

# Artificial Intelligence for Analyzing Decadal Land Changes in Sana's- Yemen From 1980 to 2020 Using Remote Sensing & GIS

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**Abstract**—Managing natural resources has become crucial due to rapid population growth, weather changes, and disasters. LULC maps are essential for planning and managing resources, but developing countries such as Yemen lack such studies and sufficient interest in this field. The problem of this study is to find solutions in studying the management of natural resources that lead to making appropriate decisions for the advancement of the economic situation and the management of agricultural, industrial, and population lands. The objectives of this research are: 1. To determine land changes in Sana'a city from 1980 to 2020. 2. To create a database for *Land Use & Land Cover* (LULC) classification of Sana'a city from 1980 to 2020. It has used remote sensing and GIS technology with Landsat images from 1980,1990,2000, 2010, and 2020 with the best classifier from the machine learning technique object-based classifier as Random Forest (RF) algorithm, affiliated to technologies Artificial intelligence (AI) technique. The research determined the changes in land in Sana'a over these decades. The findings demonstrated that in Sana'a before 2010, urban area density increased, and in 2010, it decreased. Sana'a's urban area density increased in 2020. The built-up area changed, with percentages of 12.17% in 1980, 34.24 in 1990, 40.15% in 2000, 30.94% in 2010, and 44.74% in 2020. The average classification accuracy was 99.88%. Recommendations for sustainable urban growth in Sana'a include enforcing policies to protect agricultural lands, promoting eco-friendly practices, studying socio-economic factors of urban expansion, training local planners, and educating the public on sustainable land use. This research recommends that the following studies find solutions for better resource management to enhance economic conditions and manage lands effectively.

**Keywords**—LULC; AI; Remote Sensing; GIS; Sana'a City, RF.

## I. INTRODUCTION

The LULC classification is essential to the management of natural resources and the regional socioeconomic development of nations [1]. The LUCC study informs sustainable development strategies for land resources, water resource quantity and quality, and vegetation changes [2].

Identifying changes in LULC based on remote sensing data provides the information needed to make the best decisions for the nation's benefit. Transparency on land changes is essential for land conservation and management in developing countries [3], [4].

Remote sensing is the technology for data collection covering transport data, land treatment, application processing, calibration, verification, and getting data resources for digital land [5].

AI is the development of computer systems that can perform tasks that may require human intelligence[6]. Artificial intelligence works can be categorized according to innovative processes [7]. There are two different types of machine learning[8]. The problematic path includes traditional automatic learning (not subject to supervision and semi-supervision, subject to supervision), modern machine learning, and discovering existing knowledge[9]. The soft classification is the second category.

RF is an artificial intelligence method for classifying object-oriented classification based on machine learning[10]. It is a set or collection of classification and regression trees created using random resampling of the preparation set and bootstrapping of datasets that are comparable to the preparation set [11]. Many bootstraps are used as the test set when a tree is built, which tries not to include a particular record from the first dataset[12]. The speed with all test sets measures the speculation error [13], utilizing a test set similar in size to the preparation set. The meter eliminates the need

for a separate test set [14]. It also achieves the desired speed and productive definition at the same time. In a few uncommon instances, the random forest classifier bootstraps the forecast with the most significant formal vote [15],[16],[17].

Sana'a is one of the highest and oldest continuously inhabited settlements and an important tourist destination [18]. It is situated in the country's focal point in a steep region on the Sarawat Mountains, 2300 meters above ocean level [19],[20],[21].

Sana'a has many environmental problems; according to the findings, running out of water by 2030 is a severe threat, necessitating more research to predict the situation and provide a management plan for the city [22],[23].

This work employed QGIS and SAGA GIS, a free and open-source program for automated geoscientific analysis. SAGA is a GIS program that uses straightforward and efficient spatial algorithms. It has a user-friendly interface with multiple visualization options [24],[25].

To acquire a high-resolution characterization, this research aimed to work on the classification of LULC, which depends on various parameters. It varies depending on the image, the time of day it was filmed, the used classifier, and the weather. The primary driving forces behind this study are: 1. To examine land changes in Sana'a, Yemen, over the 1980–2020 timeframe, under specific conditions, and provide noteworthy findings. 2. Create a land map that explains the main physical features of the surface, the regions where humans have impacted it, potential future development opportunities, and risk areas within the study area. 3. This piece will efficiently plan the future facets of LULC.

The contributions of this research are as follows:

- Know the size of changes in the land shape of the land during the decadal period using remote sensing & GIS.
- Creation of a database and reference LULC for Sana'a city during the decadal period from 1980 to 2020.

## II. RELATED WORK

In general, regarding the same case study, Sana'a city, we obtained only seven studies, a summary of their content as follows:

Al-Shalabi 2007 assessed and examined to confirm whether their implementations of the GIS-based model yield "oversaw development situation." Their model called Slope, Land Use, Exclusion, Urban, Transportation, and Hillshade (SLEUTH) was likewise used to anticipate urban development and land-use change. It effectively fostered a model for finding good land for metropolitan advancement in Sana'a by coordinating GIS and Multi-standards Analysis and Cellular. The eventual outcomes of the model are yearly layers that guide future metro development and land-use change (2004–2020). The information utilized in this investigation incorporates the Quick Bird satellite (0.60 m) procured in 2003 [26].

Fuchs, Hoffmann, and Schwonke (2008) have recognized changes in land use. Supervised and unsupervised classifications are utilized to break down these datasets. Areas with low and high variety are depicted and joined with land cover classes. The information in the two entropy layers of QuickBird shows indistinguishable examples of heterogeneity. Combined with current sensors (SPOT, Quick Bird), two groups of boundaries exist. The bunch contains measurable limitations. The next gathering has parameters commonly utilized in the scene [27].

In (2009) was there concentrated by Al-Adami. Their research recognized crop-proof water use by inundated yields per subbasin in the Sana'a Basin. She was using RS procedures & the ND VI method (Normalized Difference Vegetation Index) for the Landsat. Harvest ID in the Sana'a Bowl is considered—the area of developed regions by crop types in the Sana'a Bowl. Actual evapotranspiration (Estimated arrival time) was determined using ILWIS programming, Landsat TM [28].

Zeug, G., and Eckert (2010) have contemplated populace development and its appearance in developed spatial. Their research has done the Sana'a-Yemen contextual investigation. They are using remote sensing. They investigated urban development in Sana'a, which ranged from 1989 to 2007. They found the fluffy standard-based structure of anisotropic textual measures and intelligent thresholding. Their outcomes mirror the tension on the city's framework and standard assets and could add to Sana'a's suitable metropolitan arrangement. Satellite information from four sensors investigated Sana'a's urban development between 1989 and 2007 [29].

An examination in 2013 by Al-Chalabi to see how the model acts in an asset-restricted, half-baked, and uncontrolled metropolitan advancement climate, for example, in Sana'a of Yemen. That review resulted in a 29 % expansion in spatial never-ending suburbia development during the displaying time frame. It explains how the Investigator model acts in a misguided metropolitan climate when contrasted with the arranged and controlled temperature where it has been applied. The information utilized in that review was the Quickbird satellite symbolism (0.60 m) gained in 2003 [30].

Al-Chalabi presented a comparison of their and CA models in 2013. Two models have been applied in geography: their models and cell automata (CA). Their model results showed smaller urban clusters and a wider variety of growth patterns. On the other hand, the GIS-based CA model displayed a cautious development strategy that combines small groups. The city's private turn of events is suggested to incorporate adjacent lands. The introduction of results is contingent upon the five land-use types. Quick bird satellite symbology (0.60 m) acquired in 2003, flying photography (4 m) received in 1994, and computerized shape line map (10 intervals) are among the many data used in this analysis [31].

The impact of LULC change on the overflow features of the Wadi Al-Mulaikhy Sub-watershed in the Sana'a Bowl, Yemen GIS, HEC-GeoHMS expansion, and HEC-HMS model was studied by Areeq and Aklan (2019) between 1994 and 2018. The overall LULC class for agriculture decreased as a result of land-use changes. Due to Sana'a city's metro expansion, the metropolitan region significantly expanded north at the examination region's border. The physical production of LULC guides for the inquiry region in 1994 and 2018 included land-use classifications for general farming, streets, high metropolitan thickness, desolate/negligible vegetation, shrub/shrub, and metropolitan medium to low viscosity [32].

## III. MATERIAL AND METHODS

### A. Study Area Sana'a

The case study for this research is Sana'a, one of Yemen's biggest cities and the capital of the governorate of the same name [33]. GPS coordinates for the city of Sana'a are 15°N 44°E, or 15.369445 latitudes 44.1191006 with 15°22' 10.0020"N and 44°11' 27.6216"E [28]. 2,545,000 people were living in the 126 km<sup>2</sup> city of Sana'a as of 2017[29], [30].

Figure 1 illustrates the environs of the city, which are located about 2,200 meters above sea level. A mountainous valley that stretches from south to north is located in Yemen's north-central region [12]. Its total area is 126 km<sup>2</sup>, and its population is estimated at 3,937,500 (2012)[31].

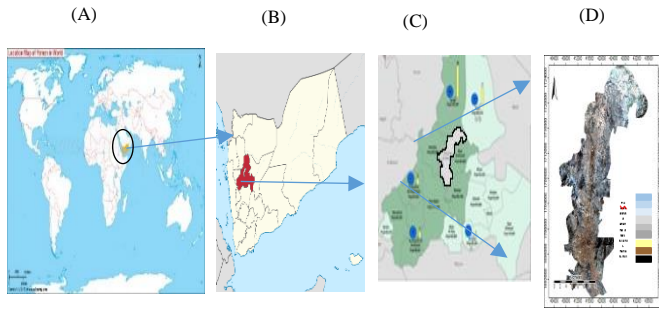


Fig. 1. Sana'a's position, (A) The global community, (B) Yemen, (C) Sana'a city; (D) Sana'a governorate

### B. Information from Satellite

This work utilized the Landsat8 Satellite Sensor (30m) and the mathematically open-source Landsat8 MSS/TM for LULC mapping. The US government's scientific agency, the United States Geological Survey (USGS) in the Sana'a region, provided the image. The base map was produced using survey images of the SOI toposheet at a scale 1:50000 [29]. It has created database details for the data collected in 1980, 1990, 2000, 2010, and 2020 in this investigation.

Figure 2: Sana'a Region on Google Maps. Figure 3 displays the Landsat8 Satellite Sensor (30m) data set for the capture and selection region research using Composite band 432.

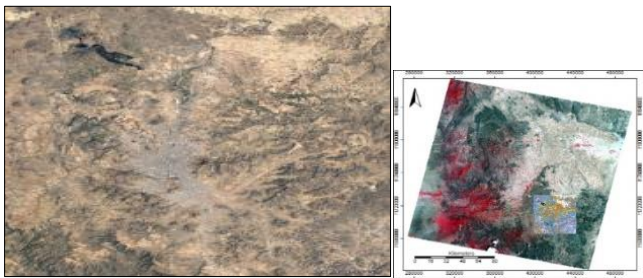


Fig 2. Google map of the Sana'a Region Fig. 3. A Landsat 8 data collection

### C. Establish a Database

The following data were used to create a database of land change observations of Sana'a, Yemen: 1980, 1990, 2000, 2010, and 2020; this allowed for the extraction of variations in the region's decadal period land changes. In 1980, the Landsat 5 satellite with the TM sensor had an accuracy of 30 meters.

In 1990, the Landsat 5 satellite with the TM sensor had an accuracy of 30 meters. In 2000, the Landsat 7 satellite with the ETM+ sensor had an accuracy of 30 meters. In 2010, the Landsat 5 satellite with the TM sensor had an accuracy of 30 meters. In 2020, the Landsat 8 satellite with the OLI and TIRS sensors had an accuracy of 30 meters.

## IV. METHODOLOGY

The critical phases of this attempted investigation are depicted in Figure 4 of the accompanying graphic.

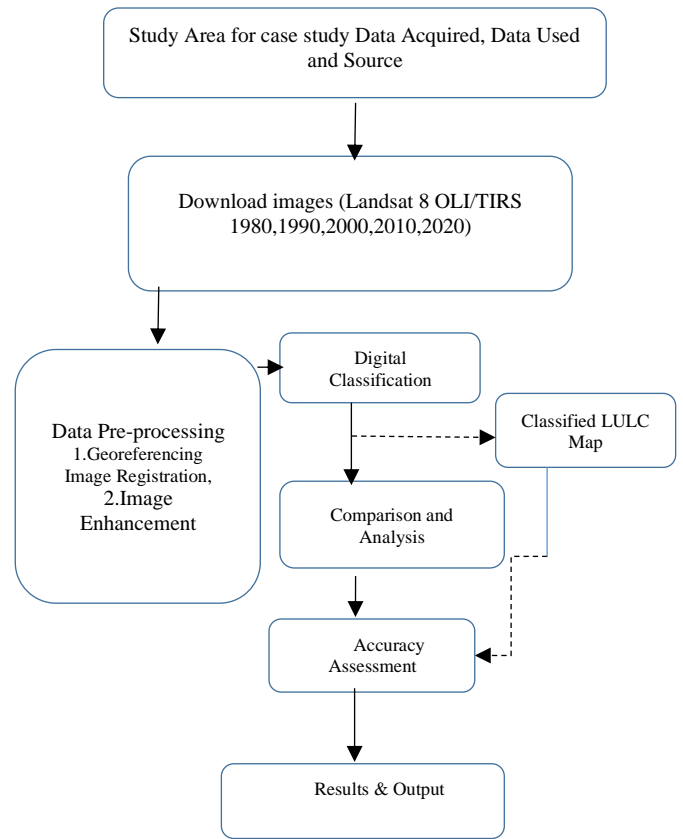


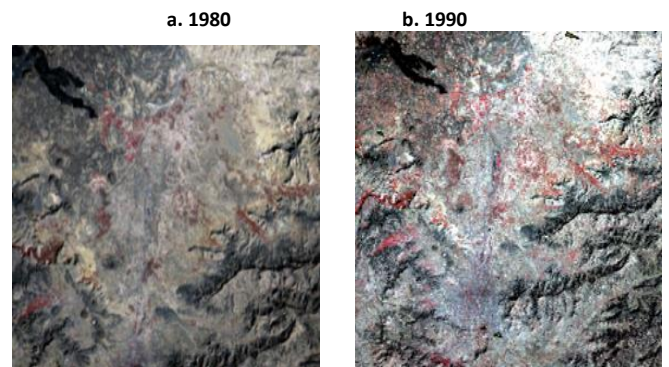
Fig.4. Workflow Diagram for Proposed Methodology

### A. Before Processing

It is the first step and a crucial duty in the LULCC process, which defines and cuts the map into designated regions using a coordinate reference system. Using remote sensing technology, the pre-processing step identifies the data downloaded from satellites. Pre-processing ensures that the data are genuine and include a geometrically calibrated reflection frequently found in the upper atmosphere.

Although the data is not publicly disseminated, the entities in charge of satellite management discontinue its use.

The pre-processed data is separated into the images displayed in WGS84 or WGS84 / UTM. For 1C-level researchers, multispectral images from Landsat8 are frequently available. Pre-processing for Landsat 8 satellite images in Band 543 during the 1980s, 1990s, 2000s, 2010s, and 2020s includes corrections. Before classification, the images of these image maps were cleaned of discrepancies. Figure 5 shows a data set from a selection area study with the Landsat8 satellite sensor (30 m) with Composite band 432



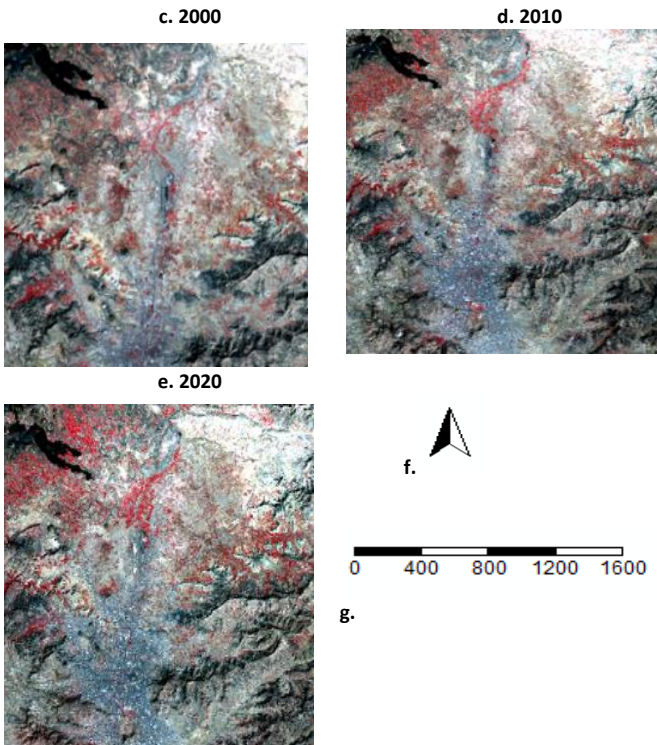


Fig. 5. Landsat 8 data set: selected area analysis using Composite band 432 (a. 1980, b. 1990, c. 2000, d. 2010, e. 2020, f. Direction, g. scale of map)

#### Sana'a city land classification from 1980 to 2020

Six samples for six parameters—High Land, Mountains, Land Area, Built-up, Vegetation, and Bare Land—are input layers for the model processing. Although the parameters in the software SAGA with these models' categorization is down to seven, the processing and results show that the parameters are six since they combine agricultural land and vegetation in one region. Make the samples based on the RGB color composites of the sentinel-2A photos. For instance, the class Vegetation (red pixels in the RGB color composite = 432) shows the intricate changes in the area. High Land refers to remote areas that may include settlements and clans with a long history and deep-rooted loyalties. Mountains are elevated earth crust sections characterized by steep sides and exposed bedrock. Land Area is measured in square kilometers and encompasses land-based regions that support populations.

This research thoroughly analyzes the classification of Sana'a city land between 1980 and 2020. LULCC was conducted in 1980, 1990, 2000, 2010, and 2020. It locates the LULC classed for Sana'a City; the categories are discernible from the variations in land change in Sana'a City, as depicted in Figure 6.

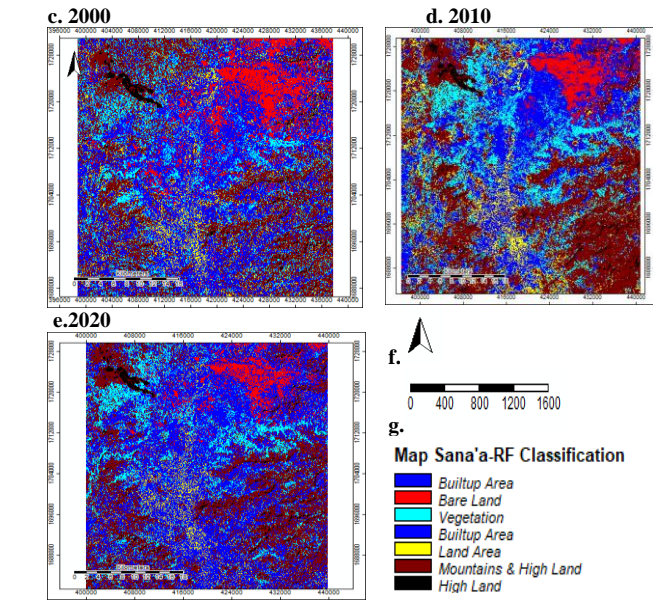
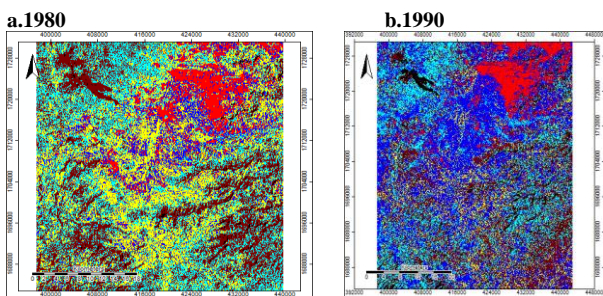


Fig 6. Classified Map for Sana'a over the five decades (1980–2020). (a. 1980, b. 1990, c. 2000, d. 2010, e. 2020, f. Direction, g. scale of map)

These areas may include streets, parks, roads, or ruins but do not contain buildings. Built-up areas consist of large and small buildings, settlements, and transportation infrastructure, as well as places like banks, schools, and hospitals that people frequent. Vegetation includes crops, fields, sparse grasslands, temperate steppes, and temperate meadows. Bare Land comprises bare soil and rocks and areas like deserts that do not contain people.

## V. RESULTS

Table 1 displays the area and percentages of LULC for Sana'a City from 1980 to 2020, based on the study's findings. The region's high land, mountains, land area, built-up area, and vegetation are all visible dimensions. Based on the study's findings, the built-up area increased from 12.17 percent in 1980 to 34.24 percent in 1990. That is normal, and due to human activity in front of ever-increasing structures and urban development, expansion will continue.

The built-up area dropped from 40.15 percent in 2000 to a non-typical 30.94 percent in 2010. 44.74 percent of the area was built up in 2020. This indicates that development, including the economy, is moving back in every direction. The remaining analytical parameters influenced growing and decreasing areas between 2010 and 2020.

TABLE 1. LULC AREA AND PERCENTAGES FOR SANA'A COUNTY'S DECADAL PERIOD FROM 1980 TO 2020

No	NAME	1980		1990		2000		2010		2020	
		AR EA m <sup>2</sup>	%	AR EA m <sup>2</sup>	%	AR EA m <sup>2</sup>	%	AR EA m <sup>2</sup>	%	AR EA m <sup>2</sup>	%
1	High Land	17	0.	93	3.	31	1.	49	2.	48	2.
		16	84	29	64	68	83	20	41	53	53
		12	%	76	%	81	%	39	%	70	%
2	Mountains	57	28	67	26	51	29	75	36	59	31
		88	.3	28	.2	27	.6	12	.7	90	.2
		4	85	3	03	1	75	5	51	4	4
		%	0	%	9	%	0	%	7	%	

3	Land Area	5096592	24.95%	2042865	7.96%	957069	5.53%	174042	8.51%	750699	3.92%
4	Built up Area	24867360	12.17%	878419	34.24%	69521	12.17%	34495	16.24%	23078	12.17%
5	Vegetation	53408	26.1%	53881	20.9%	22908	12.17%	33961	16.24%	23078	12.17%
6	Bare Land	154966	7.59%	17796	6.94%	17353	10.35%	103708	5.08%	10686	5.53%
7	Total of area	2042865	10.65%	2503143	10.43%	10285	10.28%	204428	10.28%	191728	10.28%

The primary causes of the declining populated area are missile devastation and the growth of arid land. Table 1 discusses the effects of land change in detail. The area classified as significant land-use or land-cover classes was computed for 1980, 1990, 2000, 2010, and 2020.

The region's area was 1867950000 m<sup>2</sup> in 1980 and 1497207600 m<sup>2</sup> in 2020. A 19.85% percentage of the city's total geographic area is divided between them, or 370742400. Over this time, agricultural and developed areas have seen a consistent decrease in land cover due to the expansion of forests. Of the six major LULC classes, considerable increases and decreases have been documented between 1980 and 2020.

By comparing maps for the years 1980 and 2020, the study concluded that human factors and processes have significantly impacted the shapes of the earth's surface in Sana'a. Due to human activity and the work of crushers in the mountains, numerous forms of the earth's surface that retain benefits from the Yemeni civilizational history, like castles, forts, and caves, are disappearing. The decision was made to build a database for the research area's land map.

The study suggests that to determine the mechanisms and variables influencing the formation of the earth's surface forms, biological and human geographical studies should be valued. They gain from organizing and carrying out large-scale development projects and using them to develop Sana'a's mountainous heights by creating parks, dams, and shelters. The significance of taking advantage of the study of spatial analysis and using geographic information systems to select the best location for service projects, such as designing a water barrier.

#### A. Land Change

The past section compares built-up and land areas from 1980, 1990, 2000, 2010, and 2020. The results show that 2010 the land area expanded while the built-up area shrank on a map. The results show that in 2020, the built-up area increased on a map. Figure 7 and Table 2 compare built-up areas and land areas across 1980, 1990, 2000, 2010, and 2020.

TABLE 2. LAND AREA & BUILT-UP CLASS CATEGORY RESULTS ARE COMPUTED FROM 1980 TO 2020.

	1980		1990		2000		2010		2020	
Land Area	5096592	24.95%	2042865	7.96%	957069	5.53%	174042	8.51%	750699	3.92%
Built up Area	24867360	12.17%	878419	34.24%	69521	12.17%	34495	16.24%	23078	12.17%

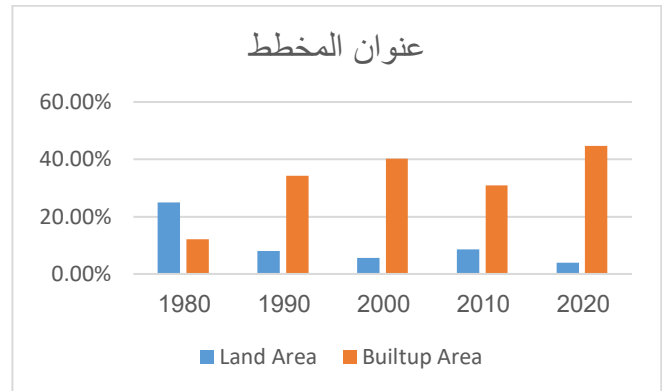


Fig.7. Chart of results of area calculated for class category land Area & Built-up from 1980 to 2020

#### B. Comparison of LULC of Decadal 1980, 1990,2000,2010,2020 Map

In Sana'a, the changes over the last decades for LULC have been negatively affected after 2010 and involve more things. We contrasted our LULC 1980 to 2020 guide and another accessible worldwide land cover. It is worth noting that the items differ in spatial goal. LULC changed for five decades from 1980 – to 2020 Every aspect of Sana'a city was altered, including the built-up area, vegetation, bare land, roads and land area, mountains and high land, and rocky area. It needs to be explained and justified, as apparent in Figure 8.

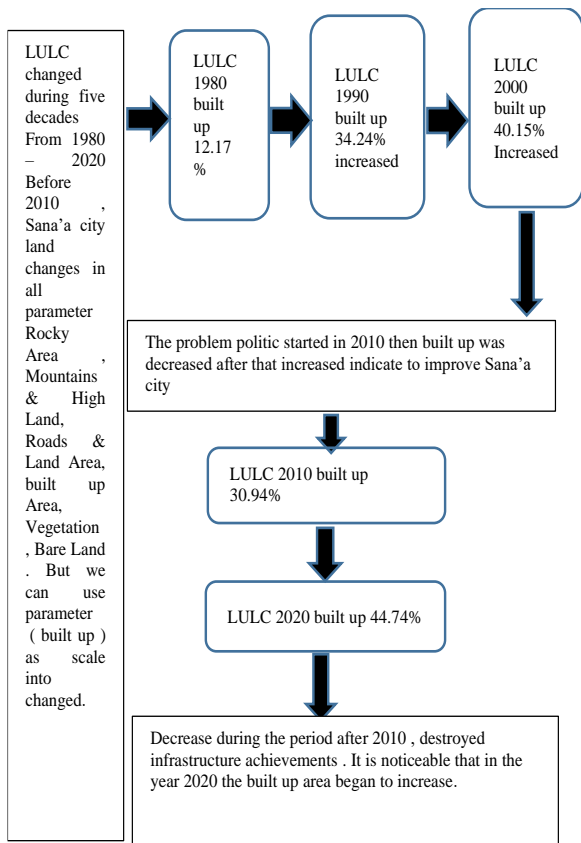


Fig 8. Steps of LULCC in this study using this flow diagram.

The current investigation indicates that Mountains changed: ( 28.34%,26.23%, 29.61%, 36.75%, and 31.24) in the years (1980, 1990, 2000, 2010, and 2020) respectively. High Land changed (0.84%, 3.64%, 1.83%, 2.41%, 2.53% ) in years (1980, 1990, 2000, 2010, and 2020) respectively. Built-up Area changed: (12.17%, 34.24%, 40.15%, 30.94%, and 44.74% ) in the years (1980, 1990, 2000, 2010, and 2020), increasing the built-up area in the city. Land Areas were (24.95%, 7.96%, 5.53%, 8.51%, 3.92% )in years (1980, 1990, 2000, 2010, and 2020) respectively. Vegetation was (26.11%, 20.99%, 12.85%, 16.31%, 12.04%) in years (1980, 1990, 2000, 2010, and 2020) respectively.

A shortage of precipitation caused an impressive reduction in the cropland region in 1990 during 1980–1990, which contrasted with 1980. During 2000 and 2010, vegetation of the same size was present in the harvest region. In 2020, vegetation indicated the fall situation in agriculture in the area. The stream result of the comparative evaluation of LULC in Sana'a over the five decades (1980–2020) is displayed in Figure 9.

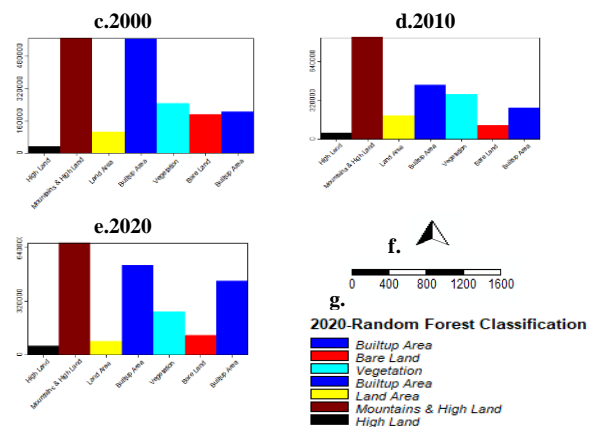
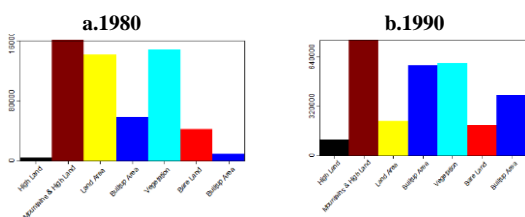


Fig.9. Comparative evaluation of LULC in Sana'a City over the five decades (1980 to 2020). (a. 1980, b. 1990, c. 2000, d. 2010, e. 2020, f. Direction, g. scale of map)

## VI. ACCURACY ESTIMATION

To estimate classification accuracy, it calculated the Confusion matrix and kappa coefficient. The classes to which pixels in an array belong for validation (ground truth) were used in the confusion matrix's rows, and the categories to which pixels were assigned to the image found in Figure 6 representation in the image were used in the confusion matrix's columns [4].

It uses the diameter of correctly categorized pixels so that pixels that aren't transferred to the correct class don't show up and suggest in-class assignment confusion across distinct land cover classes [4]. Furthermore, commission errors characterize confusion between this image class and other plot classes. They are expressed as non-diagonal elements in the rows of the confusion matrix, divided by the total number of pixels assigned to a Landsat image class corresponding to the row. Commission mistakes are the possibility that a pixel assigned to one type belongs to another [4]. Additional factors were examined for further explanation and accuracy assessment, including commission error and omissions, sensitivity and specificity, positive and negative predictive power, and kappa statistics. These variables were derived from the error matrix. See [4] for a more thorough examination of these ideas. The kappa coefficient and confusion matrix were employed to evaluate accuracy. It is also observed the kappa coefficient for the years 1980, 2010, and 2020 was 1.0, whereas for the years 1990, it was 0.997 & 2000 was 0.994. Also, the overall accuracy classification for 1980, 2010, and 2020 was 100%, whereas the overall accuracy for 1990 was 99.8% & 2000 was 99.6%. The study revealed that the region was advancing in urban-density built-up areas before 2010. Even after 2010, the built-up area fell while the land area expanded, with the built-up area being 12.17 percent in 1980, 34.24 percent in 1990, 40.15 percent in 2000, 30.94 percent in 2010, and 44.74 percent in 2020. When the Kappa coefficient equals 1, the transaction is in perfect agreement; when it is close to zero, the bargain is better than expected by chance. Kappa



values are clear, as shown in Table 3, indicating the Strength of Agreement of the A kappa coefficient.

TABLE 3. STRENGTH OF AGREEMENT OF A KAPPA COEFFICIENT

No	Kappa Value	The degree of agreement
1	<0.00	low
2	0.00-0.20	medium
3	0.21-0.40	Good
4	0.41-0.60	Very Good
5	0.61-0.80	Excellence
6	0.80-1.00	Very Excellence

According to the classification of the Kappa statistic [4], it is widely referred to as reproduced. The results of this study's Kappa coefficient, Overall Accuracy, and Average category are shown in Table 4. The average classification accuracy from 1980 to 2020 was 99.88% during the decadal period.

TABLE 4. KAPPA COEFFICIENT, OVERALL ACCURACY OF CLASSIFICATION FOR THIS STUDY

Year	Kappa Coefficient	Overall Accuracy
1980	100%	100%
1990	0.997	99.8%
2000	0.994	99.6%
2010	1.0	100%
2020	1.0	100%
<b>The average classification Accuracy for this study = 99.88%</b>		

## VII. DISCUSSION

Natural processes affect the construction and change of surface forms and land phenomena, significant in the region's comprehensive development areas. The study region is characterized by several natural features in many aspects. One biological component that affected the emergence and evolution of these manifestations was the climate. The number of individuals increases with the population, reflecting a rise in human processes. Between 1980 and 2020, human operations and activities included construction, quarrying, and other lands used for agriculture and industry. These activities will consume and convert around five tons of building materials. In total, the investment in quarries and the exploitation of quarries in the mountainous heights increased with the increase in population growth and urbanization in the study area, as well as the construction process that drains large quantities, recognizing the impact of daily human operations on the manifestations of surface forms in mountain heights.

Mountain people are eroded by consumerism, and tones are being removed every year. Different building materials, such as gravel, are needed to build houses and other residential structures. As a result, there was a massive demand for the development of numerous mines in those locations, as well as the establishment of crushers that changed the land's surface. They tried to deplete vital natural resources, demonstrating human activity and operations in the highland production zones. Today, we find a significant and clear difference in the change of appearances and shapes of the land surface in the study area. It has multiple

dimensions and effects, including torrential streams, water drainage, and the environment.

The land change classification used in this study to show the variations in land changes across the period under consideration suggests that the land use in this area is improper. In this endeavor, a database of Sana'a's LULC was constructed. Landsat satellite imagery is utilized with an RF classifier. This research is essential for underdeveloped countries since it will help with natural resource management, where LUCC is essential to regional economic development and resource management. Destroyed the nation's infrastructure, impeding the crucial development of Sana'a's economy, society, environment, health, and agriculture.

The findings indicated there is a difference in land changes across four decades. The land change classification used in this study to show the variations in land changes across the time under consideration suggests that the land use in this area is improper. In this endeavor, a database of Sana'a's LULC was constructed. Landsat satellite imagery is utilized with an RF classifier. This research is essential for underdeveloped countries since it will help with natural resource management, where LUCC is essential to regional economic development and resource management. Destroyed the nation's infrastructure, impeding the crucial development of Sana'a's economy, society, environment, health, and agriculture.

Developing surface forms and mountain heights in Sana'a is one of the essential land research studies that must be considered. It gives a clear image to planners when conducting development projects. Creating a water barrier in Wadi Ajlan to preserve and avoid dangerous regions by utilizing the steep heights to construct a shelter would be one of Sana'a's most significant strategic economic projects. The floodwaters will play a crucial role in recharging Sana'a's groundwater, which has been severely depleted. The study concluded that human factors and processes have greatly affected the shapes of the Earth's surface in Sana'a by comparing maps For the year 1980 and the year 2020. Human activities have affected the disappearance of many forms of the Earth's surface that contain gains from the Yemeni civilizational heritage, such as castles, forts, and caves due to human activities and the work of crushers in the mountains. It was reached to create a database for a geomorphological map of the study area.

The study recommends valuing biological and human geographical studies to identify the processes and factors affecting the formation of the Earth's surface forms. They benefit from planning and conducting comprehensive development projects and employing them to develop the mountainous heights in Sana'a through building dams and parks and establishing a shelter. Benefiting from the study of spatial analysis and choosing the optimal site through geographic information systems to make service projects, such as planning to develop a water barrier. To verify the findings of this study, it has been referring to the 2016 documentation on Sana'a, Yemen, issued by UN-Habitat, the Joint Research Center for their technology in developing damage assessments and land-use mappings for the city of Sana'a Funded, European Union[45]. Because of the scarcity of studies on land use in Sana'a, it has relied on validation through this documentation.

Each segment uses the most recent data to build a unique image using an area-based methodology. These are combined to deliver the most current holistic knowledge backed up by contextual data and analysis [34].

## VIII. CONCLUSION

This research has provided information about Sana'a's LULC for four decades. The discovery of the change in LULC based on remote sensing data is the source of information to make appropriate decisions for the benefit of the countries. Disclosure of land change is a factor for conserving land and considering management and development.

Here are some recommendations for Sana'a's moves towards more sustainable and well-managed urban growth, ensuring the efficient use of its natural resources and improving the quality of life for its residents as following:

1. Enforce policies to protect agricultural lands and natural resources through zoning regulations, incentives for sustainable practices, and penalties for unauthorized land use changes.
2. Encourage environmentally balanced urban growth by creating green spaces, sustainable infrastructure, and eco-friendly building practices.
3. Study the socio-economic factors behind urban expansion and agricultural land conversion.
4. Develop urban plans that balance growth with preserving agricultural and bare lands.
5. Train local planners and stakeholders using LULC maps and machine learning tools for better resource management and urban planning.

## ACKNOWLEDGMENT

The authors are thankful to the presidency of Al-Razi University and the Scientific Research Center for facilitating the completion of this study.

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## الذكاء الاصطناعي لتحليل التغيرات الأرضية العقدية في صنعاء - اليمن

من 1980 إلى 2020 باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية

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### ملخص البحث

أصبح إدارة الموارد الطبيعية أمراً حاسماً بسبب النمو السكاني السريع والتغيرات الجوية والكوارث. تعتبر خرائط استخدام الأراضي وغطاء الأرض ضرورية للتخطيط وإدارة الموارد، ولكن البلدان النامية مثل اليمن تفتقر إلى مثل هذه الدراسات والاهتمام الكافي في هذا المجال. مشكلة هذه الدراسة هي إيجاد حلول في دراسة إدارة الموارد الطبيعية التي تؤدي إلى اتخاذ قرارات مناسبة لتحسين الوضع الاقتصادي وإدارة الأراضي الزراعية والصناعية والسكنية. أهداف هذا البحث هي: (1) تحديد التغيرات في استخدام الأراضي في مدينة صنعاء من عام 1980 إلى عام 2020. (2) إنشاء قاعدة بيانات لتصنيف استخدام الأراضي وغطاء الأرض (LULC) لمدينة صنعاء من عام 1980 إلى عام 2020. استخدم البحث تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية مع صور لاندسات من الأعوام 1980، 1990، 2000، 2010، و2020 مع أفضل مصنع من تقنية التعلم الآلي كخوارزمية الغابات العشوائية (RF) التابعة لتقنيات الذكاء الاصطناعي (AI). حددت الدراسة التغيرات في الأراضي في صنعاء على مدار هذه العقود. وأظهرت النتائج أن كثافة المناطق العمرانية في صنعاء قبل عام 2010 زادت، وفي عام 2010 انخفضت. وزادت كثافة المناطق العمرانية في صنعاء في عام 2020. تغيرت المناطق المبنية بنسب 12.17% في عام 1980، و34.24% في عام 1990، و40.15% في عام 2000، و30.94% في عام 2010، و44.74% في عام 2020. كان متوسط دقة التصنيف 99.88%. وتشمل التوصيات للنمو الحضري المستدام في صنعاء تطبيق السياسات لحماية الأراضي الزراعية، وتعزيز الممارسات الصديقة للبيئة، ودراسة العوامل الاجتماعية والاقتصادية للتوسع الحضري، وتدريب المخططين المحليين، وحث الجمهور حول الاستخدام المستدام للأراضي. يوصي هذا البحث بإجراء المزيد من الدراسات لإيجاد حلول لإدارة الموارد بشكل أفضل لتحسين الأوضاع الاقتصادية وإدارة الأراضي بفعالية.

الكلمات المفتاحية: استخدام الأراضي وغطاء الأرض، الذكاء الاصطناعي، الاستشعار عن بعد، نظم المعلومات الجغرافية، مدينة صنعاء، الغابات العشوائية