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Assessment of Desertification Changes in Baghdad Using Remote Sensing and the Minimum Distance Classification Algorithm (2013–2023)

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Abstract

New research was conducted to evaluate and track the development of desertification in Baghdad city during 2013, 2018, and 2023 with the use of remote sensing and a minimum distance classifier. The objective of the research is to provide a complete scientific view of the rate and change of desertification during each period of time, through advanced analysis methods that can help to understand the trend of desertification. The distance classifier was used as the primary classification and analysis tool; therefore, the spatial pattern of desertification was recognized across the studied years. By applying this technique, areas that are highly affected by desertification were identified, and those areas that have seen a decrease or increase in their desertification areas were identified. In addition to evaluating the factors that are responsible for the worsening of desertification (e.g., climate change and human activity), multiple sources of satellite data were utilized to evaluate the temporal trend of desertification changes and to make estimations regarding future projections for changes in desertification.

Keywords

Baghdad, Envi 5.3, Classifier, Minimum Distance Classifier, Remote Sensing, Geographic Information Systems.



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Introduction

The application of remote sensing technologies has proven beneficial for observing and assessing environmental alterations across extensive regions. The remote sensing data will provide critical information on the magnitude and intensity of desertification in Baghdad. The land cover, vegetation health and soil moisture, all of which are indicators of desertification, can be monitored using remote sensing techniques. Furthermore, minimum distance classifier can also help identify the correct land cover categories and identification of desertification processes taking place. Understanding the patterns and trends of desertification in Baghdad through remote sensing can ultimately inform policymakers and land managers on strategies to combat and mitigate the impacts of desertification in the region [1].

Role of Remote Sensing and Minimum Distance Classifier in Monitoring Desertification

The remote sensing technology, especially the advanced classification methods such as minimum distance classification (MDC), is very effective for monitoring the processes of desertification. In light of ongoing urban expansion and alterations in land utilisation impacting delicate ecosystems, it is crucial to accurately identify and observe desertification phenomena. The research shows that several classification methods can identify specific features in a landscape such as greenhouses, showing the application of remote sensing in different contexts of land monitoring. Additionally, it emphasises the necessity of enhancing the classification rate in the picture analysis of remote sensing data and illustrates the capability of employing genetic algorithms to refine models grounded in neural networks. Considering all these elements, scholars can enhance the precision and dependability of desertification surveillance throughout time to deepen their comprehension of the mechanisms that contribute to sustainable land stewardship in regions like Baghdad.

I. Desertification and the use of remote sensing techniques for analysis: The use of remote sensing techniques in the analysis of desertification.

The remote sensing techniques have been proved to be an indispensable tool for desertification monitoring because of its ability to provide detailed and timely information in remote, vast and inaccessible areas. They depend on satellite and aircraft measurements of land cover, vegetation health and soil conditions, all of which are critical measures of desertification. By applying sophisticated image processing methods such as the Minimum Distance Classifier, scientists are able to precisely classify and map out land cover types, which will result in the detection of areas undergoing desertification processes. Furthermore, remote sensing data can be combined with onsite measurements and environmental models to enhance desertification assessments [4]. This multi-dimensional approach can provide a broader perspective on the dynamics of desertification and offer insights into sustainable land management strategies. Finally, remote sensing technologies have great potential to be used for desertification monitoring which can help land managers and policy makers to manage and combat desertification and simultaneously bolster resilience in ecosystems.

A. An Explanation of the Technology Behind Remote Sensing

Remote sensing technology is becoming increasingly important in monitoring and analysing environmental changes such as desertification. Remote sensing uses a variety of sensors on satellites, aircraft or drones to gather information about land cover, vegetation health, soil moisture and other important factors. This data is vital for the evaluation and prediction of desertification processes that may have a great impact on ecosystems and human populations [6]. Remote sensing also enables the detection of changes over large areas, offering a full picture of the extent and severity of desertification. Recent advances in remote sensing technology, including higher spatial resolution and improved data processing techniques, have allowed investigators to

conduct more detailed and precise analyses of desertification dynamics over time. This has led to a better understanding of the factors driving desertification and the development of effective strategies for mitigation and adaptation. Additionally, remote sensing data can be integrated with classification techniques like the Minimum Distance Classifier to classify land cover types and monitor changes in desertification patterns over multiple time periods [7].

1 Explain what is meant by Remote sensing and its applications.

The process of gleaning data from a distance, using different types of sensors and technologies, including satellites or drones, is known as remote sensing. In this way, the researchers can get information about the surface of the earth without coming into contact with it, thus allowing them to understand changes and trends that may occur over time [8]. Remote sensing is particularly important in the context of desertification in the city of Baghdad for monitoring and analysis of the desertification phenomena. With these image classification techniques (e.g. minimum distance classifier) it is possible to determine the type of land cover present in a particular area, identify loss of vegetation cover, soil moisture and other indicators of desertification. These data driven insights can give decision makers and land managers the information they need to make appropriate intervention choices, and to lessen the impact of desertification on the surrounding environment and communities. Remote sensing is developing rapidly, offering new possibilities for global environmental studies and solutions to environmental problems.

2 Types of Remote Sensing Data Applied in Desertification Studies:

Optical data, such as the multispectral data from Landsat and Sentinel, are used to monitor a changing vegetation cover, land use change, and soil degradation over time, so as to study desertification [10]. The platforms allow the measurement of the health of the vegetation, biomass and TST, all important parameters of the desertification

processes. Data from satellite radars (e.g. RADARSAT, Sentinel-1) can also be used to understand desertification phenomena through soil moisture content, surface roughness and land surface deformation, even when there are cloudy sky conditions. The combination of optical and radar data can provide better monitoring and analysis of desertification patterns and trends and a more comprehensive view of desertification can be achieved in regions like Baghdad. However, to achieve accurate and reliable results, these remote sensing datasets need to be calibrated and validated against ground truth data [11].

III. In the analysis of desertification, the Minimum Distance Classifier (MDC) was applied: The Minimum Distance Classifier (MDC) has been used here for the analysis of desertification.

Remote sensing and minimum distance classifier has been found to be useful in monitoring the trends of desertification in Baghdad. The use of satellite data for land use monitoring and identification of land cover changes and desertification processes is reviewed. The minimum distance classifier algorithm is one of the most important algorithms used in this analysis, which classified the various land cover types and identified desertified and non-desertified land areas according to the spectral signature. This practice is found to be highly accurate in determining the degraded zones and can be used to implement intervention and management measures that can help reverse desertification. In addition, the use of remote sensing data allows to do an extensive assessment over time and thus obtain a complete picture of the dynamics of desertification in the region [12]. In terms of desertification analysis and monitoring, a combination of remote sensing and minimum distance classifier is a powerful tool for sustainable land management practices.

To learn the Minimum Distance Classifier Algorithm. To learn the Algorithm: Minimum Distance Classifier.

Minimum Distance Classifier algorithm is a basic method used in remote sensing analysis and is a technique used by researchers for classification of land cover types using spectral signatures. This algorithm uses the Euclidean distance between a

spectral value and the mean of a class to identify the class of a pixel. The algorithm classifies land cover in satellite images by assigning each pixel to the class that is the shortest distance away, making it a simple yet effective way of categorizing land cover. Training samples distribution and spectral bands selection, however, are important to consider to optimize the performance of the classifier. The reliability of the assigned classification also depends largely on the quality of training data and the classification of the spectral classes set by the researcher [13]. Thus, understanding the principles and intricacies of the Minimum Distance Classifier algorithm is essential for accurately analyzing and monitoring desertification processes in Baghdad using remote sensing.

The working principle of the minimum distance classifier and its principles: Working principle of minimum distance classifier and its principles.

The principles and working of the Minimum Distance Classifier (MDC) are very important to achieve accurate interpretation and monitoring of desertification in the City of Baghdad through the remote sensing data. MDC is a supervised classification method that classifies the pixels based on the shortest distance to the mean vector of each class using the classification labels. Kind of Remote Sensing Data used for Desertification Studies:

Optical information obtained by means of satellite observations, for example multispectral data collected by the Landsat and Sentinel satellites, can be applied to study desertification, by assessing changes in land use and soil deterioration, as well as modifications in vegetation density over time [10]. These systems allow the assessment of the health of the vegetation, the quantity of biomass present, and the TST; these three variables are relevant to assess the development of desertification processes. When clouds prevent us from using optical information, satellite radar data (e.g., RADARSAT, Sentinel-1) can provide information on desertification through the analysis of soil moisture content, surface roughness, etc.

Advantages and Disadvantages of Minimum Distance Classifier in Desertification Monitoring

The use of remote sensing methods combined with minimum distance classifier (MDC) has shown to have significant possibilities for the monitoring of desertification. Minimum Distance Classifier (MDC) offers several advantages including simplicity and effectiveness of classifying spectral data; therefore, MDC can be considered as an appropriate indicator for the assessment of land degradation within large arid regions. MDC can classify land cover types effectively; therefore, researchers can identify areas at risk of desertification and develop strategies to prevent or control desertification [15]. However, the limitations of MDC should also be acknowledged. The classifier assumes that all spectral classes are normally distributed. This is often incorrect in the extremely variable desert environment. In addition, there is a large amount of ground-truth data required for training purposes when using MDC. Obtaining such data can be problematic in the isolated desert regions. While there are disadvantages to MDC, it can still provide valuable information for monitoring desertification and developing strategies for sustainable land-use in the desert.

V. Methodology

The classifier chosen for this study was the minimal distance classifier as it is the easiest to archive. The classifier training did not involve all five training data types. They were mainly classified into subgroups based on the differences in spectral values. Subgroups were then used to train the classifier. Finally, the subgroups were combined into the classes that were originally formed. The initial categorisation of the training data was done using K-means clustering. K-means algorithm is an efficient iterative method is used in many fields of clustering applications. The method utilises a point-centric clustering strategy starting with randomly assigned cluster centroids. Then, in each iteration, the technique tunes the cluster centroid so that it can minimise the clustering error that emerges. This makes it possible to classify each specimen into a certain category. This development uses a simple

iterative hill climbing approach from initial centers which are usually randomly chosen from the training dataset.

The K-means algorithm is very fast but it suffers from many major limitations. These are the dependence of the performance on the initial conditions, the tendency to converge to local optimal solutions and the infeasibility of obtaining a global solution for large problems in a reasonable computational time. In this study, optimal initial conditions were found using the K-means technique. PSO was used to find the optimal initial conditions. Particle Swarm Optimization (PSO) is a collective intelligence search technique that is inspired by natural social behaviour. Due to the nature of the algorithm, each possible solution in Particle Swarm Optimization can be viewed as a particle within the search space. Fitness values are assigned to each particle and evaluated by a fitness function to

enhance their performance. Each particle uses its own memory and the collective knowledge that the swarm has obtained to find the best solution.

In the current study, the K-means algorithm was employed to incorporate the results of the PSO module as the initial clustering centroids. Consequently, the optimal centers underwent additional processing to derive the conclusive results for the minimal distance classifier [19]. Consequently, the results of the pre-classification indicated that the subgroups were the most efficacious. The aggregation of these subgroups was employed in lieu of the average of the initial training data to execute minimal distance classification using Euclidean distance. This was executed in accordance with the clustering centroids of the subgroups. A. The flowchart illustrating the PSO-K-means-based MDC is presented in Fig. 2.

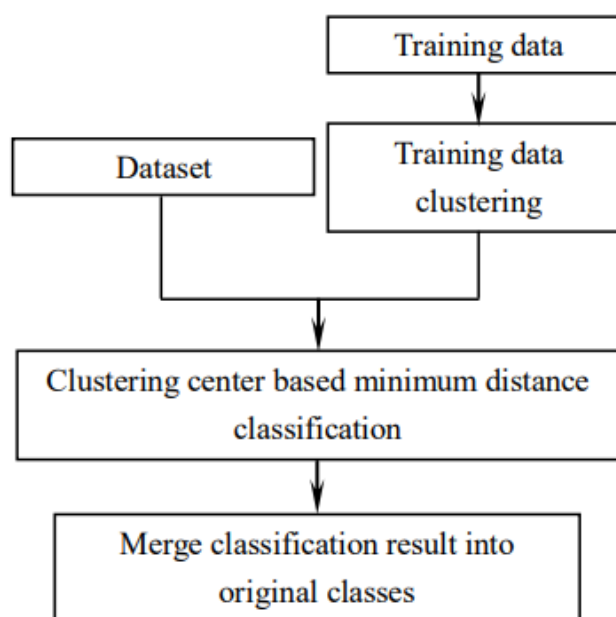


Figure 1. Flowchart of pre-classification-based MDC

4. RESULTS AND DISCUSSION

To gather bands, the satellite image is accessed in ENVI 5.3. For the band gathering, an available instrument is chosen; this is usually done from the toolbar or resource menu. Techniques that can be used include adaptable methods like contrast enhancement and picture correction. The analysis criteria determine which particular bands from the

original image should be assembled. In ENVI 5.3, the band collection procedure begins when the desired bands are chosen. Based on the information included in the satellite picture, the software gathers data for the band-gathering process. In accordance with the band collection protocol, the processed image is retained in a format suitable for data analysis or

future research endeavours. ENVI 5.3 initiates the image to which the file types will be implemented.

You can find the Apply Shape Files tool by navigating through the toolbar or list and choosing the relevant option. The file name of the form, which must be applied to the chosen image, is supplied. The use of the form files will then occur on the image using Apply Shape Files, allowing the geographic data in the file to be displayed or recognized on the image. It is important to review the results after the use of the format file to increase understanding and make changes to geographic data for multiple uses.

Shape Files provide a way to display geographic data on an image, create boundaries of geographic areas, and assess the pattern of points. By employing this methodology, an efficient instrument for geographic analysis may be acquired, hence improving comprehension of the spatial geographical information derived from aerial photography. Annually, the study area is determined through the utilisation of training sets and a maximum probability classification method. The land cover of the surveyed region can be classified into four primary groups; Table 1 delineates the components of soil, flora, aquatic environments, and urban areas.

Table 1. Selecting the appropriate training group

Classes	color	Classes	color
urban	orange	soil	yellow
water	dark blue	plant	green

The satellite picture meant for band collecting is chosen after opening the ENVI 5.3 application. The selected instrument for the band may usually be located in the resource menu or toolbar. Techniques that are flexible in a range of situations, such image correction and contrast enhancement, are taken into consideration. The original image's bands that will be merged and utilized for analysis are chosen. The features of the analysis affect the choice of band. The band collection procedure, which gathers bands using satellite image data, is started inside ENVI 5.3

after the appropriate bands have been selected. Subsequent to the band collection, the image is preserved in a manner suitable for data processing or future research. To ensure dependable results, individuals must also possess expertise in the interpretation and processing of satellite imagery. Figure 2 depicts the categorization subsequent to the selection of training groups and the completion of the classification task.

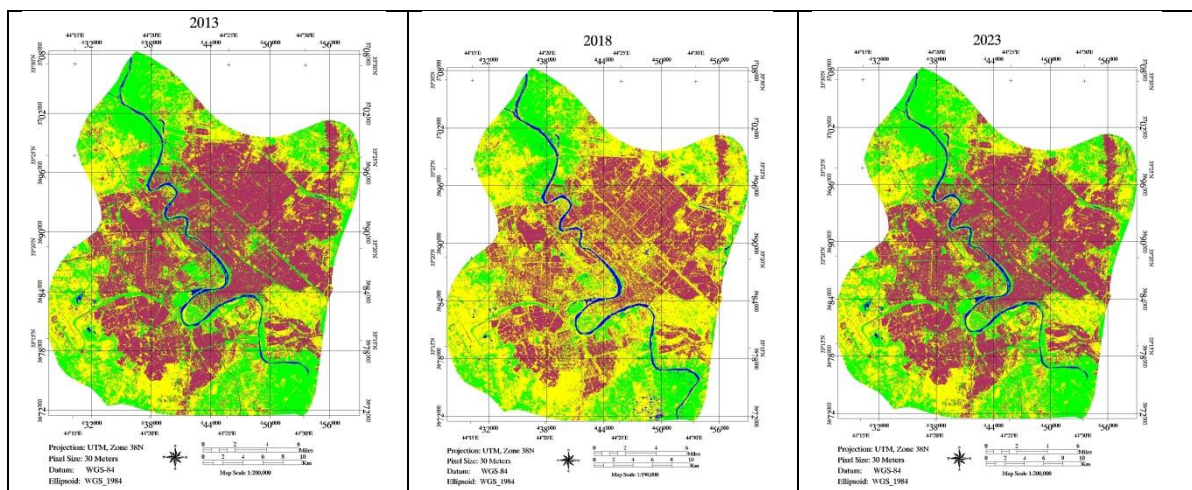


Figure 2. Images after classification

The Jeffries and Matusita scales are used by researchers, particularly in image processing, to compare the digital pictures of the chosen collections. Make use of statistical variances in the data distribution across many locations. For the purpose of studying picture classification discrimination across categories, this distance is used to quantify classification accuracy. Good layer distinction is indicated by a wide gap between Jeffries and Matusita, which results from a large data difference between the two groups. Because Jeffries-Matosita's distance can be skewed or noisy, classification may need huge data sets. Instead of being a complete replacement, it is typically used as an additional tool to assess evaluation accuracy.

The Jeffries-Matusita distance is a helpful technique in image analysis and classification for figuring out how differentiable particular classes are in digital pictures. Determine the spectral separability of every pair of training subclasses using the Jeffries-Matusita dimension standard in order to assess coaching group quality objectively. Over the years, all pairings of training groups from subclasses attained a distance greater than 1.9. accuracy calculation The Matusita-Jefferies Researchers utilize distance as a statistical method to assess Overall When assessing the effectiveness of classification and prediction models in fields like machine learning, remote sensing, and image processing, accuracy is a frequently used parameter. The goal of overall accuracy is to gauge how well a model predicts various classes in the data.

To ensure accuracy Classified image information is authenticated against factual data. The

classification precision was assessed through user, product, and overall correctness. The disturbance matrix derived from the product accuracy and user accuracy is utilized to calculate the overall accuracy. Product accuracy, or accuracy within certain categories, is determined by dividing the aggregate by the exact count of categorized pixels. A group of pixels is classified into a similar category according to its user precision, which is assessed. The subsequent equation delineates overall precision [20]:

$$Accuracy = \frac{\text{Digit of right categorized}}{\text{Total number of pixels}} * 100\%$$

The Kappa factor ranges from 1.0 to 0. The description of the Kappa factor is presented below:

$$K = \frac{n \sum_{i=1}^P x_{ii} - \sum_{i=1}^P (x_i \times x_{+i})}{n^2 - \sum_{i=1}^P (x_i \times x_{+i})}$$

N represents the aggregate digit for each pixel, P denotes the digit for segment, $\sum x_{ii}$ signifies the whole crumb for the confusion matrix, $\sum x_i$ indicates the entirety for line I, and $\sum x_{+i}$ reflects the entirety for pole i.

In order to determine the overall ranking accuracy, the validity of the findings was assessed using the selected coaching groups. The values of the Kappa Coefficient are 1.0000 in 2013, 0.9666 in 2028, and 1.0000 in 2023, whereas the values of the (Overall accuracy) for three years are 100.0000% in 2013, 97.3400% in 2018, and 100.0000% in 2023. High kappa factors and high gross precision showed great levels of accuracy and agreement, respectively, in the categorization results. Compute each classed scene's statistics and the study's approach, as seen in Figure 3.

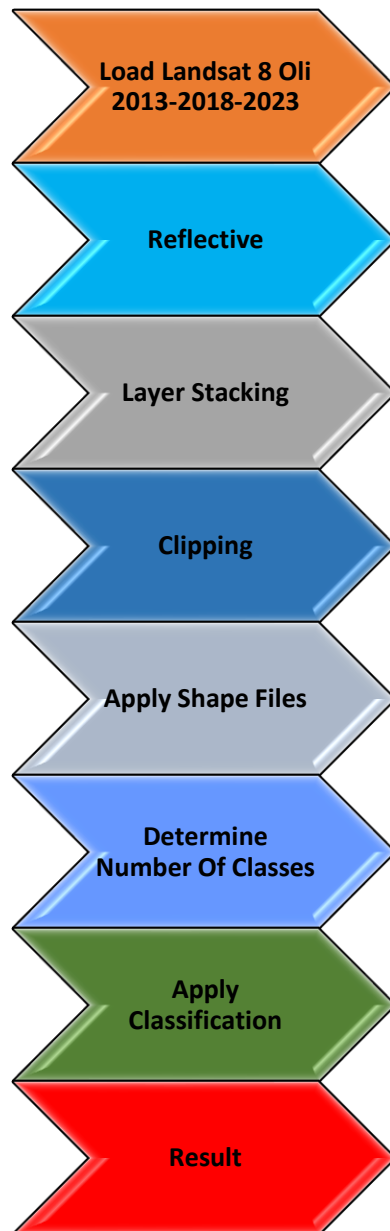


Figure 3. illustrates the sequence of our procedures leading to the outcomes.

Upon the conclusion of operations arranged by outcomes, they were presented in Table 2 and occurred in the years 2013, 2018, and 2023.

Table 2. displays the classifications that represent the percentage and area covered within the research region.

Out of image	plants	soil	water	urban	classes
white	green	yellow	blue	maroon	color
28.91%	11.062	35.34	1.758	22.183	2023%
333.6138	127.65548	407.8236	20.28732	255.99182	2023(Km ²)
28.91%	14.739	36.435	0.921	18.995	2018%
333.6138	170.088	420.459	10.628	219.202	2018(Km ²)
28.91%	24.201	27.926	0.943	18.02	2013%
333.6138	279.279	322.26604	10.882	207.95	2013(Km ²)

The categorization rates for urban areas were studied and compared over different years. The analysis revealed that in 2023, there was significant urban expansion compared to 2013, as seen in Figure 4.

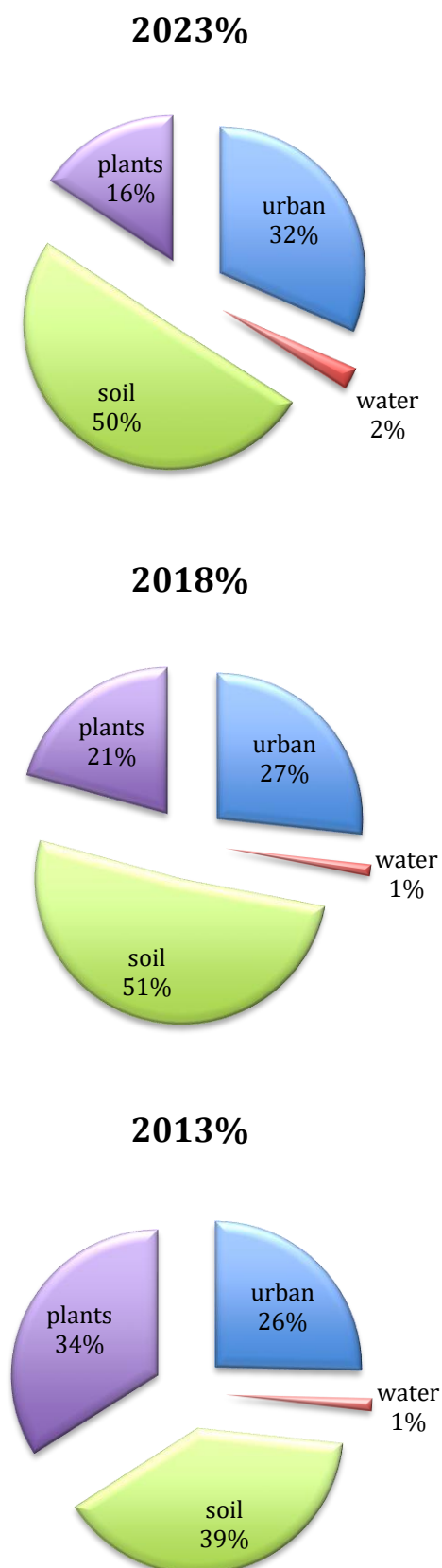


Figure 4. displays the categorization results of the research region from 2013 to 2023.

The results' validity was evaluated by determining the total classification accuracy derived from the chosen training groups. The classification accuracy metrics for the three years are presented in Table 3, demonstrating substantial overall accuracy alongside heightened Kappa coefficients in the classification outcomes.

Table 3. Outcomes of classification exhibiting the utmost accuracy and kappa coefficients

Item	In:2013	In:2018	In:2023
Overall Accuracy	96.7078%	94.0341%	99.5074%
Kappa Coefficient	0.9560	0.9197	0.9941

The urban area of Baghdad rose from 39% in 2013 to 50% in 2023 at a pace that remained consistent throughout the years, which resulted in considerable expansion in desert regions between the years 2013 and 2023. This strategy was selected because, in comparison to other categorization approaches, it was simpler to understand and implement. The region was selected for its significance in order to investigate the pollution that is the consequence of the spread of these pollutants and the influence that it has on the environment. This is due to the fact that Baghdad is regarded as a wall that pursues and filters these pollutants, as well as decreasing the impact of temperature variations.

The environment in the surrounding area includes pollution, a dearth of plant spaces, and arid regions, all of which would result in diminished oxygen levels and an increase in carbon dioxide levels. The Baghdad research became a model for future pollution in the whole Iraq area as a result of all of these variables, which led to the significance of the Baghdad assessment. In order to demonstrate the substantial rise, the extent of desert regions was estimated in square kilometers, as can be seen in Figure 5. With the urban area growing at a steady rate throughout the years, there was also a considerable drop in plant spaces between 2013 and 2023. This was due to the fact that the urban area rose from 34% in 2013 to 16% in 2023.

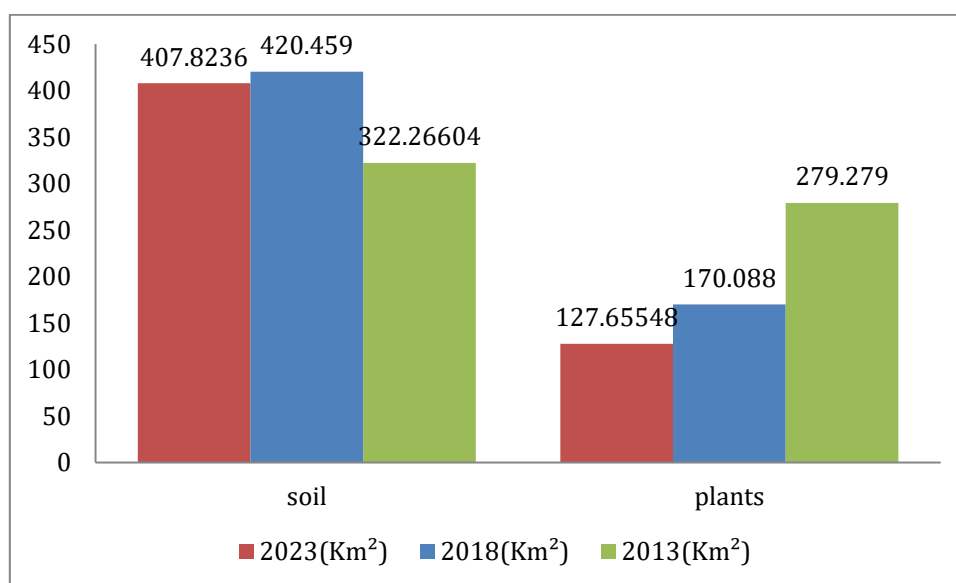


Figure 5. The area of plants and soil areas was measured in square kilometers.

5. CONCLUSION

Amazing findings were obtained utilizing the minimum distance approach to examine Baghdad's desertification and vegetation. From 2013 to 2023, Baghdad's urban area grew from 39% to 50%, indicating stable expansion. This growth has greatly encroached on desert regions, demonstrating urban sprawl's catastrophic influence on the environment.

To categorize land cover changes over time, the minimum distance approach was used for its simplicity and efficacy. It reveals urbanization and desertification spatial dynamics better than other categorization methods. The spread of contaminants and their environmental effects have been extensively studied using this methodical methodology, which is essential for understanding and alleviating urban environmental issues. During the research, it was determined that Baghdad is accumulating and concentrating pollutants which are having a negative impact on the quality of the air in the area and also affecting the ability to regulate temperatures within the region. The poor air quality, lack of greenery and vegetation, as well as the increasing development in Baghdad's environment has reduced oxygen levels and increased carbon dioxide levels.

In Baghdad, the problem of the environment is representative of all the issues facing Iraq. This research demonstrates how important it will be to study the overall effects of urbanization on environmental trends and sustainability. Since the area affected by desertification was determined in square kilometers, the geographical difference is very high throughout.

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