilla city, where new housing and residential areas were settled between 2011 and 2022 (Figs. 7 and 8). So, the increase in Urbanization Areas (Urban and Roads classes) from 2002 to 2022 of about 27.98% of the area of AL-Hilla city (Table 4). In Figs. 6–8, 12 and Table 4, there was significantly decreased changes occurred in the classes of the study area for the period from 2002 to 2022 of the Water Bodies, Vegetation, and Soil Area with a decrease percent were about of - 03.80%, - 15.63%, and - 08.55% respectively. Fig. 12 illustrates the changes in each class between 2002-2022.

## Urbanization Growth Analysis

Table 5 indicates the annual urbanization areas (urban and roads areas) growth percentage rate, from the period 2002 to 2022. (K) is represented as a key index to validate urbanization region growth, as indicates in (Eq.1) below[27]:

$$k = \left(\frac{Ub - Ua}{Ua}\right) * \frac{1}{T} * 100\% \quad (1)$$

where, the (Ua), and (Ub) represent the urban region at the starting and end of the study interval times, respectively, and (T) is represented the entire time of the this study from (a to b).

**Table 5.** AL-Hilla's annual urban region growth rate (2002–2022).

| Date | Urban region ($km^2$) | The annual growth (%) |
|---|---|---|
| 2002 | 16.59 | ------- |
| 2011 | 34.37 | 11.91 |
| 2022 | 45.88 | 03.39 |

The outcomes of this study show that urbanization growth of AL-Hilla city occurred in two phases in the period of (2002–2022). The first phase occurred from 2002 to 2011, and the second one occurred from 2011 to 2022. During the first stage, the urban area has been expanded over nine years by 17.78 $km^2$ (or 1.96 $km^2$ each year). The urbanization increased from 16.59 $km^2$ (or 11.44 %) to 34.37 $km^2$ (or 23.70%) of the study area from 2002 to 2011. In this stage, the dominant urbanization expansion was horizontal expansion in AL-Hilla city. However, with counting the areas of both urban and roads over the nine years from 2002 to 2011, the urban increased from 33.4$Km^2$ to 53.66 $Km^2$. The amount of annual growth of urban and road areas between (2002 – 2011) and (2011 – 2022) was recorded to be 6.7% and 3.8% respectively as illustrated in Table 6.

**Table 6.** AL-Hilla's annual urban region growth rate (2002–2022).

| Date | Urban region ($km^2$) | The annual growth (%) |
|---|---|---|
| 2002 | 33.40 | ----- |
| 2011 | 53.66 | 6.7% |
| 2022 | 73.97 | 3.8% |

The second period, which start from 2011 to 2022, urban area was dramatic growth. The urbanization areas expanded by 11.51 km2 (or 1.15 km2 each year). The infrastructures projects in Al-Hilla, including houses, residential, schools, universities, water supply stations, and electricity and service buildings, led to the increase in the urban center's expansion. The dominant expansion in AL-Hilla was vertical urbanization between 2011 to 2022. The annual growth rate was 3.39%, which indicates that the urban growth in AL-Hilla has been almost steady for the study area between 2002-2022. However, with counting the areas of both urban and roads over the ten years from 2011 to 2022, the urban increased from 53.66 $Km^2$ to reaches about 73.97 $Km^2$. The annual growth rate was 3.8% as illustrated in Table 6. The results reported by[17 & 38], investigating urban area sprawl, using satellite images from the Landsat satellite system of the MSS, TM, and ETM+, indicated, that the dramatic urbanization region growth occurred on the main roads and plantation land. The present research shows outcomes, that are better than those of [17 & 38].

# Conclusions

For mapping and monitoring the classes of both of lands area changes in urbanization expansion in AL-Hilla city, five categories were used to produce the maps from classified images using the Mahanalobis distance classifier to classify the QuickBird-2, WorldView-2, and Sentinel-2 satellite images of 2002, 2011 and 2022. The outcomes indicated the accuracies of about 85.94%, 89.82%, and 93.67% to 2002, 2011, and 2022 images, respectively. The result shows, that the increase was from 33.40 $Km^2$ in 2002 to be about 73.97 $km^2$ in 2022. The increase in urbanization was almost 27.98% in the last 20 years. During the same time, the expansion was into two different phases: (1) a high-rate from 2002 to 2011, and (2) a steady-rate stage during 2011–2022. Concentric urbanization sprawl was the main category of urban growth from 2002 to 2022, this growth has occurred in residential areas, new facilities buildings, and transportation system routes of AL-Hilla city, as well as a number of schools and universities, lots of offices, and buildings, were established from 2002–2022. The horizontal urbanization area expansion was the dominant expansion at the time of (2002–2022). The urbanization concentration and multiple-nuclei urbanization expansion were the main urban areas growth types model in AL-Hilla from 2011 to 2022, where the increase of the infrastructure projects leads to an increase in urban expansion of the AL-Hilla centers. In addition, vertical urbanization expansion became dominant during the last 10 years from 2011 to 2022. The study outcomes provide criteria to help decision makers and would be allowed the urban decision and planners makers to have full understanding, and assessment of the urbanization growth to develop a better strategy for urban area sustainability in AL-Hilla city.

# Declarations


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### Competing interests

The authors have no conflicts of interest.

### Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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# Figures

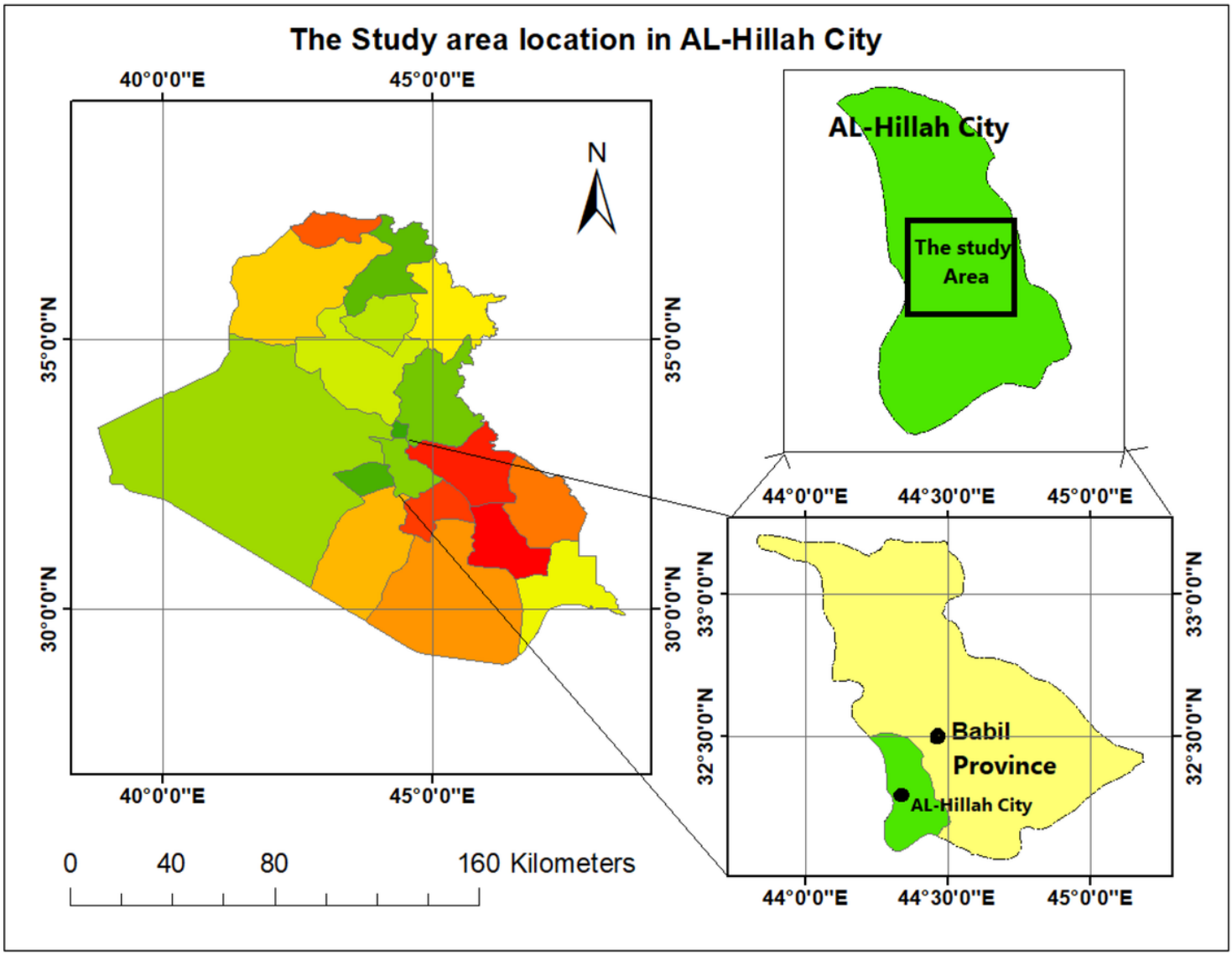



Figure 1

Description of the AL-Hilla City, Babylon, Iraq.

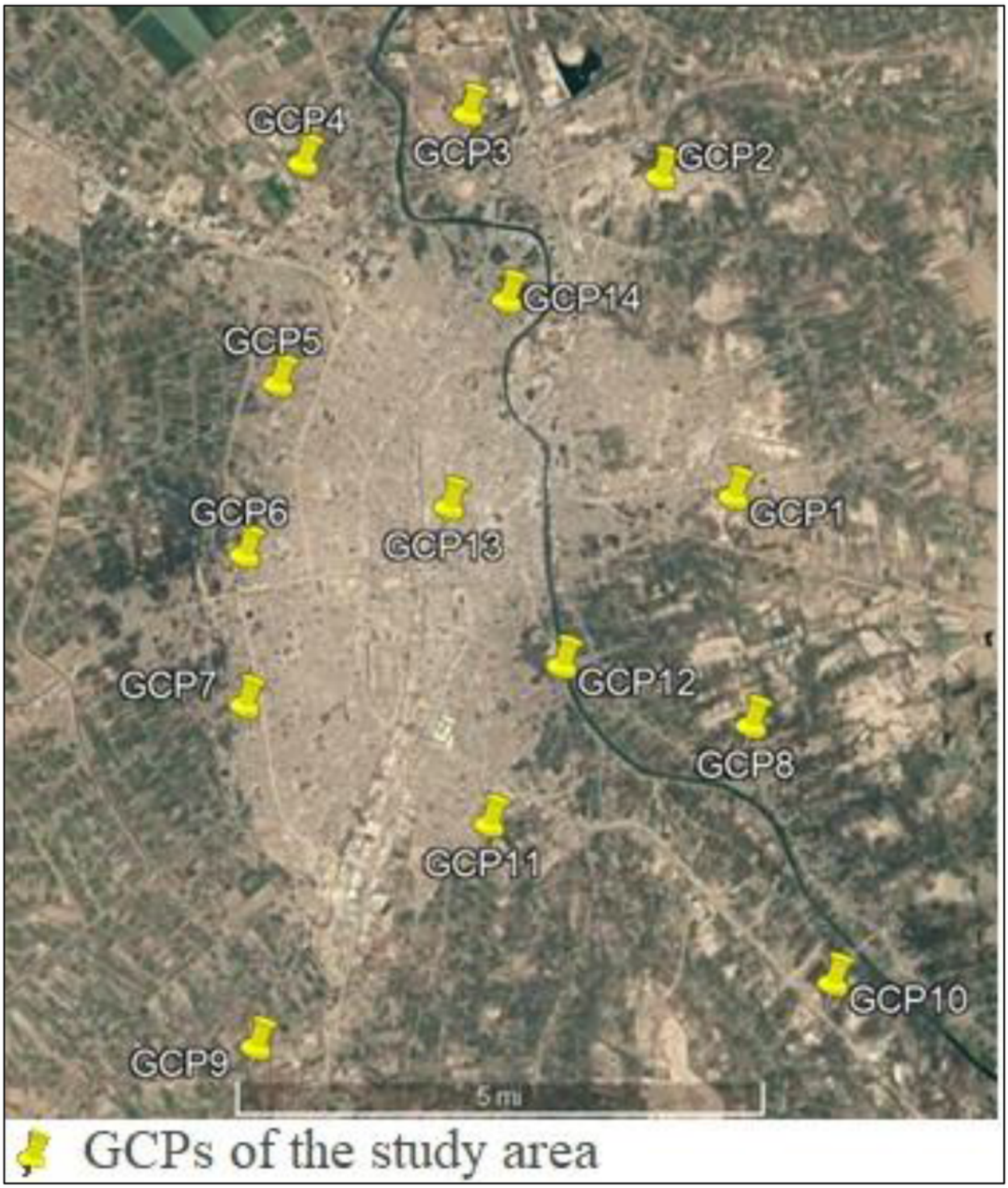



**Figure 2**

Shows the location of the collected GCPs in AL-Hilla, Babylon, Iraq.

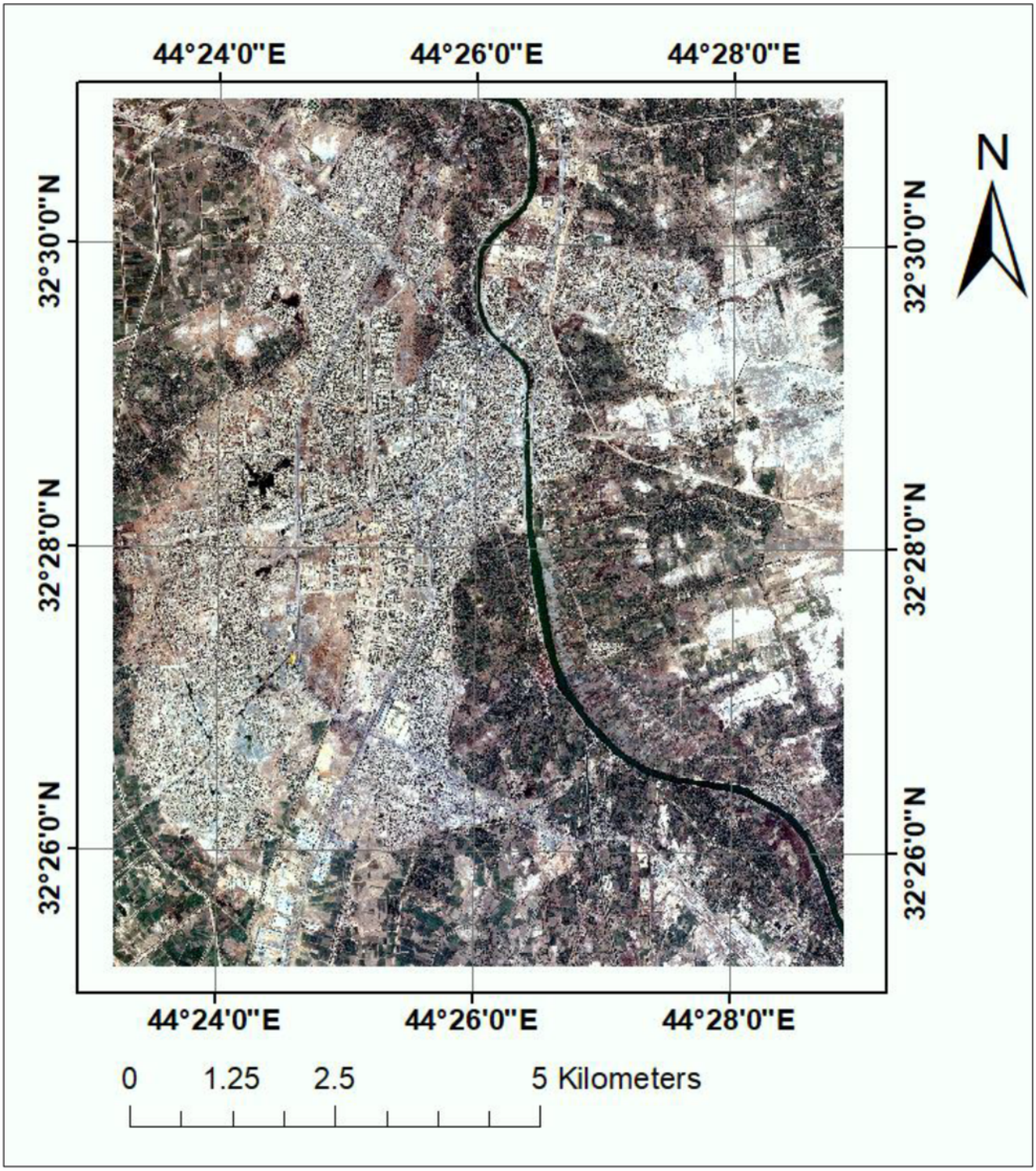



**Figure 3**

The QuickBird-2 satellite imagery of 2002.

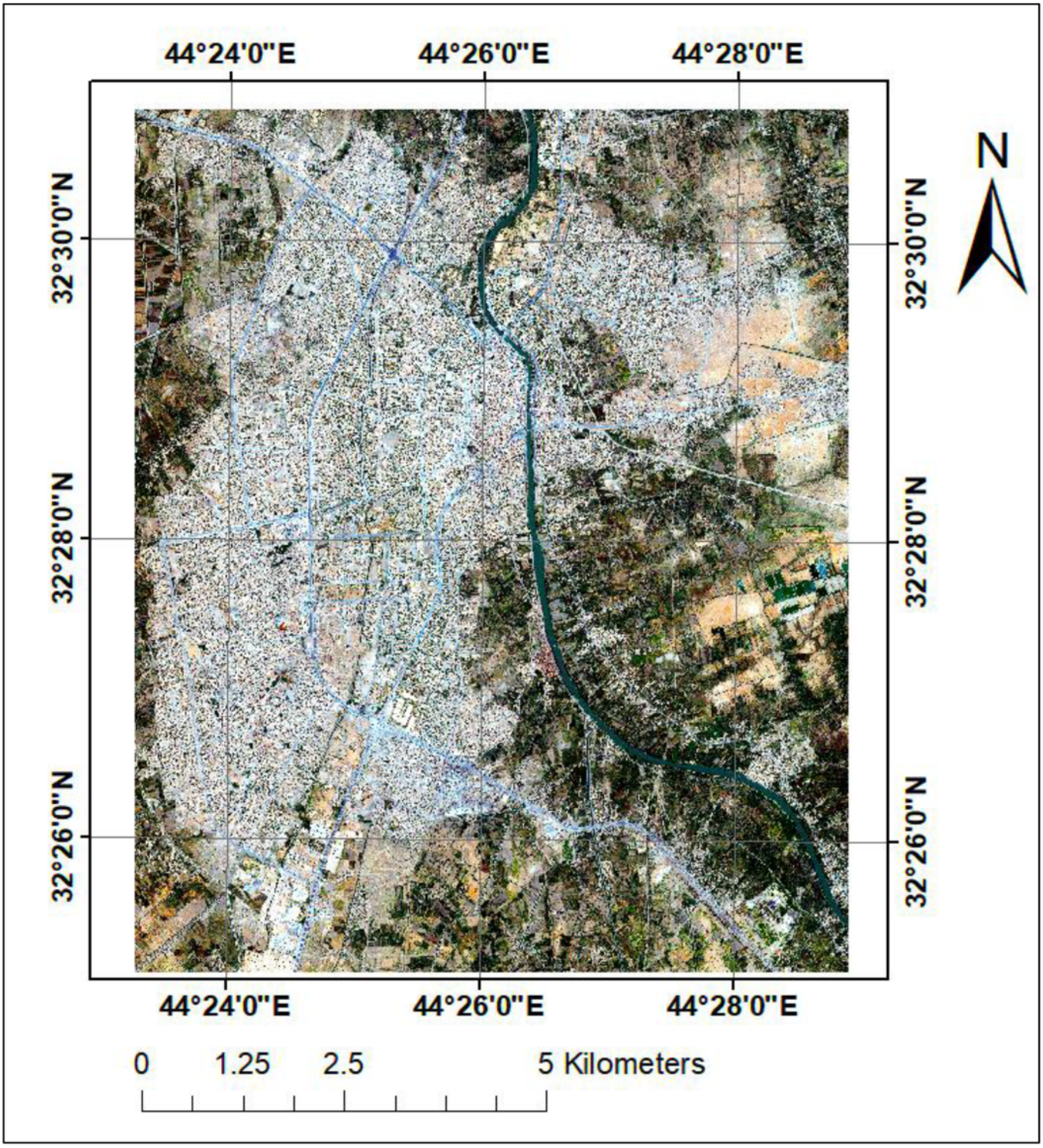



**Figure 4**

The WorldView-2 satellite imagery of 2011.

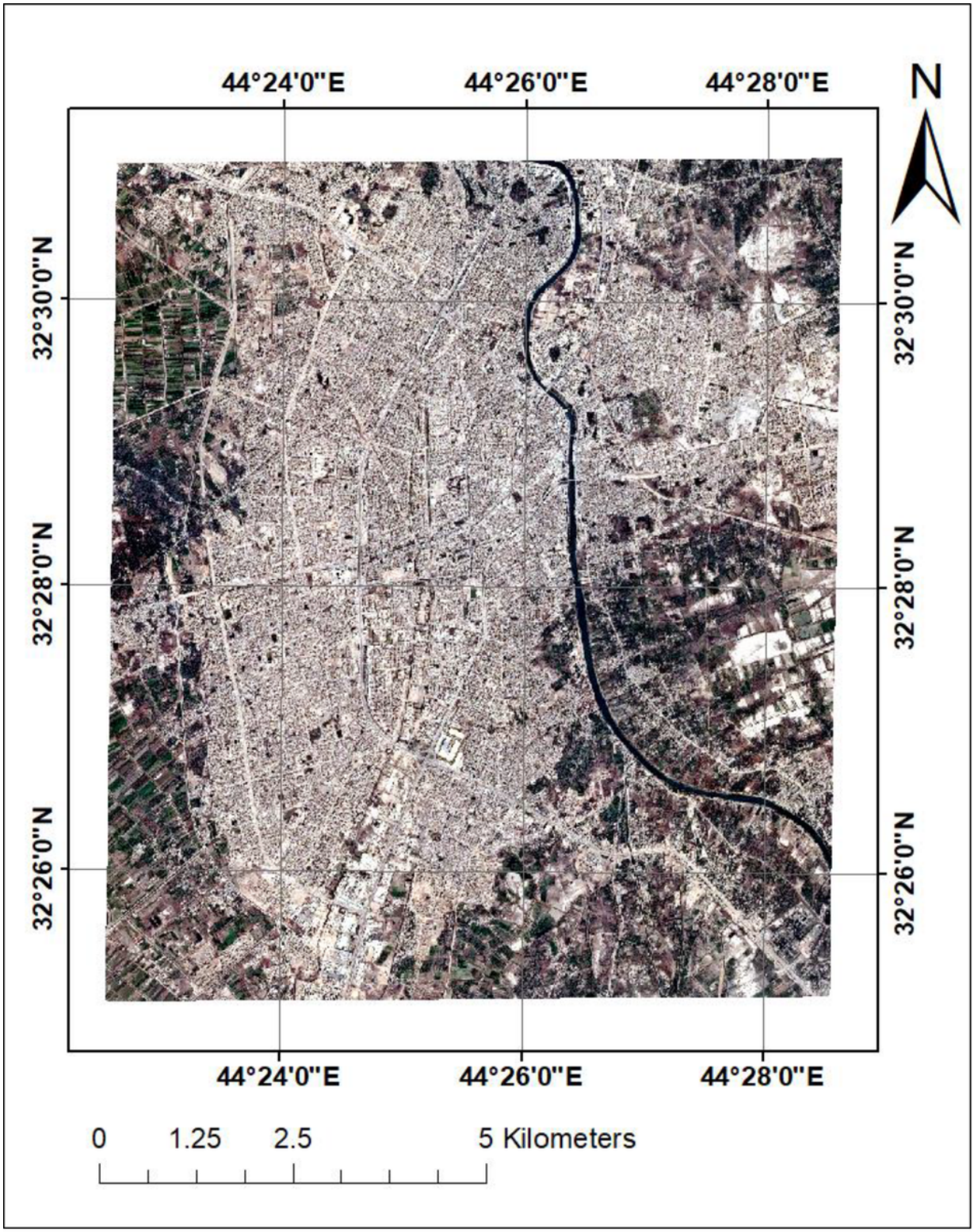



**Figure 5**

The Sentinel-2 satellite imagery of 2022

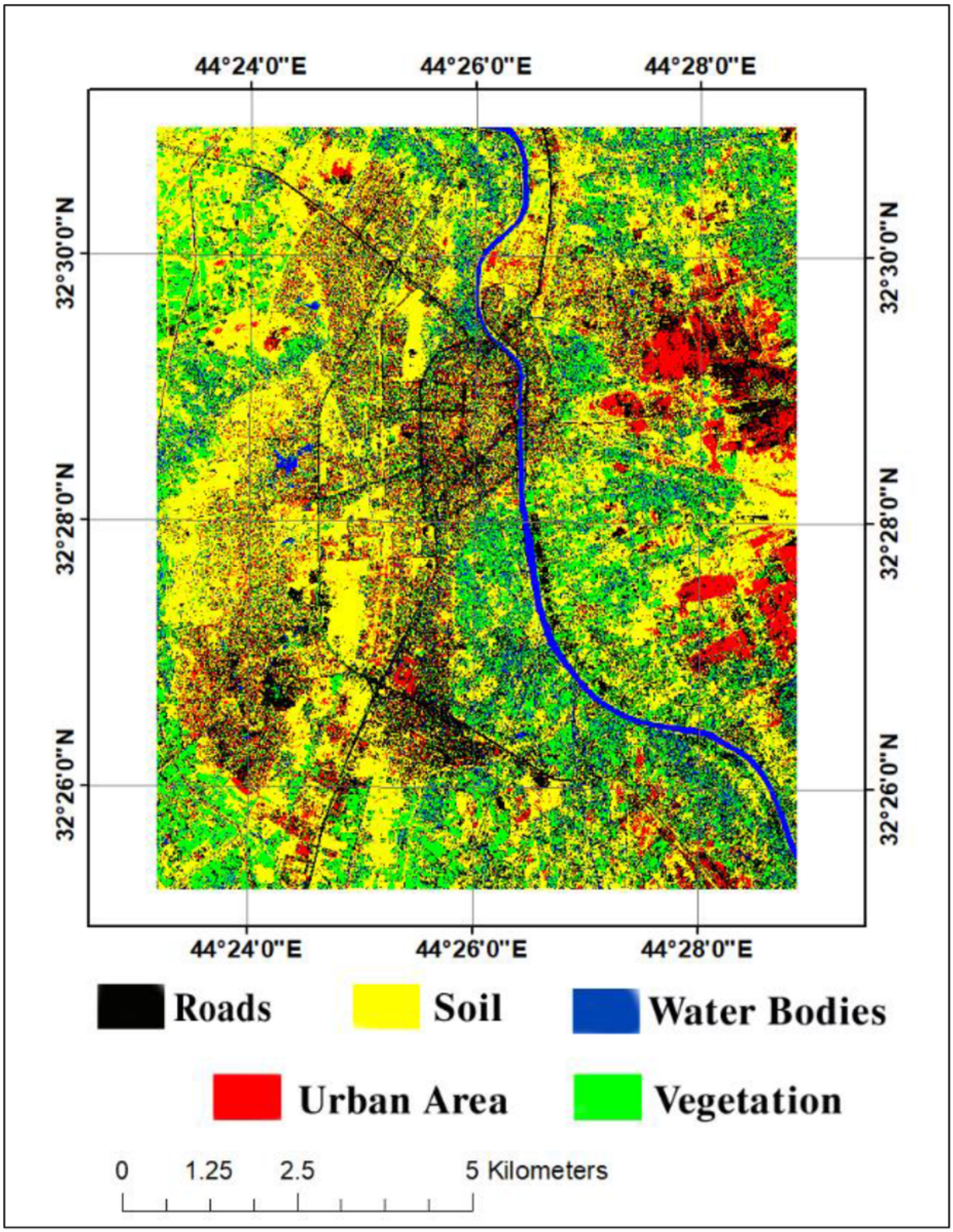
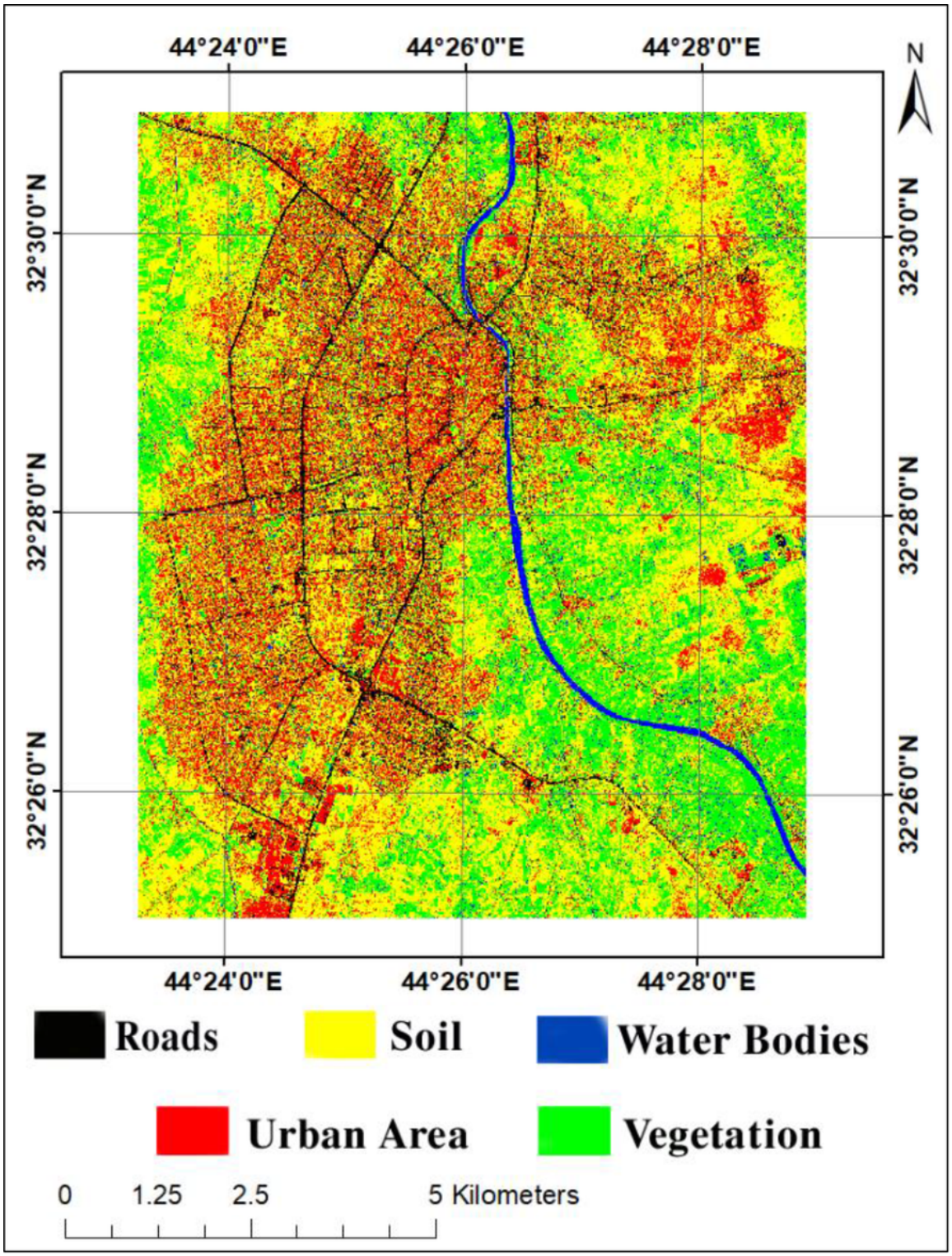



**Figure 6**

Classified thematic map of AL-Hilla of the QuickBird satellite image (2002)




## Figure 7

Classified thematic map of AL-Hilla of the WorldView-2 satellite image (2011).

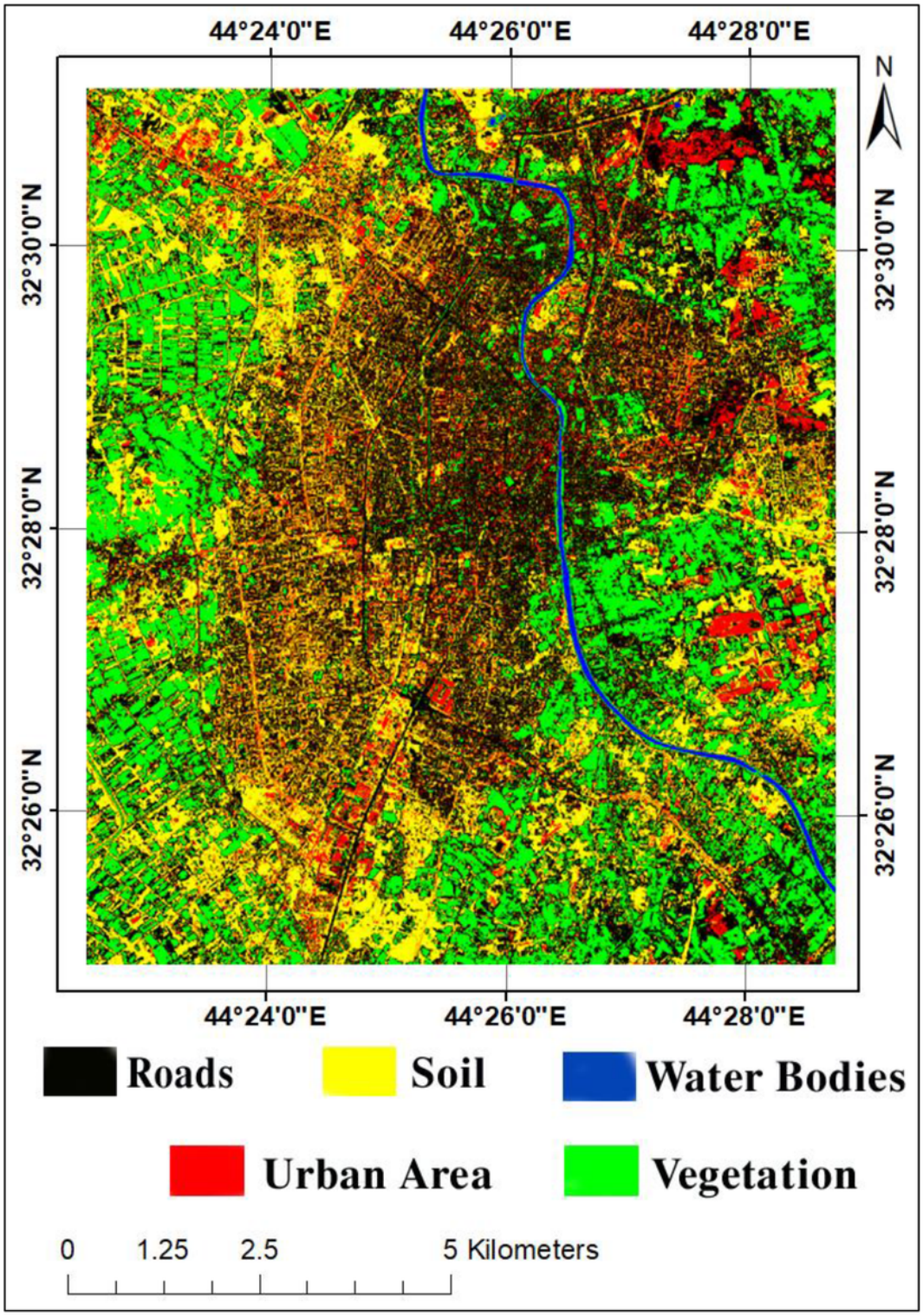



**Figure 8**

Classified thematic map of AL-Hilla of the Sentinel-2 satellite image (2022).

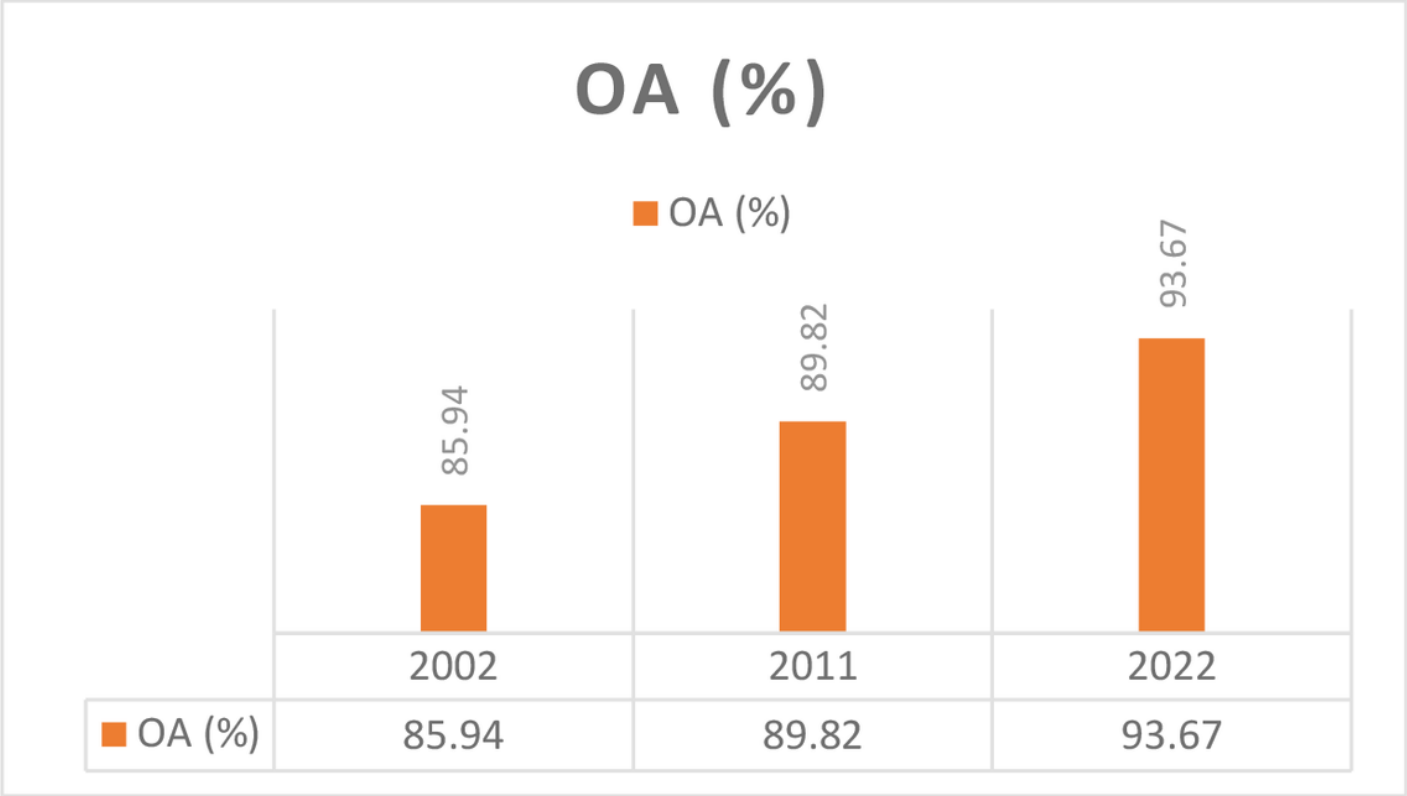



**Figure 9**

indicates the overall accuracies of the classified images of all the applied images of 2002, 2011 and 2022

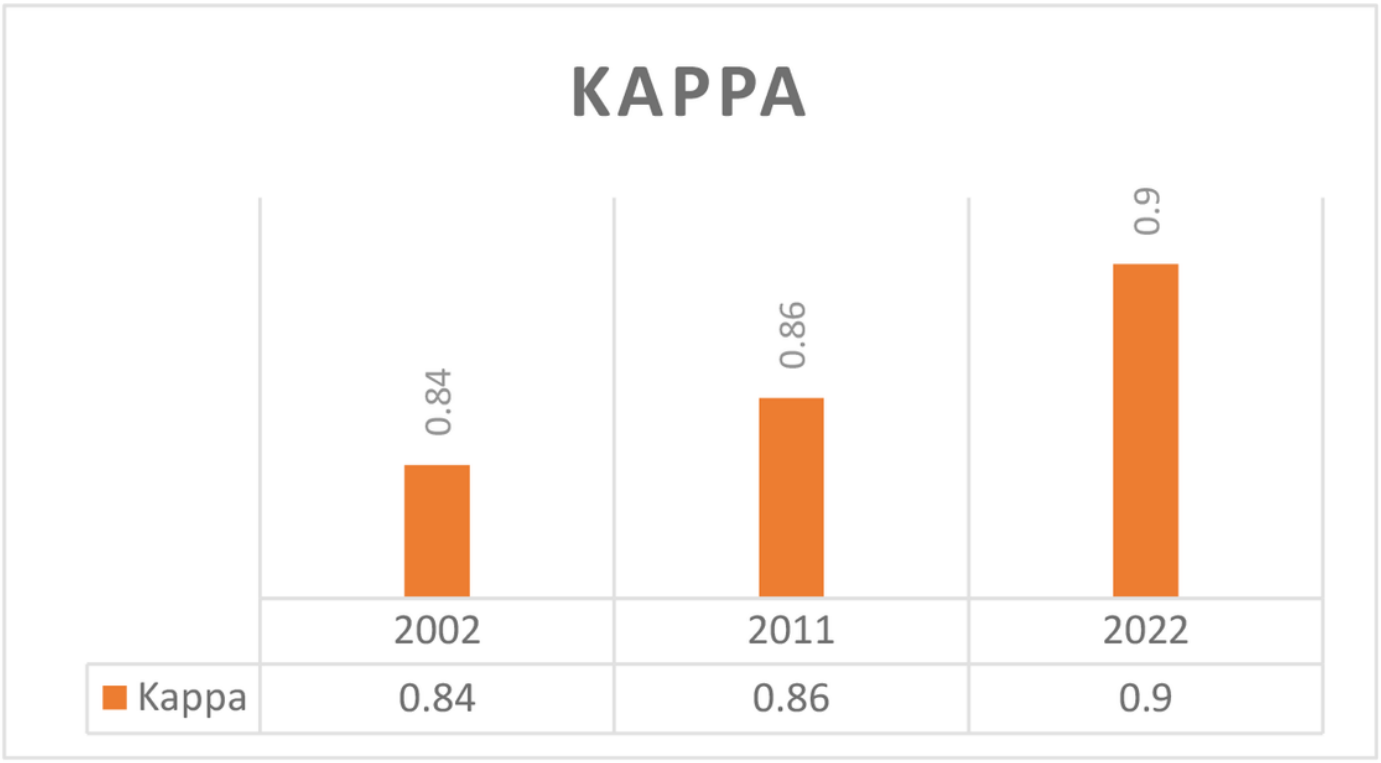



**Figure 10**

indicate the kappa coefficients of the classified images of all the applied images of 2002, 2011, and 2022.

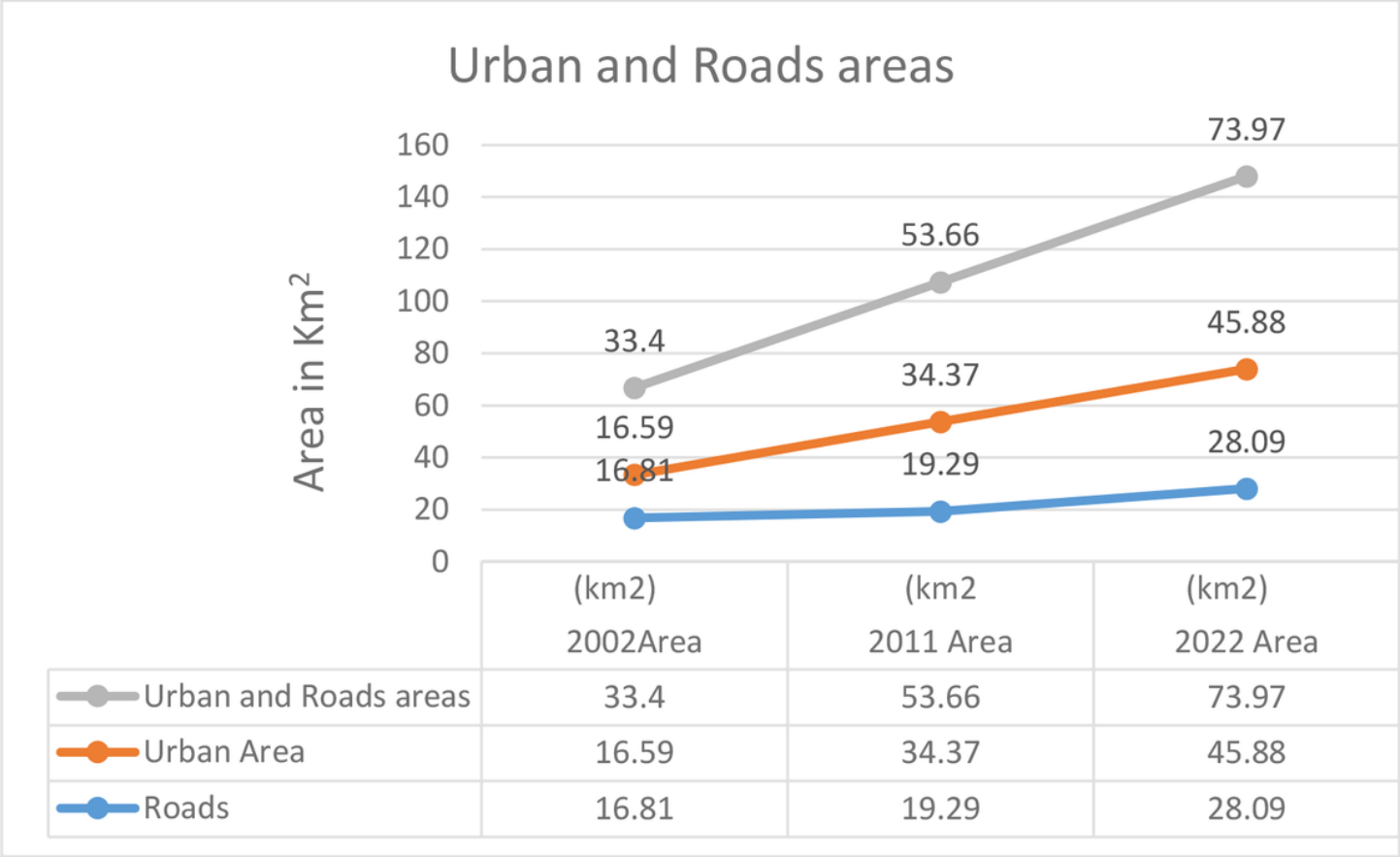



**Figure 11**

Total Urban areas of (Roads and Urban) of 2002, 2011 and 2022 in AL-Hilla city

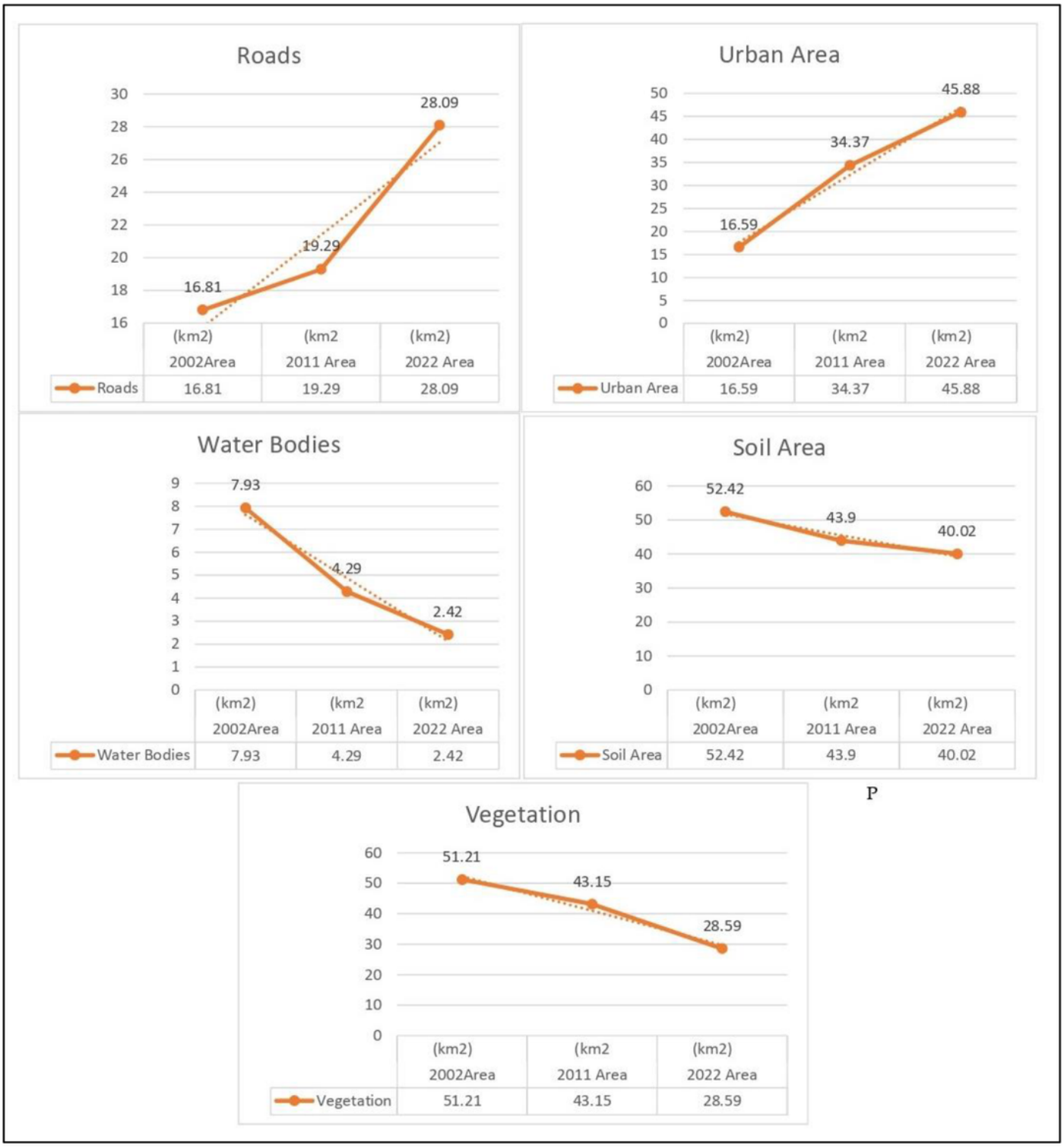



**Figure 12**

Changes in the classes between 2002-202

# Supplementary Files

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