Monitoring land use and land cover (LULC) in the Khorezm oasis using the Esri Sentinel-2 Land Cover Explorer database

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Abstract: In the following study, using highly-developed remote sensing methodologies, a historical over-ten-year study of the LULC phenomenon of the Khorezm Oasis was conducted. The analysis provides valuable insights about agricultural change, water management policies and the alteration of LULC in the region, including several processes, changes in plants and irrigation levels, population density and growth of urban structures. Consequently, the work establishes an interrelation between climate variability and therefore, this assessment comes with useful policy information for any policy maker or relevant stakeholders who wish to implement good land management policies and policies that reduce any negative effects on the environment within the Khorezm Oasis. Based on the below results, it was indicated that there is a divergence in change in agricultural land, water areas, natural vegetation, and urban form based on 2018 to 2022, informing of the decrease in water areas, tree coverage, and cane regions, as well as the increase in built-up areas and bare ground. These transformations are explored with respect to socio-economic characteristics, climate fluctuations, and policy management, providing useful guides for professional communities and policymakers to design more favourable conditions for sustainable management of land and agriculture.

1 Introduction

As one of the most important centres of agriculture and as a specific ecological province of Central Asia, the Khorezm oasis shows changes in the coverage of the land surface and the uses made of that surface, which are essential for the purposes of analysis and planning for the future. This paper presents an analysis of land cover data, which contains information on the availability of forests, wetlands, impervious surfaces, agricultural lands, and water bodies, to support the decisions taken by the environmental managers [17]. They also enable them understand the prevailing condition of the land and assess all the effects resulting from prior management activities. Using satellite and aerial images and assessing the land cover changes that are characteristic of the region, experts can create land cover maps that contain important information about the changes in the landscape of the given area.

Different global changes induced by the excessive use of fossil fuels and intensive industrialized farming methods have intensified in the last two centuries and thus partly increased the size of deserts [18]. The areas threatened comprise the Khorezm oasis which stretches for over 300 kilometers across regions in Uzbekistan and Turkmenistan. The shape was made through the activities of the Amudarya River from the period of thousands of years ago as the flat plain and different area has been vital for its agricultural land.

To track and investigate these shifts, the paper utilizes the ESRI Sentinel 2 Land Cover Explorer database, which is a component of the European Space Agency's (ESA) Copernicus initiative. This makes it possible to classify the land cover with higher accuracy into 11 classes including forest, wetland/water, and artificial surfaces/ built-up area, Cropland/Orchards, and more with the resolution of 10 meters. This makes it to offer a whole wealth of information on the land cover without further attest to the atmospheric and radiometer corrections.

This research work synchronises an over ten-year study examining LULC changes in the Khorezm oasis. [2,3,7,9,19]. This work analyzed the spatial and temporal patterns of land change including the conversion of agricultural lands into non-agricultural uses, manifestation of urban sprawl, and deforestation through both modern Sentinel 2 satellite data. In this regard, it engages socio-economic data, climate data, and changes in policy antecedents to expound on factors driving these alterations. The study has revealed massive changes in the extent of agricultural lands, water bodies, forests and scrubs, and the urban map over the years 2018 to 2022. The decline of water bodies, forest and cane zones in contrast to an augmentation of built-up zones and exposed earth surface is useful for the policy makers as well as other stakeholders to ponder over.

The study uses advanced remote sensing techniques, ESRI Sentinel-2 Land Cover Explorer database to look into the impact of human activities, climate variability and agricultural practices on the environment.

The main objectives of this research are:

- To see the big changes in land cover and how it relates to socio-economic and climate factors.
- To provide information and data to policymakers and stakeholders to make better land management decisions to address water scarcity, desertification, and urbanization.

2 Materials and methods

2.1 Study area

The Khorezm oasis is located in the lower part of the Amudarya, from latitude 50° 41' to 54° 14' latitude, longitude from 64° 54' to 68° 21' longitude (Figure 1). Khorezm region of Uzbekistan, Karakhalpakhstan's southwest portion, and Turkmenistan's northeastern portion of Tashkhovuz region comprise the Khorezm oasis [1]. It shares (partially) borders with the Kyzylkum desert to the south, the Ustyurt plateau and Karakum deserts to the west, and the Kungirot latitude to the north. The shape of Khorezm oasis is associated with the Amudarya cumulative activity. For thousands of years, the river's sediment and clay deposits accumulated in this region, creating deltas (Figure 1) [1]. The Khorezm oasis extended until the Tuyamoin Strait in the south.

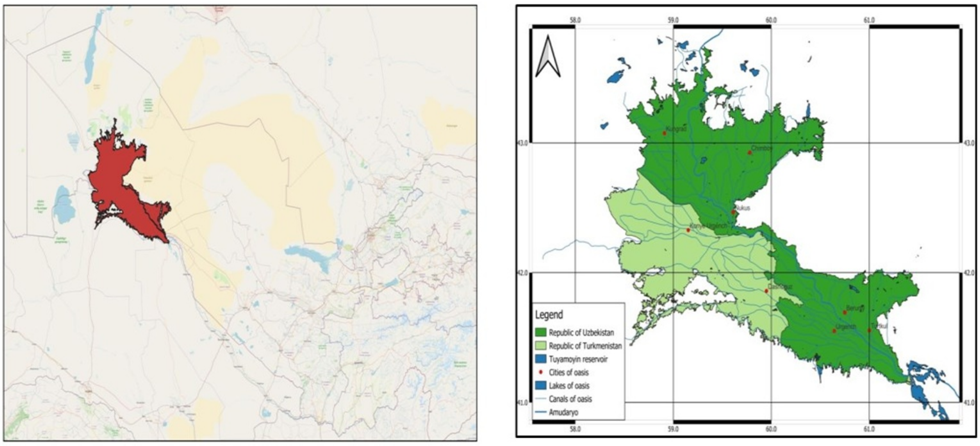

Fig. 1. Location of the Khorezm oasis.

The oasis stretches from southeast to northwest for more than 300 kilometers. Its widths are 10–12 km in the Tuyamoyn strait, 120–130 km in the northern portion, and 70–80 km in the Takhtatash strait, which is the western portion of the Sultan Uwais ridge. The formation of the Khorezm oasis occurred during the Quaternary era due to the gradual built-up of glacial delta deposits and the expansion of the delta towards the Aral Sea and the Sarikamish depression. Their lithologic composition and age are different. Certain minor depressions also contain lake deposits. Agro-irrigation layers (two to three meters thick) have accumulated on cultivated land since ancient times. The Khorezm oasis is essentially a flat plain with a gentle north and northwest slope. The Amudarya (especially in the northern portion of the oasis) stretches and flows slowly because of the low slope. There were created river-beds (Kokhnadaryo, Dryolik, Dvdon, Shortonboy, Kreitozak, Itkrozak, Karaozak, etc.) and various hills and ridges with varying elevations among them.

2.2 Methodology

There are several ways to monitor land use and land cover, but in this research paper we aim to classify based on the Esri Sentinel-2 Land Cover Explorer database [2,4,5]. This database is based on data from Sentinel-2 satellites included in the Copernicus program of the European Space Agency. It also increases the ability to study the Earth's surface in detail thanks to the superior optical capabilities of the Sentinel-2 satellites [12,13]. The database helps in the formation of the classification of different type of the cover of the land types including the forests, the water body, urban areas, agricultural fields etc. Thus classes let the users define the possibility of distribution of various land covers within the given area.

There are several pros and cons of monitoring techniques using the ESRI Sentinel-2 Land Cover Explorer database. One of the main advantages is that atmospheric [5] and radiometric [6] correction will not be necessary. In addition, Sentnel 2 is a non-commercial satellite with a resolution of 10 m, providing relatively high resolution. On the other hand, there are several disadvantages of using this database. One of them is that this database contains data after 2017, and data before 2017 is not included. Therefore, the ability to perform long-term analyzes is somewhat limited. In addition, annual average data can be obtained in database, short-term, for example, monthly or weekly data are less available.

To do this, investigate LULC changes in the Khorezm oasis area and to carry out this goal the ESRI Sentinel 2 Land Cover Explorer database was used. This came from the second generation of the European Space Agency's Copernicus program that contains improved and higher quality data crucial in distinguishing and monitoring land covers and change.

2.2.1 Data Collection:

The LULC data sources obtained from ESRI Sentinel 2 Land Cover Explorer that namely 10m resolution for the years of 2018, 2020 and 2022 are the primary data sources of the study [20, 21]. LULC data sources from ESRI Sentinel 2 Land Cover Explorer, i.e. 10 m resolution for the years 2018, 2020 and 2022 are the main data sources of the study.

This database was created based on the Universal Transverse Mercator (UTM) WGS84 projection, which was converted to EPSG:32641 - WGS 84 / UTM zone 41N for the Khorzam Oasis, where the research area was calculated. One evident drawback was inadequacy of the database to contain data collected before November 2017, which slightly limited the potential to conduct longer historical studies.

2.2.2 Data Processing:

The acquired satellite images were georeferenced using quantitative software QGIS 3.28.2 software. The methodology involved several key stages:

1. Image combination:At the first stage, satellite images of the particular years were integrated to get the exhaustive information over the years of observation.

2. Land cover classification: Then, the resulting combined images were grouped into seven categories of land use which includes water, trees, cane, crop fields, built-up, bare ground as well as sand.

3. Area determination: This was done to assess the extent of changes to the classified land cover type in order to determine changes for various years (Figure 2).

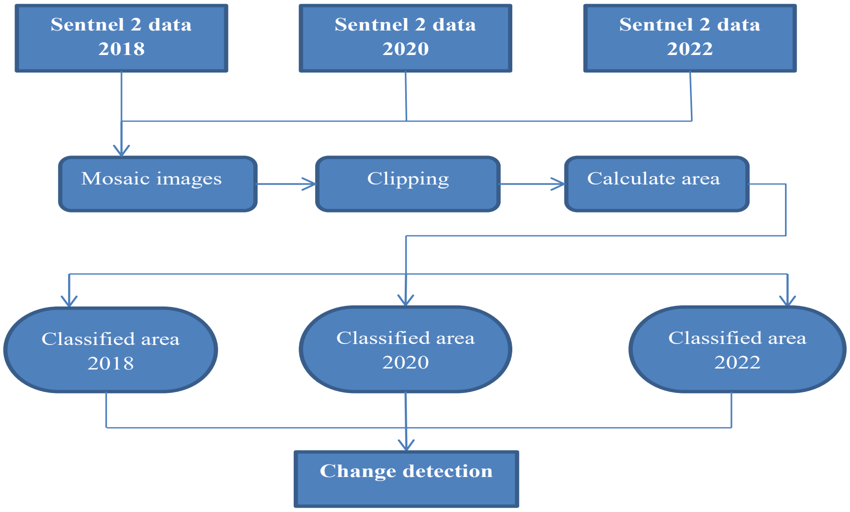

Fig. 2. Flowchart of the methodology.

2.3 Analysis

The classified areas were as follows: to make the results more comprehensible and to be able to analyze the LULC change, the study period of 5 years from 2018 to 2022 was considered. These involved various aspects that included, demographic features, socio-economic activity patterns, climate dynamics, population growth rates and changes in policies in utilization of land and water resources among others.

The methodologically unique approach based on the integration of the remote sensing data, the highly-technological image analysis and the extensive analytical work offered the essential understanding of the changes in the configuration of the Khorezm oasis in the micro-regional scale. The outcomes reveal the need to advance the water management strategies, the use of the climate-proof techniques of handling the arable land, and bolstering the collaboration between different disciplines to encourage effective utilize of the scarce land and water sources in the oasis.

3 Results

3.1. Monitoring land use/land cover changes

The Khorezm oasis has undergone significant and differentiated land use and land cover dynamics from 2018 to 2022 that reflect the general environmental and socioeconomic processes in the area. The some main changes were given below:

Water areas: Turns out, the total water-covered area of the oasis was 375.8431 km² according to year 2018. It was recorded that this figure had dropped down to 351.0813 km² by 2022, making a decrease by 24.7618 km² which is huge enough.

Tree coverage: The same situation goes for the space covered by trees, which plunged from 23.2386 km² in 2018 to 11.8568 km² in 2022

Cane areas: This is an important agricultural and ecological feature of the region, decreased significantly from 119.4266 km² in 2018 to 79.6461 km² in 2022.

Cultivated areas (Crops): The cultivated area, the most extensive type of land cover in the oasis, suffered a considerable drop. While in 2018 the cultivated area reached 17,735.06 km², in 2022 it was 17,041.69 km², meaning a decrease of 693.37 km².

Sand Areas: The same declining trend was observed for sand areas, which represent barren or thinly vegetated land. In 2018, sand areas occupied 495.8879 km² of the study area, but in 2022 this expanded to 467.5481 km², decreasing by 28.3398 km².

Built-up areas: Unlike the natural and agricultural land cover types, which are in a declining trend, built-up areas within the Khorezm oasis have consistently increased.

Bare ground: An increase in the area of bare ground, which represents soil or sand with little or no vegetation, was also noted. From 2018 to 2022, the area of bare ground expanded from 6,662.273 km² to 7,311.949 km², increasing by 649.676 km² (Table 1).

The land use and land cover changes observed within the study area imply various environmental challenges that face the Khorezm oasis, such as water scarcity, deforestation, land degradation [8] and urban expansion.

The biggest change during the studied period was crops (It is the surface of land on which a crop is grown. In general, the area measured for cadastral purposes includes, in addition to the area cultivated, headlands, ditches and other non-cultivated areas), that is, the area of crops has decreased from 62% to 59%, which means that fertile land is decreasing, which creates the need to further strengthen food security in the country.

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Table 1 LULC changes between 2018 and 2022 in the Khorezm Oasis.

Classes		2018 (km^2)	2020 (km^2)	2022 (km^2)	Change between 2018 and 2022 (km^2)
1	Water	375,8431	384,1204	351,0813	-24,7618
2	Trees	23,2386	16,4238	11,8568	-11,3818
3	Cane area	119,4266	82,522	79,6461	-39,7805
4	Crops	17735,06	18051,65	17041,69	-693,37
5	Built-up area	3429,112	3530,587	3577,07	+147,958
6	Sand area	495,8879	431,3445	467,5481	-28,3398
7	Bare ground	6662,273	6344,192	7311,949	+649,676
Total area		28840,84	28840,84	28840,84	0

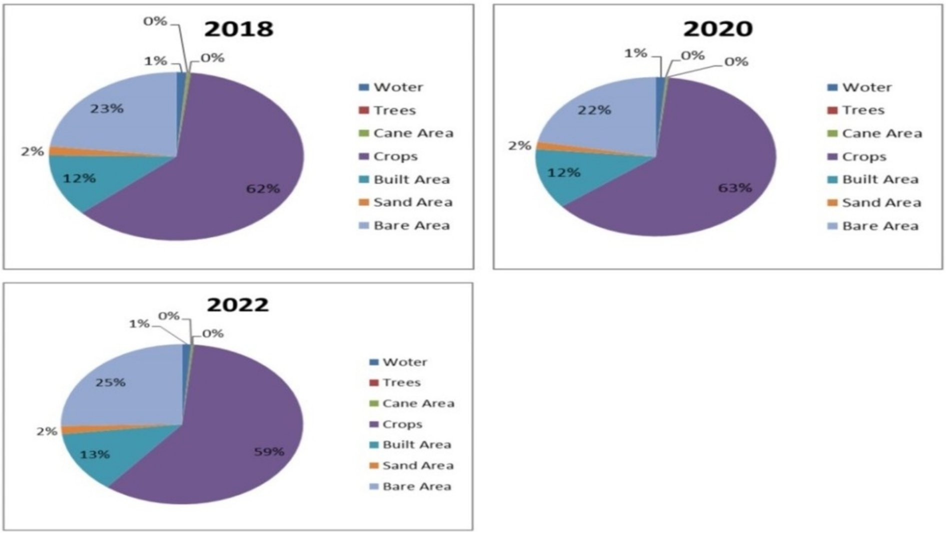

Fig. 3. LULC changes between 2018 and 2022 in Khorezm Oasis in percentage.

Another negative trend identified during the research is the increase of Bare ground [11] (Bare soil means soil or sand not covered by grass, sod, other live ground covers, wood chips, gravel, artificial turf, or similar covering). Bare ground has increased from 23% to 25% between 2008 and 2022. The main reasons for this are the deterioration of the water supply to the oasis, and periodic droughts [14]. (Figure 3.)

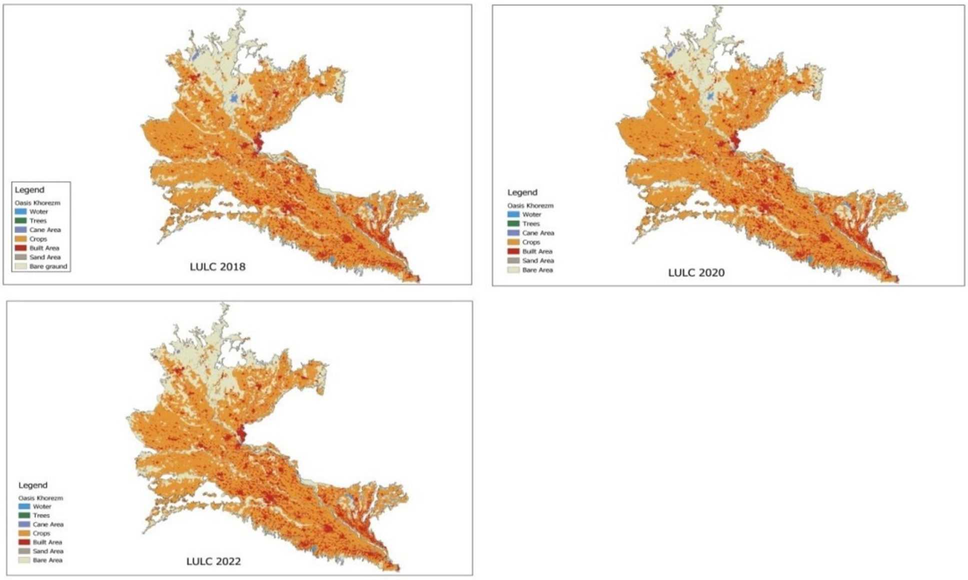

Fig. 4. LULC of Oasis Khorezm.

There are different approaches to the classification of the Khorezm oasis area, but within the framework of these studies, the Khorezm oasis was conditionally divided into 7 classes [2,7]. They are as follows: water, tree, cane area, crops, built-up area, sand area, bare ground. (Figure 4)

According to the classification map of Khorzam Oasis, bare ground has expanded in the northern and northwestern parts of the oasis. One of the main reasons for this is the lack of water due to the fact that the above areas are located in the lower part of the Amudarya. Also, it can be seen that the bare ground has increased in the central part of the oasis. Urbanization, which is one of the main causes of desertification [15] is growing year by year, and this process is growing rapidly, especially in the central part of the oasis.

4 Discussion

The dynamics of water flow [16] has a direct influence on the change of land cover in the Khorezm oasis. It is clear that the Amudarya, which is the main water source of the oasis, has different water levels in different years. (Figure 5)

The analysis of the figure 5 shows that there is a trend of decreasing water flow for many years. In general analysis, it can be seen that the trend slopes decrease from left to right side of the diagram, which means that the water flow decreased during the observed period. In different years, the water flow values are very different. In some years, the volume of water flow has increased dramatically. The largest maximum value of annual water flow was observed in 1992 and 1998, and the minimum value was observed in 2002, 2008 and 2018. Here are some main discussions arised:

Water zones: In 2022, the amount of water entering the oasis was more than in 2018 and 2020. However, in 2022, the water area in the oasis decreased by 24.7618 km/sq. The main reason for this is that the government has not developed early informing/warning system. As a result, most of the water flowed into the lakes and outside from the oasis.

Tree cover: The reduction of 11.3818 km² is mainly due to global climate change, deforestation, and conversion of forested land to other land uses such as urbanization or simply expanding agricultural land.

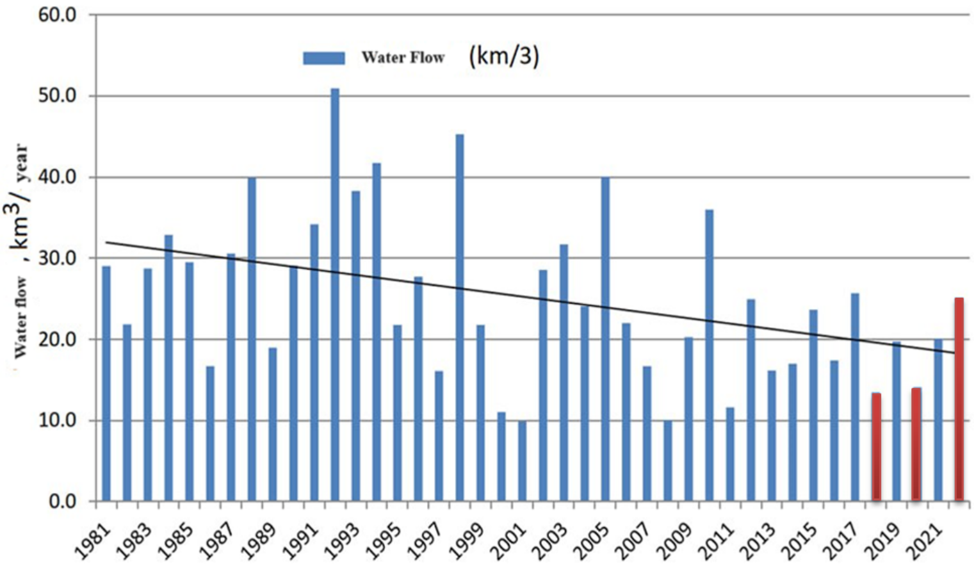

Fig. 5. Conducting state monitoring of groundwater in the Khorezm region and the southern regions of the Republic of Karakalpakstan [10].

Cane Areas: During the research period, in 2018, 2020, 2022, the amount of Amudarya water was 13, 14 and 26 km/cubic, respectively. The minimum amount of water during the research period was recorded in 2018. It can be seen that the volume of the cane area increased in the same year (Table 1). The main reason for this a large area of the riverbed formed, which creates favorable conditions for the growth and development of plants such as reeds.

Cultivated areas (Crops): The reduction of these productive agricultural areas is more general problems, like soil exhaustion, irrational water distribution among farmers even an increase in the area of lands with fallow crops, or even the transformation of cultivated areas into other types of land.

Sand areas: The results of the study have showed that the change of the sand area in the oasis has a direct relationship with the water flow. In years of high-water flow, areas with the sandy soil decreased.

Built-up areas: In contrast to the declining natural and agricultural land cover types in the Khorezm oasis, built-up areas have been steadily increased. The main reasons for this are the regular the population grows and the acceleration of urbanization processes.

Bare ground: The expansion of bare ground area may be attributed to land degradation, deforestation and erosion due to poor water management and climate change. It needs further investigation.

5 Conclusion

The comprehensive study of (LULC) changes in the Khorezm Oasis, facilitated by remote sensing technology, has provided significant insights into the region's dynamic environmental transformations over the past decades. The analysis of satellite imagery and ground truth data highlighted notable shifts in agricultural practices, urban expansion, and natural vegetation coverage.

Key findings indicate that the prevailing changes in LULC are predominantly driven by a combination of socio-economic factors and climatic variations. Agricultural intensification, often influenced by policies aimed at boosting crop yields and economic returns, has led to extensive modification of land use patterns. This intensification, coupled with inadequate water management practices, has exacerbated issues such as soil salinity and land degradation. Additionally, the expansion of urban areas and infrastructure development, propelled by population growth and economic activities, has significantly altered the natural landscape.

The integration of remote sensing techniques with socio-economic and climatological data has proven essential for understanding and managing LULC changes in Khorezm Oasis. Policymakers and stakeholders are urged to consider these insights when devising sustainable land management and agricultural practices. Emphasis should be placed on improving water management, adopting climate-resilient agricultural methods, and balancing development with environmental conservation to ensure the long-term ecological and economic vitality of the region.

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