LAND USE LAND COVER(LULC) CLASSIFICATION

FOR THE KURDISTAN REGION OF IRAQ

Foreword

Knowing how to use the land, the level of green cover and the amount of surface water in the Kurdistan region is one of the most important information for now and for the future based on which government makes many decisions.
No doubt, many changes happened in terms of urbanization and reduction of land used for agricultural purposes, and Kurdistan region is constantly faced with water problem for drinking or for agriculture due to climate change, which had a great impact on livelihood in general.

In this regard, Kurdistan Region Statistics Office (KRSO) worked to obtain this information during the past 12 months relying on the human resources of KRSO in the Department of Geographical Information system (GIS) and Salaheddin University in Erbil using modern technology to reduce costs and time. This work was done with the support of the World Food Programme (WFP). this work is presented in details in this report for decision-makers to get benefit from.

Fortunately, instead of buying expensive satellite images, the Salahuddin University team used new methods and trained the staff of KRSO to continue updating data and information to benefit the relevant authorities such as the Ministries of Municipalities and Tourism, Agriculture and Water Resources, Board of Environment Protection and preservation and many other parties.
It is a great honor that this work was successfully done for the first time in Iraq, for this reason, the Ministry of Agriculture and the Central Statistical organization of Iraq (CSO) requested the same work to be done jointly with KRSO at the national level.
This report contains important details such as classification of types of land using in terms of agriculture, vegetation, buildings and other types of land cover based on which current and future plans can be done and suitable agricultural land can be best used to provide food security and the right way of using water resources to reduce water waste.
Here, I would like to thank the team of Salaheddin University for their efforts and hard work with us to successfully implement the project. I would like also to thank the World Food Programme (WFP) for their financial support to conduct this work.
I would like to thank the staff of KRSO in the Geographical Information System department and statistical directorates for field auditing at the level of governorates to ensure the accuracy of the satellite images.
At the end, we hope that the relevant parties in Kurdistan Region Government to take more advantage of this information as an opportunity to build agricultural and environmental infrastructure in the future and working for its sustainability.

Serwan Muhammad Muhyiddin
President of KRSO

Foreword

As Iraq continues its journey of development and progress, understanding the intricate dynamics of land use and land cover becomes increasingly vital. The Land Use Land Cover Analysis Report presented herein stands as a significant milestone in our collective efforts toward informed decision-making and sustainable development. Land Use Land Cover (LULC) project generates high-resolution satellite imagery crucial for understanding environmental challenges, guiding sustainable development, and showing the diverse ecological zones in need of protection against climate change.

The detailed maps of Iraq's changing landscapes will help decision-makers identify critical drivers. This information provides a foundation for informed decisions, supporting evidence-based policies and resource allocation to tackle climate-related challenges.

By mapping urban areas, water bodies, and various ecosystems, this project supports sustainable urban planning, efficient water resource management, and the conservation of ecosystems. The LULC classification suggests promoting sustainable agricultural practices, conserving wetlands and marshland vegetation, encouraging afforestation and reforestation, and improving land use. This classification's data will help to shape evidence-based policies tailored to the needs of Iraqi communities.

Iraq's rich history, diverse geography, and cultural heritage are intricately intertwined with the land. As we move forward, this report serves as a crucial foundation for steering Iraq's land management practices towards sustainability, resilience, and harmony with nature. It underscores the importance of balancing development needs with the preservation of Iraq's natural resources for the benefit of current and future generations. This report stands poised to contribute significantly to improved agriculture, enhanced food security, and better water resource management, among other sectors grappling with the impact of climate change.

By harnessing the power of data and informed decision-making, informed decisions pave the way for a more sustainable future for Iraq. This project reflects our dedication to leaving no one behind as we move towards a better future.

This accomplishment is the culmination of robust partnerships between the World Food Programme in Iraq, the Kurdistan Region Statistical Office (KRSO), Central Statistics Organization (CSO) of the Ministry of Planning and Cultivision, an Iraqi company engaged in research and using cutting edge technologies and tools.

I am pleased to underscore the expertise contributed by various UN agencies—UNFPA, FAO, UNDP, UN-Habitat, UNMAS, UNICEF, and WFP—whose collaboration has fortified this project. The maps generated through this collective expertise hold the key to addressing critical global challenges, from climate-induced migration to biodiversity loss, land degradation, natural disasters, and the overarching impact of climate change, aligning directly with the pursuit of Sustainable Development Goals.

I extend my gratitude to the German Federal Ministry for Economic Cooperation and Development (BMZ) for its generous funding, partners, and stakeholders involved in this remarkable project. Together, let us celebrate this achievement and continue our joined efforts towards a more prosperous environment for Iraq.

Sincerely,

Ally-Raza Qureshi, Country Director, and Representative WFP Iraq

FINAL REPORT

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Land Use Land Cover (LULC) Classification using Google Earth Engine for the Kurdistan Region of Iraq Based on Sentinel-2

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Abstract

Land use and land cover (LULC) mapping is essential for understanding the distribution and extent of various land cover types within a region. This study aimed to provide a comprehensive LULC classification for the Kurdistan Region of Iraq based on remote sensing data. The study area covered a total area of 46465.1 km2, and the LULC classification was derived using Landsat 8 and Sentinel imagery and ground-truth data collected through fieldwork. The results of the study show that the dominant LULC classes in Kurdistan Region are grassland (13354 ,%28.7 km2), arable land (10 years) (11283 ,%24.3 km2), and open forests and shrubland (7483 ,%16.1 km2). The other significant LULC classes in the region include irrigated land (3425 ,%7.4 km2), dense forest (,%6.8 3180 km2), and uncultivated land (2811 ,%6 km2). Urban areas occupy only %1.9 (876 km2) of the total area, and water bodies and wetlands constitute %0.8 (389 km2) and %0.01 (4.1 km2) of the region, respectively.

The study findings have important implications for land management and conservation efforts in the region. The dominant land cover types, such as grasslands and arable land, are crucial for agriculture and livestock grazing, and their sustainable management is essential for the region's food security. The open forests and shrublands, which are also prominent, are important for biodiversity conservation and ecological services such as carbon sequestration in Kurdistan Region and Iraq. The identification of areas of dense forest and water bodies is also crucial for conservation planning and management.

In conclusion, this study provides a detailed LULC classification for Kurdistan Region, which can be used as a basis for land management and conservation planning. The study findings highlight the importance of sustainable management of grasslands and arable land for food security and the conservation of open forests and shrublands for biodiversity and ecological services.

C ontents

Executive summary

The land use and land cover (LULC) classification for the Kurdistan Region revealed a total area of 46,465.1 km2, of which %67.2 is covered by vegetation. Grasslands are the most extensive LULC class in the region, occupying %28.7 of the total area, followed by arable land (10 years) with %24.3 and open forests and shrubland with %16.1. Dense forest covers %6.8, while abandoned farmland accounts for %6 of the region's area. The urban areas, water bodies, wetlands, palm trees, and herbaceous and mangroves cover less than %2 of the total area each.

The classification revealed that the region has substantial natural resources, such as dense forests and grasslands, which play a significant role in the region's ecosystem services, including water regulation, carbon sequestration, and biodiversity conservation. The irrigated land and rainfed areas account for %7.4 and %2.3 of the region's area, respectively, supporting the agricultural sector, which is a crucial component of the region's economy. Based on the findings of the report, the following recommendations are made:

- Promote sustainable agricultural practices: Given the challenges faced by farmers in Kurdistan Region, there is a need to promote sustainable agricultural practices that can help in improving soil health, conserving water resources, and increasing crop yields. This is a paramount approach to improve the resilience of farming systems during clime change and water scarcity in many parts of the Kurdistan Region.
- Prioritise conservation of water bodies and natural vegetation: Despite occupying a small portion of the land area, surface water bodies and natural vegetation and grasslands are essential as water resources for agriculture, residential and industrial requirement, and critical habitats for biodiversity conservation, they are also precious natural resources in Kurdistan Region.

Therefore, there is a need to prioritise their conservation and management to protect the species that depend on them.

- Encourage afforestation and reforestation: With only about %22.9 of the land area covered by dense forests and open forests and shrublands, there is a need to sustain and encourage afforestation and reforestation to improve the country's ecosystem and protect against desertification. This can also assist in combating climate change consequences through improving carbon sequestration and increasing carbon stock in the region.
- Improve land use planning: The analysis of LULC classes provides useful information for land use planning, and it is recommended to use this information to guide the development and management of natural resources in each province and throughout all provinces of the Kurdistan Region of Iraq. A better understanding of the country's LULC categories can help in identifying areas that are suitable for different land uses and prevent the misuse of natural resources in the region.

The LULC classification provides valuable information for land-use planning, natural resource management, and environmental assessment in the region. It can help policymakers and planners in decision-making, identifying areas for conservation and restoration, and monitoring land-use changes over time. The classification can also provide insights into the spatial distribution of resources, supporting the development of strategies for sustainable land use and management in the region.

Introduction

The Earth's land cover is continuously changing due to a combination of human activities, such as urbanisation and agricultural expansion, and natural processes like flooding and bushfires (Yang et al., 2020). These changes have significant impacts on human life, and therefore, it is essential to have effective monitoring mechanisms in place for sustainable management and utilisation of natural resources such as forests, land, and water. With the development of satellite remote sensing technology, monitoring natural resources and human activities on the Earth's surface has been revolutionised, enabling regular monitoring of these resources (Foley et al., 2005). Information on land use and land cover, including forest cover, agronomic activities, and human activities, is crucial for developing strategies for land planning and management (Turner et al., 2007).

Land Use and Land Cover (LULC) change is a significant transformation that occurs on the Earth's surface, and it is noticeable to humans. LULC maps are essential tools that illustrate the interactions between the Earth's land and atmosphere, and the connections between human activities and the natural environment. Accurate geoinformation about these interactions is necessary for policymakers to establish sustainable development and planning policies (Mirmazloumi et al., 2022).

LULC is categorized into two primary categories, namely agricultural land use and built-up land, with areas having minimal human influence classified as "land cover," including water bodies, rangeland, and bare land. It is crucial to assess LULC change accurately at various geographic scales to achieve environmental conservation, resource management, land use planning, and sustainable development. Detailed plans based on LULC data are necessary to reduce the negative impacts of LULC change, which requires a rigorous and accurate assessment of the past and present effects of LULC modification. The quantification of the LULC change rate over time and the detection and explanation of natural and human causes of LULC change are essential in achieving these goals (Mirmazloumi et al., 2022).

Human demands, climate change, and environmental, cultural, and economic constraints have significantly influenced LULC change and the ability of biological systems to meet human needs at both the global and regional scales. Human activities such as urbanization, industrialization, mismanaged agricultural practices, deforestation, and overgrazing have directly and indirectly stressed natural behaviours and caused ecosystem degradation. This has led to heavy rainfall, extended drought, temperature rises, and flooding, which threaten the provision of human resources on earth. To manage available resources and monitor environmental changes, LULC data is needed to identify changes in the past and present and to plan for future sustainable development. LULC analysis is critical as sustainable development solutions depend on regional and local variables. Change detection and land use/land cover change analysis help to understand environmental changes and human-natural environment interactions. Various techniques and approaches, such as pixel-based image classification methods and machine learning techniques, have been developed and evaluated using remote sensing applications and geographic information systems to obtain precise and effective data on LULC trends and changes. High-resolution data such as Sentinel data are now available and used for classification.

The Kurdistan Region of Iraq (KRI) encountered various challenges in the early 1980s, such as political, social, economic, and security issues, including local conflicts, population displacement, the deployment of chemical weapons, wars with neighbouring countries (Iraq-Iran war 1988–1980 and Iraq-Kuwait war in 1991–1990) (Ulrichsen 2013). These events have been extensively studied and documented (Marr and Al-Marashi, 2018; Black 1993; Leezenberg 2012; Karsh 2009; Razoux 2015). In the following years until 2020, the region also experienced the US-Iraq conflict, the conflict between Kurdish and Iraqi forces against ISIS, and subsequent civilian displacement (World Bank 2015).

Additionally, natural factors such as climate change, flooding, and increasing temperatures have also impacted the LULC changes in the area over this time frame. This study aims to analyse the LULC changes in the region taking into account all of these factors.

2. Objectives and scope of the project

The global availability of relevant data on land cover and land use is evaluated, with the data typically being accessible as category maps generated using semi-automated algorithms that rely on remote sensing imagery as the primary input. Land cover pertains to the physical surface characteristics of land, including vegetation type and human-made structures. Land use, on the other hand, refers to the social and economic functions of land in fulfilling the demand for food, fibre, shelter, and natural resources. While the two concepts are interrelated, their connection is complicated. For example, a grassland land cover can support various land uses, such as livestock production and recreation, while a single land use, such as mixed farming, can comprise multiple cover types such as grassland, cultivated, and fallow/bare areas.

In this project, the difference between land cover and land use will be made when appropriate. Preferably, land cover and land use data from Earth observation sources will be used. The report outlines several characteristics of Earth observation-based data, including data collection procedures, reliability checks, geographical coverage, format, spatial resolution, temporal resolution, thematic resolution, and data source. These characteristics will be examined in depth for each dataset below. The discussion will start with the data collection and classification process, followed by a review of accuracy assessment results, when applicable, to evaluate the reliability of the data products.

Raster format resolution refers to the estimated size of the raster grid, which can be influenced by factors such as the cartographic scale of the source map, whereas in vector format, the resolution is typically determined by the imaging resolution of the sensor(s) used to capture the source observations and can impact the spatial resolution of land cover products. Temporal resolution pertains to the frequency with which datasets are produced and the years for which datasets are available. Thematic resolution pertains to the categories of land cover or socioeconomic use distinguished in the dataset, including the classification used. Data source pertains to the institution responsible for providing the dataset and how the data may be accessed.

3. Significance of Land Use and Land Cover (LULC) Maps

Land cover refers to the physical features on the surface of the earth, while land use refers to the human activities and purposes for which the land is utilized. Land Use and Land Cover (LULC) is a method of categorizing and analysing the physical and human aspects of land within a specific time frame. Understanding both land use and land cover is important for land management, planning and decision-making.

3.1. Why is LULC Important for Planning?

Socio-economic surveys are crucial for understanding and planning a society's growth, and they include both spatial and non-spatial datasets. LULC maps, which show how land is used within an area, play an essential role in sustainable development planning, monitoring, and management at various levels. These maps can help authorities generate planning models and prevent unregulated urban development. Additionally, they provide valuable information about the environment and ecosystem and can be used to study the impact of human activities. By monitoring changes in LULC over time, authorities can identify patterns that may require intervention and develop strategies for mitigating negative effects. Overall, LULC maps are an important tool for promoting sustainable development and protecting the environment by providing policymakers and planners with detailed information about land use patterns.

Essentially, land cover classification mapping provides planners with a simple way to know what they have, how much they have, and where it is located. The metadata allows a user to pick an area and find out percentage-wise what type of land cover is there.

When the Ministry of Planning possesses statistical data on land resources, planning decisions become more informed, enabling a better understanding of the overall landscape and facilitating the incorporation of diverse requirements, rather than focusing solely on individual considerations. This data serves several important purposes:

It enables us to ascertain the various types of land classes that exist.

b) It provides information regarding the specific locations of each land class.

c) It quantifies the proportion of each land class within the overall resource pool.

d) By possessing this knowledge, the Ministry of Planning can make well-informed decisions and develop effective strategies that consider the diverse needs and demands of multiple sectors involved.

3.2. Value of Land Cover Mapping

The production of accurate and timely land use and land cover (LULC) maps is essential for a wide range of applications, including disaster and hazard monitoring, urban and regional planning, natural resources and environmental and agronomic management, and food security. These maps play a critical role in addressing significant global challenges such as population migration, urbanization, biodiversity loss, land degradation, natural disasters, and climate change. Therefore, it is imperative to produce LULC maps that are precise and up-to-date. In summary, LULC maps are crucial for monitoring and quantifying the below aspects.

Environmental – habitat, water/air quality, carbon storage & sequestration

b) Economic – heating & cooling, infrastructure & design, increased property values

c) Social - greening initiatives, sense of community, & public health

d) Land conversion- Land conversion refers to the process of changing the use or purpose of a piece of land from one form to another. It involves transforming land from its existing state, such as agricultural land, forested areas, or natural habitats, into a different use, such as urban development, industrial sites, or infrastructure projects

e) Air- carbon market, non-attainment (ozone), quality of life, climate change modelling

f) Water-supply, conservation, watershed protection, modelling tools

g) Modelling, Research & Policy- future land use, program effectiveness, monitoring, outreach, education, economic development.

3.3. Land Cover Classification Mapping using Google Earth Engine platform

Google Earth Engine (GEE) is a cloud-based platform that allows users to analyse geospatial data at scale. GEE is flexible, providing users with a variety of tools and functions that can be customised to meet the specific needs of their project. The platform's open nature has made geospatial analysis accessible to a wider audience. It is free to use and has extensive documentation, making it easy for researchers, students, and practitioners to get started with geospatial analysis. GEE's ability to handle large amounts of data quickly and efficiently makes it an ideal tool for projects that require the processing of large geospatial datasets.

For this project, Land Cover Classification Mapping is created by combining geospatial features from Google Earth Engine (GEE) platform. It is a significantly faster and inexpensive method of mapping ground features. Google Earth Engine offers a planetary-scale platform for Earth science data and research. Earth Engine Explorer (EE Explorer) is a lightweight geospatial image data viewer that has access to a broad collection of global and regional datasets from the Earth Engine Data Catalogue. It enables rapid data viewing with the ability to zoom and pan anywhere on Earth, adjust display settings, and layer data to study change over time. The goals of this project are to use EE Explorer for LULC mapping, to discover and see new data, and to provide a starting place to visualise how our knowledge of land use classes may be improved.

3.4. The Digital Image Classification & Analysis to Detect Features

The accuracy of land-cover information obtained from remote sensing data depends greatly on the selection of appropriate classification algorithms and features extracted from the satellite data. Different classification algorithms, such as simple statistical classifiers and machine learning classifiers, are used depending on the type and source of the satellite imagery. Spectral indices, such as the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil Adjusted Vegetation Index (SAVI) for vegetation, Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) (Xu, 2006) for open water surface, Normalized Difference Built-up Index (NDBI) and Index-based Built-up Index (IBI) for urban built-up areas, are commonly used to extract specific land-cover information. With the availability of high-resolution satellite imagery, such as Sentinel-2, new land-cover products have been developed with higher accuracy. For instance, the latest FROM-GLC10 product was created by training a random forest classifier on Sentinel-2 reflectance bands and a series of spectral indices. Image classification and analysis to detect land features are based on the following properties.

1 - Pattern Recognition
2 - Spectral Content
3 - Spatial Context
4 - Texture

Note: Once imagery is analysed, it is compared with selected ground-truth samples to evaluate accuracy. Then the software is adjusted to compensate for inconsistencies, ensuring a final product whose accuracy is comparable with traditional, more costly and time-consuming methods.

Note: The process of automated feature extraction, including ground truth sampling, yields fast results, the accuracy of which is on par with that of traditional manual digitization and, in some cases, better.

4. Study area and methods of LULC classification

4.1. Study area

The study area selected for this research is the Kurdistan Region of Iraq (KRI), specifically the governorates of Erbil, Duhok, Sulaymaniyah, and Halabja. The KRI is located in the northern part of Iraq and shares borders with Syria, Iran, and Turkey (Figure 1).
It covers a significant portion of the entire Iraq territory, spanning approximately 46,000 km2 and situated between latitudes 34° and 37° and longitudes 41° and 46° (Gaznayee et al., 2022). The KRI is characterized by a diverse physical environment, with elevations ranging from 88 meters in the southern parts to over 3603 meters (such as Halgurd and Zagros Mountain) in the north and northeast.

The climate of the KRI is Mediterranean, with cold and rainy winters and hot and dry summers. The precipitation rates in the region vary depending on the area's location. The northern and mountainous parts of the KRI experience high precipitation rates, while the southern plains are generally dry (Razvanchy 2018; Karim and Amin, 2018). Precipitation usually occurs between October and May, with the southwestern parts receiving around 350 mm of rainfall, while the northern and north-eastern parts receive over 1200 mm (Karim and Amin, 2018). The KRI is divided into three different zones based on the rainfall amounts: assured rainfall zone (>500 mm), semi-assured rainfall zone (500-350 mm), and unassured rainfall zone (<350 mm). The KRI's mean daily temperature ranges from 5 °C in winter to 30 °C in summer, with temperatures in the southern parts reaching up to 50 °C in the daytime. Around %37.2 of the KRI's agricultural lands are rain-fed, with the remaining lands using irrigation methods. Furthermore, the division of the KRI into three different zones based on rainfall amounts has important implications for water management and agriculture. The areas with assured and semi-assured rainfall may be more suitable for rain-fed agriculture, while the unassured rainfall zone may require more dependence on irrigation methods to support crop production. Managing water resources and implementing appropriate irrigation techniques can be crucial for ensuring food security and sustaining livelihoods in the Kurdistan region.

Overall, understanding the physical environment and climate of Kurdistan is essential for addressing various ecological and societal challenges facing the region. This knowledge can help inform policies and strategies for managing natural resources, promoting sustainable agriculture, and mitigating the impacts of climate change.

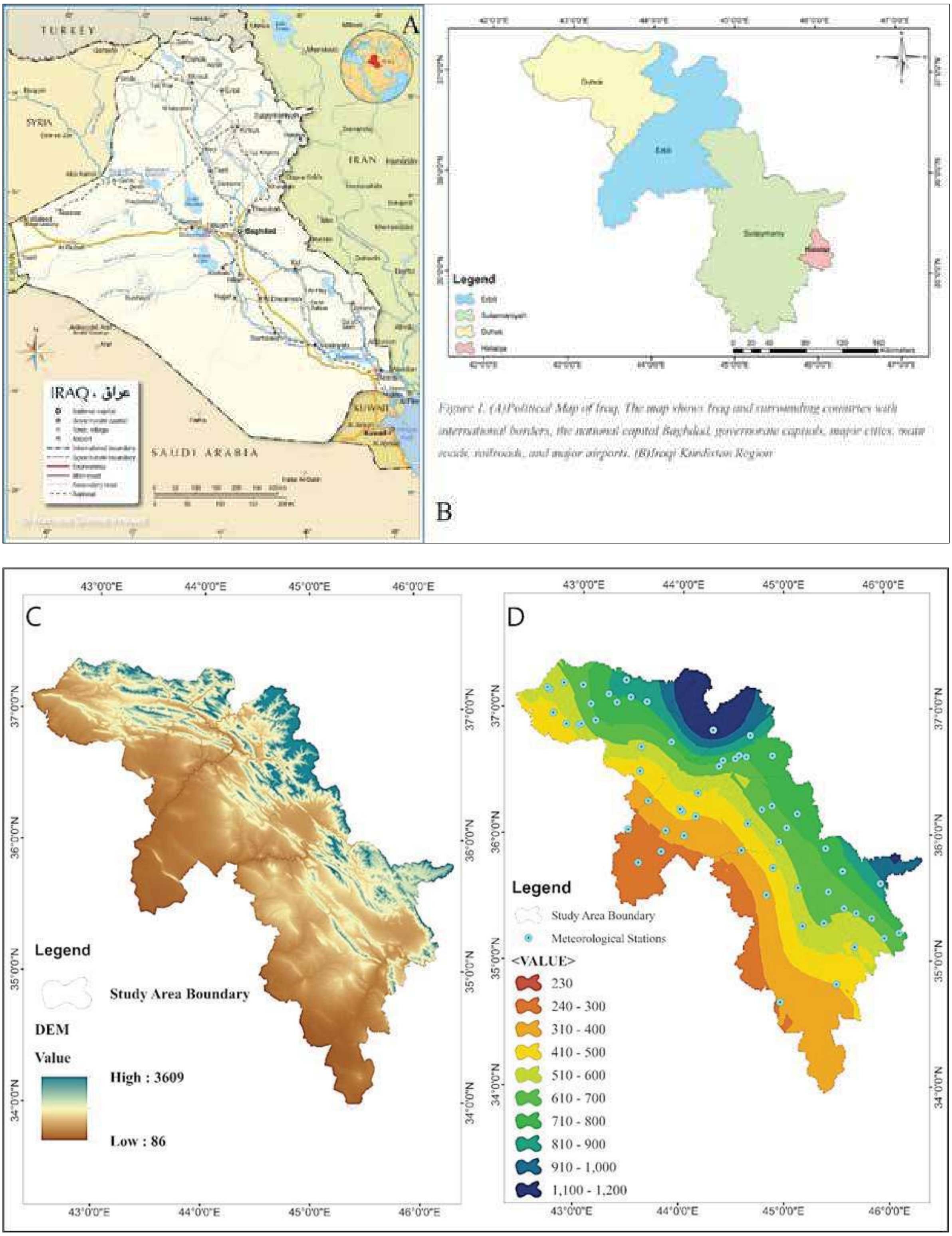


Figure 1: **(A)** Political Map of Iraq, the map shows Iraq and surrounding countries with international borders. **(B)** Location map of the study area in the KRI, **(C)** the elevation map of the study area, and **(D)** the average of 24 years' precipitation map(mm) of KRI

4.2. Provinces in Kurdistan Region of Iraq

The Kurdistan Region is an autonomous region in northern Iraq, which is divided into four provinces or governorates. These provinces are Erbil, Sulaymaniyah, Duhok and Halabja provinces. Erbil province is the largest and most populated province in the Kurdistan Region, with its capital being the city of Erbil. It is located in the eastern part of the region and is known for its historical landmarks and cultural sites. Sulaymaniyah province is located in the south-eastern part of the Kurdistan Region and its capital is the city of Sulaymaniyah. It is known for its scenic mountains, cultural attractions, and historic landmarks. Duhok Province is located in the north-western part of the Kurdistan Region and its capital is the city of Duhok. It is known for its beautiful natural scenery, historical sites, and religious shrines. And finally, Halabja Province is located in the eastern part of the Kurdistan Region and its capital is the city of Halabja. It is known for its beautiful landscapes, historical landmarks, and cultural attractions. The governorates are further divided into districts and sub-districts.

4.3. Erbil Province

Erbil Governorate, situated in the Kurdistan Region, is a major economic centre and the capital of Kurdistan. It has a population of around 2.9 million people and experiences a semi-arid continental climate, with hot, dry summers and cold, wet winters. Rainfall occurs mostly in October and November, with an annual average of 543 mm. The governorate is bordered by the Tigris and Little Zab rivers in the south and the Zagros Mountain range in the northeast.

The area has a rich history and cultural heritage, with archaeological sites like the Citadel of Erbil, a UNESCO World Heritage site, dating back to ancient times. Erbil Governorate is home to various communities, including Kurdish, Arab, Turkmen, and Assyrian.

The economy of Erbil is diverse, with industries like oil and gas, agriculture, tourism, and construction contributing to its growth. The governorate has

various significant infrastructure projects underway, such as the expansion of Erbil International Airport and the Erbil-Baghdad highway project.
Overall, Erbil Governorate is an essential and dynamic region within Kurdistan, with a thriving economy and a rich cultural heritage.

4.4. Al-Sulaymaniyah Province

Sulaymaniyah, also spelled Slemani, is situated in the eastern part of the Kurdistan Region in Iraq, and it is the second-largest city in the region after Erbil. It has a population of around 1.6 million people. The city is surrounded by mountains and hills such as the Azmar, Goizha, Qaiwan, Baranan, and Tasluja ranges. These natural features make Sulaymaniyah an attractive destination for visitors. Sulaymaniyah has a semi-arid climate with hot and dry summers and cold and wet winters. The average annual rainfall is 700mm, and the temperature can reach up to 45°C (in summer and drop below freezing in winter.

The Dam of Dokan, located approximately 60 km northwest of Sulaymaniyah, is one of Iraq's largest dams built on the Minor Zab River to produce hydroelectric power and regulate the river's flow. It has become a popular tourist destination offering various water-based activities, including fishing and boating.

4.5. Duhok Province

Duhok Governorate is situated in the autonomous Kurdistan Region of Iraq and has Duhok city as its administrative centre. The region's location near the Turkey-Syria-Iraq border and its mountainous terrain make it a crucial strategic location. The estimated population of Duhok province is approximately 1,292,535 people. It shares borders with Turkey and Syria and is the northernmost governorate in Iraq. The topography of the region is mostly made up of mountain slopes, hills, and valleys, with mountain ranges surrounding it on three sides.

On the west side of the governorate lies the Sumail plain. The elevation of Duhok district ranges from 334 to 1212 meters above sea level.

Duhok Governorate experiences a climate similar to that of the surrounding areas, with hot and dry summers and mild winters. Precipitation is typically limited to the winter months and averages around 700 mm per year.

4.6. Halabja Province

Halabja Governorate is a region located in the Kurdistan Region of Iraq, which was established in 2014 after separating from the Al-Sulaymaniyah Governorate. It is the least populated governorate in Iraq and has its capital in the city of Halabja, approximately 206,790. The city is situated approximately 240 km northeast of Baghdad and near the Iranian border. It lies at the base of the greater Hewraman region, surrounded by the Hawraman and Shnrwe ranges in the northeast, the Balambo range in the south, and the Sirwan river in the west. Halabja experiences a hot-summer Mediterranean climate with hot summers and cool, wet winters. The average annual rainfall in the area is 660mm.

4.7. Methodology of Lan
d Use Land Cover from Sentinel Platform

The major objectives of this study are to map LULCs and to detect and analyse LULC changes in the study area during the last three decades. We developed a 15-class scheme for the study area.

The methodology of this study involves several key phases:

1. Data pre-processing,
2. Image segmentation,
3. Scheme of classification,
4. Image classification,
5. Select validation data samples,
6. Accuracy Assessment,

7. LULC mapping, and
8. Change detection, with several sub-step.

The layer displays a map of land use/land cover (LULC). The map is derived from Sentinel-2 imagery at 10m resolution (Figure 2). It is a composite of LULC predictions for 8 classes throughout the year in order to generate a representative snapshot of 2022. The underlying deep learning model uses 6 bands of Sentinel-2 surface reflectance data: visible blue, green, red, near-infrared, and two shortwave infrared bands. To create the final map, the model is run on multiple dates of imagery throughout the year, and the outputs are composited into a final representative map of 2022.

4.8. Class definitions

Urban: Human-made structures; office buildings, and residential housing; examples: houses, dense villages/towns/cities, and asphalt, streets, roads and highways. "Urban" generally refers to anything related to cities or urban areas, as opposed to rural areas. Urban areas are typically characterized by variety of built environments, complex transportation systems.
Water body: where water was predominantly present throughout the year; may not cover areas with sporadic or ephemeral water; contains little to no sparse vegetation, no rock outcrop nor built-up features like docks; examples: rivers, ponds, and lakes. A water body refers to any significant accumulation of water, such as an ocean, a lake, a river, a stream, a pond, a wetland, or any other natural or artificial body of water. Water bodies play a critical role in the earth's ecosystem, and they are essential for supporting a variety of plant and animal species, as well as for human use. Water bodies are typically classified according to their size, shape, location, and water quality. For example, oceans are the largest water bodies on earth, covering more than %70 of the planet's surface. Lakes, on the other hand, are generally smaller and are often located inland, while rivers and streams are

flowing bodies of water that transport water from one location to another. Water bodies can also be classified as freshwater or saltwater, depending on their salinity levels. Freshwater bodies, such as lakes and rivers, contain very low levels of dissolved salts, while saltwater bodies, such as oceans, contain high levels of salt.

Wetland: Refers to lands that have a distinct ecosystem that is flooded or saturated by water, either permanently or seasonally. Wetlands are areas of land that are covered by water, either seasonally or permanently. They are characterized by the presence of water-loving plants, known as hydrophytes, and soils that are saturated with water for at least part of the year. Wetlands provide important habitat for a wide variety of plant and animal species, including migratory birds, fish, amphibians, and reptiles. They also serve a variety of ecological functions, such as filtering water, reducing flood risk, and storing carbon.

Dense Forests: Dense forests refer to forest areas that have a high concentration of trees and vegetation, creating a thick and lush canopy. These forests are characterized by their dense tree cover, which limits sunlight penetration to the forest floor, resulting in lower understory vegetation growth. The trees in dense forests are often tall and closely spaced, with little open space between them. They provide essential habitat for a wide variety of plant and animal species, and play an important role in regulating the earth's climate by storing carbon and producing oxygen. Dense forests also provide numerous benefits to human society, such as timber, non-timber forest products, and recreational opportunities.

Open Forests and Shrubland: Open forests and shrublands are types of vegetation that occur in areas where tree cover is less dense than in dense forests. They are characterized by lower tree densities and more open spaces between trees, allowing more sunlight to penetrate the forest floor and support a more diverse understory vegetation. Open forests typically have trees that are widely spaced and shorter in stature than those in dense forests, while shrublands are dominated by shrubs and other low-growing plants. These types of vegetation can occur in a variety of biomes, including grasslands, savannas, and woodlands, and are often found in regions with seasonal climates or where natural disturbances such as fires or grazing by large herbivores have occurred. Open forests and shrublands provide important habitats for a variety of plant and animal species, and they are also used for a range of human activities such as grazing livestock and recreation. However, they are also vulnerable to environment al pressures such as climate change, habitat loss, and invasive species.

Palm Tree: Refers to lands cultivated with palm trees, including palm trees in all ages and irrigated.

Irrigated land: Irrigated land is a type of cultivated land that requires artificial watering during the growing season due to a lack of natural precipitation or specific plant water requirements. Irrigation is used in various agricultural settings, and different methods of water delivery can be used, such as surface irrigation, sprinkler systems, or centre pivoted irrigation. Irrigated agriculture has been practiced for a long time and has been instrumental in increasing crop yields and food production in regions with limited rainfall. However, irrigation can also have negative environmental consequences, such as soil salinization, groundwater depletion, and water pollution. It is essential to use sustainable management practices and technologies to ensure the long-term sustainability of irrigated agriculture and the ecosystems it supports.

Rainfed: Refers to agricultural lands that only reply on precipitation (often rainfall) to grow crops in particular cereal crops and legumes. In rainfed agriculture, the timing and amount of rainfall are crucial factors that determine crop yield and quality. The management practices used in rainfed agriculture are often different from those used in irrigated agriculture, as farmers must adapt to the natural variability of rainfall and soil moisture. Rainfed agriculture is prevalent in many regions of the world, particularly in areas where water resources are limited or unreliable. However, it can also be affected by climate change and variability, leading to droughts and other weather-related risks that can impact crop yields and food security.

Arable land (5 years): Arable land is any land capable of being ploughed and used to grow crops at least once within the last 5 years. This definition takes into account the recent history of the land's use and its ability to support agricultural activities. Arable land can vary in quality and suitability for crop production depending on factors such as soil type, topography, and climate. In some regions, arable land is scarce, and there are competing demands for its use, such as for urbanization or natural resource extraction. The sustainable management of arable land is critical for food security and the livelihoods of farmers and rural communities worldwide.

Arable land (10 years): Arable land is any land capable of being ploughed and used to grow crops at least once within the last 10 years.

Grassland: Open areas covered in homogeneous grasses with little to no taller vegetation; wild cereals and grasses with no obvious human plotting (i.e., not a plotted field); examples: natural meadows and fields with sparse to no tree cover, open soil with few to no trees, parks/lawns, pastures. Grassland refers to an area dominated by grasses, with little to no tall vegetation or trees. It can include a variety of grass species, and it may also contain some wildflowers or other non-woody plants. Grasslands may be natural, with no obvious signs of human intervention or plotting, or they may be managed for agricultural or recreational purposes. Some grasslands are characterized by more moisture and higher productivity, while others are drier and less productive. The vegetation in grasslands is typically adapted to fire, grazing, and other disturbances, and these disturbances can help maintain the health and diversity of the grassland ecosystem. Examples of grasslands include natural meadows, fields with sparse or no tree cover, open soil areas with few or no trees, parks and lawns, and pastures. Grasslands are found on every continent except Antarctica and play an important role in supporting biodiversity, carbon storage, and other ecosystem services. However, like other ecosystems, grasslands can be threatened by habitat loss, degradation, and other human activities.

Herbaceous and Mangrove: Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present in salt, brackish, or freshwater. Herbaceous lands are dominated by herbaceous vegetation, which consists of non-woody plants such as grasses, sedges, and forbs. These lands can be found in both freshwater and saltwater environments, and they can support a variety of wildlife, including fish, amphibians, and waterfowl. Mangrove lands, on the other hand, are characterized by the presence of mangrove trees and other woody vegetation that are adapted to saline or brackish water conditions. Both herbaceous and mangrove lands are important ecosystems that provide a range of ecosystem services, including carbon storage, water purification, and habitat for wildlife. However, these ecosystems can also be threatened by human activities, such as coastal development, pollution, and overfishing. Conservation and management efforts are necessary to ensure the long-term sustainability of these ecosystems and the benefits they provide.

Desertificated Land: Refers to the lands with sandy soil with no vegetation. These lands usually have an extreme climate with almost no or a few millimetres of rain. Desertification refers to the degradation of land in arid, semi-arid, and dry sub-humid areas, resulting in the loss of vegetation, soil fertility, and biodiversity. This can occur due to a variety of factors, including climate change, overgrazing, deforestation, and inappropriate agricultural practices. Desertified lands may have sandy soils with little to no vegetation, but they can also have other soil types and some vegetation cover. The defining characteristic of desertified land is that it has experienced significant degradation, leading to reduced productivity and ecological function. The climate in these areas can be extreme, with limited rainfall, high temperatures, and strong winds. Desertification is a serious global issue that can lead to food insecurity, poverty, and environmental degradation. Efforts to combat desertification include sustainable land management practices, reforestation, and water conservation measures, among others.

Rock surface: Bare Ground Areas of rock with very sparse to no vegetation for the entire year; large areas of land no to little vegetation; examples: exposed rock or rocky soil; large homogeneous impervious surfaces including parking structures, Rock surfaces are typically inhospitable to plant life due to their lack of soil and water retention capacity. However, some plants, such as lichens and mosses, can colonize and grow on these surfaces. Rock surfaces are important for a variety of ecological and geological processes, such as erosion and weathering, and can serve as habitats for specialized organisms. It's worth noting that large areas of impervious surfaces, like parking structures and roads, are typically classified as urban or built-up areas rather than rock surfaces. However, some classification systems may include impervious surfaces as a subset of rock surfaces.

Uncultivated (Abandoned farmland): Refers to the open land that has no buildings and is not being used and cultivated, often bare lands, it can be used for several purposes, particularly for residential, agricultural and industrial use. Uncultivated land, also known as abandoned farmland, refers to agricultural land that is no longer being used for farming and has been left to grow wild. This can occur due to a variety of reasons, such as economic factors, changes in land ownership, or environmental degradation. Abandoned farmland can have both positive and negative impacts on the environment. On one hand, it can provide habitat for wildlife and promote biodiversity, as well

as allow for natural regeneration of soil and vegetation. On the other hand, it can contribute to the spread of invasive species and increase the risk of wildfires, especially in areas with accumulated dry biomass.
In some cases, abandoned farmland may be suitable for reforestation or restoration projects, which can help to mitigate environmental impacts and promote sustainable land use.

4.9. Data Collection

There are different remote sensing-based satellite data freely available for downloading and further analysis. Open-source tools used for analysing this data, such as Google Earth Engine, QGIS and GIS for this work. Satellite images were analysed from the Sentinel 2-A, and B satellites in this Project (Figure 2). The project used a variety of climatic and geographic data. The required data were collected from both secondary and primary resources.

4.10.Sentinel-1

The Sentinel-1 mission operates a dual-polarization C-band synthetic aperture radar (SAR) imaging during day and night, enabling them to acquire imagery regardless of the weather. In 12 days, Sentinel-1 revisits the same coverage as Sentinel-2, while the repeat cycle is 6 days over Europe. The GEE database provides processed Sentinel-1 Ground Range Detected (GRD) scenes in three instrument modes of IW (Interferometric Wide Swath), EW (Extra Wide Swath), and SM (Strip Map), which contain either one of three spatial resolutions (25 ,10 or 40 m) and one or two out of four band combinations (Vertical-Vertical (VV): single co-polarization, Horizontal-Horizontal (HH): single co-polarization, VV + VH: dual-band cross-polarization, and HH + HV: dual-band cross-polarization), depending on the instrument’s polarization settings. The Sentinel-1 GRD products were already rectified and converted to the backscattering coefficient (σ˚, dB). They underwent five steps: (1) orbit correction, (2) GRD border noise removal, (3) thermal noise removal, (4) radiometric calibration, and (5) terrain correction. For this work, Sentinel-1 images were used to cover the project area.

4.11. Sentinel-2

The Copernicus Sentinel-2 systematically covers more than %90 of the world, including the Mediterranean Sea; the twin satellites of Sentinel-2 regularly revisit all continental land surfaces with a high revisit frequency of five days. The optical instrument payload of Sentinel-2 consists of 13 spectral bands: four bands at a 10 m spatial resolution (Blue (2), Green (3), Red (4), and NIR (8)), six bands at 20 m (Red edge(6) 2 ,(5) 1, and (7) 3, Narrow Near Infrared (8A), SWIR(11) 1, and SWIR(12) 2), and three bands at 60 m (Aerosols (1), Water vapor (9), and Cloud mask (10)) spatial resolution. In this work, 12 images at bands 4 ,3 ,2, and 8 from 2022 were used.

4.12. ASTER and SRTM

Digital Elevation Model (DEM) data was also incorporated with three other remote sensing data sources to enhance the final classification results (Figure 2). A DEM is a raster-based data source in which each pixel value represents the corresponding altitude above sea level, which is considered a primary attribute of the Earth's surface. In this paper, DEM data from two remote sensing sources were employed. The first DEM has been derived from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The ASTER instrument has the capability of acquiring images through its back-ward-looking telescope and thus can provide along-track stereo pairs. These pairs are processed using standard photogrammetric approaches and a detailed camera model to produce DEM data with approximately 30 m spatial resolution.

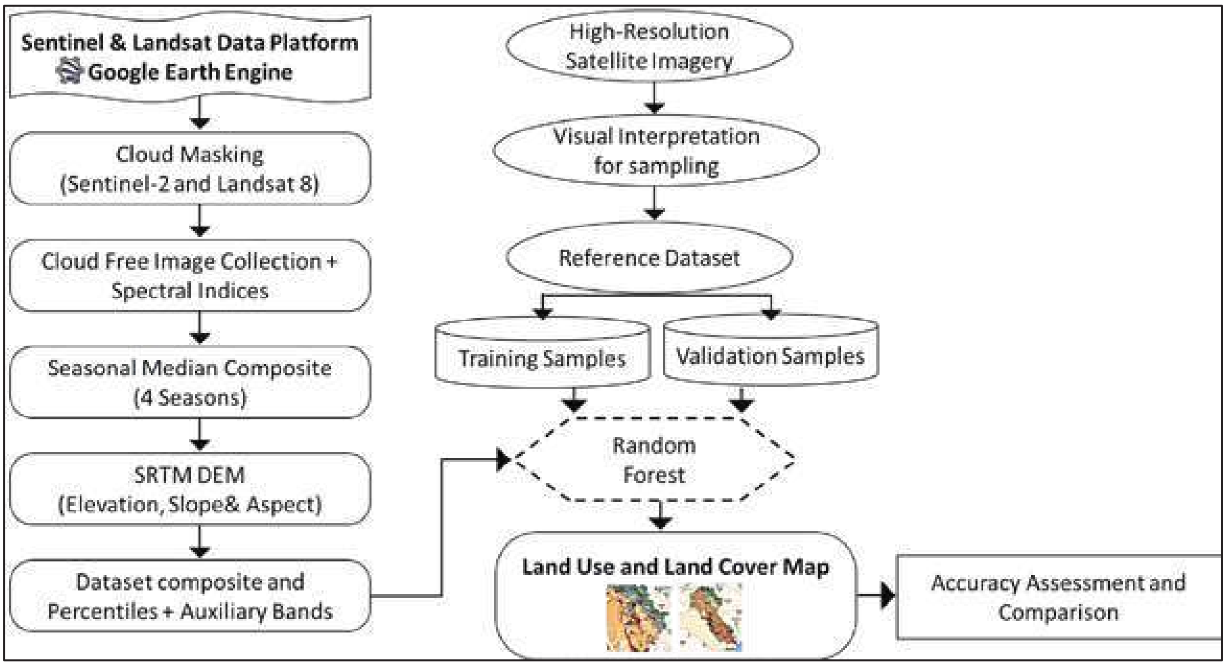


Figure 2: The flow-chart of methodology implemented for land use and land cover (LULC) mapping

4.13. Remotely Sensed and Field Data

Satellite data products, like meteorological data, play an important role in remote sensing since they can be remotely and easily accessible from open-source sites, making them perfect for large-scale LCLU evaluations.

For this project, data was obtained via remote sensing and Field data. Sentinel-2 images will be utilised to assess the LULC, anticipating obtaining as many as possible satellite images for more precise calculations.

The required images will be utilised for the period 2018, and 2022 from the United States Geological Survey (USGS) website and Copernicus Open Access Hub <https://earthexplorer.usgs.gov/> and <https://scihub.copernicus.eu/dhus/#/home>.

5. Results:

5.1. Land use and land cover distribution in Kurdistan Region of Iraq

The land use and land cover (LULC) classes of the Kurdistan Region of Iraq (KRI) provide valuable information on the distribution of different types of ecosystems and land uses across the region. The LULC map portrays a comprehensive list of the LULC classes in the Kurdistan region, along with their corresponding areas in square kilometres (km2) and percentages of the total area with an overall accuracy of %95 (Figure 3, Figure 4 and Table 1). Fifteen classes were identified for KRI including urban areas, water bodies, wetlands, dense forests, open forests and shrubland, palm trees, irrigated land, rainfed land, arable land, grassland, herbaceous and mangrove, desertificated land, rock surface, and uncultivated/abandoned farmland. Grassland, Arable land (10 years), open forest and shrublands occupy the largest area of KRI, followed by irrigated lands, dense forest, and uncultivated (Abandoned farmland).

The least occupy KRI lands are wetlands, water bodies, rainfed lands, and urban and desertificated lands.The size and distribution of these LULC classes have important implications for various aspects of life in the region, including agriculture, biodiversity, water resources, and urban planning.

Understanding the LULC classes of the Kurdistan region is crucial for sustainable development and effective natural resource management in the region. The most important LULC classes in the region, based on their percentage coverage, are:

- Grassland - covering %28.7 (13354 km2) of the total area, indicating the region's significant pasture and grazing land. This LULC class is essential for supporting livestock and wildlife in the region.
- Arable land (10 years) - covering %24.3 (~11283 km2) of the total area, indicating the significant role of agriculture in the region's economy. This LULC class includes croplands that have been used within the last ten years.

- Open forests and shrubland - covering %16.1 (~7483 km2) of the total area, indicating the importance of forests and woodlands in the region. This LULC class includes woodlands, forests, and shrublands that are not dense.
- Dense forest- covering %6.8 (3180 km2) of the total area of the region. This class includes major trees growing in the mountains of the Kurdistan Region such as oak trees. The oak tree (Quercus aegilops) comprises ~%70 of the oak forests in the Kurdistan region.

The LULC map of the Kurdistan region provides insights into the agricultural LULC classes in the region. There are four important LULC classes that represent agricultural lands, namely Arable land (5 years), Arable land (10 years), Irrigated lands, Rainfed lands and Grasslands.

Arable land (5 years) LULC class covers %3.5 of the total area in the region, which is equivalent to 1621.8 km2. This class refers to croplands that have been used within the last five years. It is generally used for growing cereal crops, such as wheat, barley, and maize, as well as other cash crops, such as vegetables and fruits. Arable land (10 years) LULC class covers %24.3 of the total area in the region, which is equivalent to 11283.4 km2. This class refers to croplands that have been used within the last ten years. These lands are usually not frequently used for agriculture and may have higher levels of inputs such as irrigation, fertilizers, and pesticides and/ or limited precipitation in some years of the last 10 years. Arable land (10 years) is used for growing various crops, including wheat, barley, rice, corn, sunflower, fruits, and vegetables.

Irrigated land LULC class covers %7.4 of the total area in the region, which is equivalent to 3425 km2. Irrigated land is land that is artificially supplied with water through irrigation systems such as canals, sprinklers, or drip irrigation and etc using either surface water or ground water (extracted from onsite wells) and/or both water resources. It is typically used for growing crops such as rice, vegetables, and fruits.

Rainfed LULC class covers %2.3 of the total area in the region, which is equivalent to 1060.1 km2. Rainfed land is land that relies merely on natural rainfall for crop growth in areas where sufficient precipitation is guaranteed to grow crops. These lands are typically used for growing cereal crops such as wheat and barley.

Grasslands can also be used for agricultural purposes, particularly for livestock grazing and hay production in the Kurdistan region. The grassland land use/land cover (LULC) class covers the largest are of the region (%28.7 of the total area), which is equivalent to 13354.1 km2. This vast area of grassland provides significant opportunities for livestock grazing and hay production, which are important components of the region's agricultural economy.

The agricultural LULC classes in the region play a vital role in providing food and income for the population and supporting the economy. However, inappropriate, and unsustainable agricultural practices can lead to soil degradation, water depletion, and other potential environmental issues. Therefore, proper management practices such as conservation agriculture, crop rotation and other modern agricultural practices are essential to ensure the sustainability of these agronomic LULC classes.

The Urban LULC class in KRI covers %1.9 of the total area, which is equivalent to 875.7 km2. This class represents areas that are highly developed and densely populated, including cities, towns, and industrial areas as well as main roads inner-city motorways and highways that connect KRI provinces. Urban areas in the KRI are centres of economic activity, housing, and infrastructure development. The rapid expansion of urban areas in recent years (in particular after 2003) has led to the development of new housing and commercial areas, as well as infrastructure such as roads, bridges, and transportation networks.

The water body category in the Kurdistan Region encompasses a variety of surface water bodies, such as rivers, streams, lakes, ponds, and reservoirs. These water bodies cover approximately 38876.9 km2, which is equivalent to %0.8 of the region's total area. They are essential in meeting the water needs of the region, including irrigation, domestic, and industrial uses. Additionally, they support aquatic flora and fauna and contribute to the region's biodiversity.
The Kurdistan Region is home to several water bodies, including rivers, lakes, and reservoirs. Some of the major water bodies in the region are:

Tigris River: The Tigris River is one of the two great rivers of Mesopotamia, and it flows through the Kurdistan Region. The river is approximately 1,900 km2 long and is the primary source of water for the region.
Lake Dukan: Lake Dukan is a reservoir located in Sulaymaniyah Governorate in the Kurdistan Region. It was created in the 1950s by the construction of the Dukan Dam on the Little Zab River. The lake provides water for irrigation, drinking, and electricity generation.

Lake Darbandikhan: Lake Darbandikhan is a reservoir located in Sulaymaniyah Governorate in the Kurdistan Region. It was created in the 1960s by the construction of the Darbandikhan Dam on the Sirwan River. The lake provides water for irrigation, drinking, and electricity generation.
Little Zab River: The Little Zab River is a tributary of the Tigris River, and it flows through the Kurdistan Region. The river is approximately 400 km long and is an important source of water for the region.

These water bodies play a crucial role in the economy and livelihoods of the people in the Kurdistan Region, providing water for agriculture, drinking, and electricity generation.

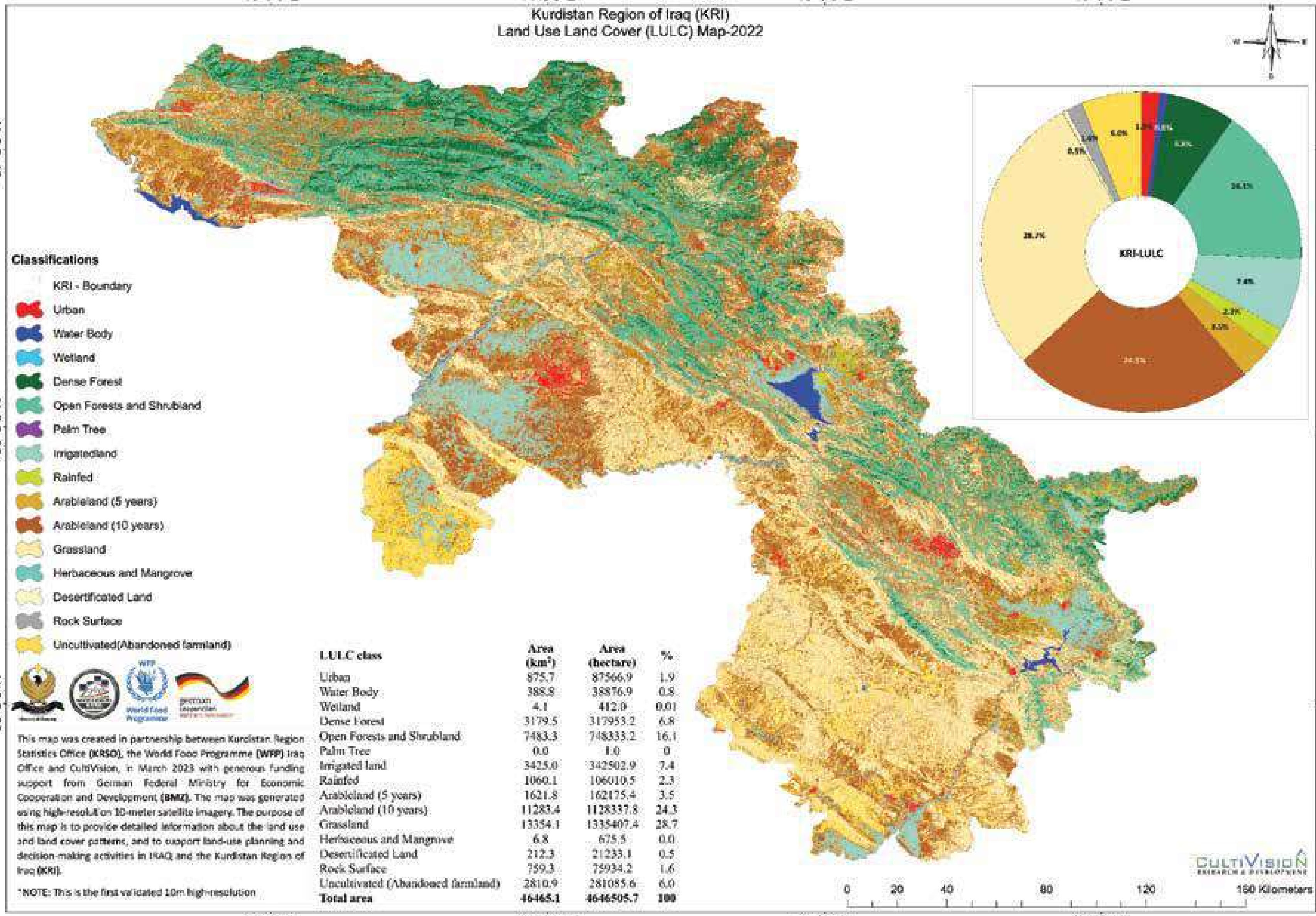
The amount of rainfall that used to fall annually sizes the watershed area of the river. Some of this volume is lost, depending on the type of soil, some of it evaporates due to temperature, lack of vegetation cover or soil moisture. The water of the Kurdistan region is collected in the river basin of the KRI rivers. Area and volume are both measurements used to describe water bodies, but they refer to different characteristics of the body of water.

Area refers to the surface area of the water body, which is the amount of space it covers when viewed from above. This is a two-dimensional measurement, and it is typically expressed in units such as square meters or square kilometers. The area of a water body is important for understanding its extent and for calculating things like the amount of solar radiation that it absorbs.

Volume, on the other hand, refers to the amount of water that is contained within the water body. This is a three-dimensional measurement, and it is typically expressed in units such as cubic meters or cubic kilometers. The volume of a water body is important for understanding its capacity to store water and for calculating things like the amount of water that can be withdrawn from it.

To calculate the volume of a water body, we need to know its area as well as its depth. Once we know the area and the average depth of the water body, we can use the formula “volume = area x depth” to calculate the total volume of water contained within the water body.

In summary, the main difference between area and volume of a water body is that the area refers to the surface area of the water body while volume refers to the amount of water contained within it.



LULC class	Area (km²)	Area (hectare)	%
Urban	875.7	87566.9	1.9
Water Body	388.8	38876.9	0.8
Wetland	4.1	412.0	0.01
Dense Forest	3179.5	317953.2	6.8
Open Forests and Shrubland	7483.3	748333.2	16.1
Palm Tree	0.0	1.0	0
Irrigated land	3425.0	342502.9	7.4
Rainfed	1060.1	106010.5	2.3
Arableland (5 years)	1621.8	162175.4	3.5
Arableland (10 years)	11283.4	1128337.8	24.3
Grassland	13354.1	1335407.4	28.7
Herbaceous and Mangrove	6.8	675.5	0.0
Desertificated Land	212.3	21233.1	0.5
Rock Surface	759.3	75934.2	1.6
Uncultivated (Abandoned farmland)	2810.9	281085.6	6.0
Total area	**46465.1**	**4646505.7**	**100**

Figure 3: The spatial distribution of land use and land cover of the Kurdistan Region of Iraq for 2022

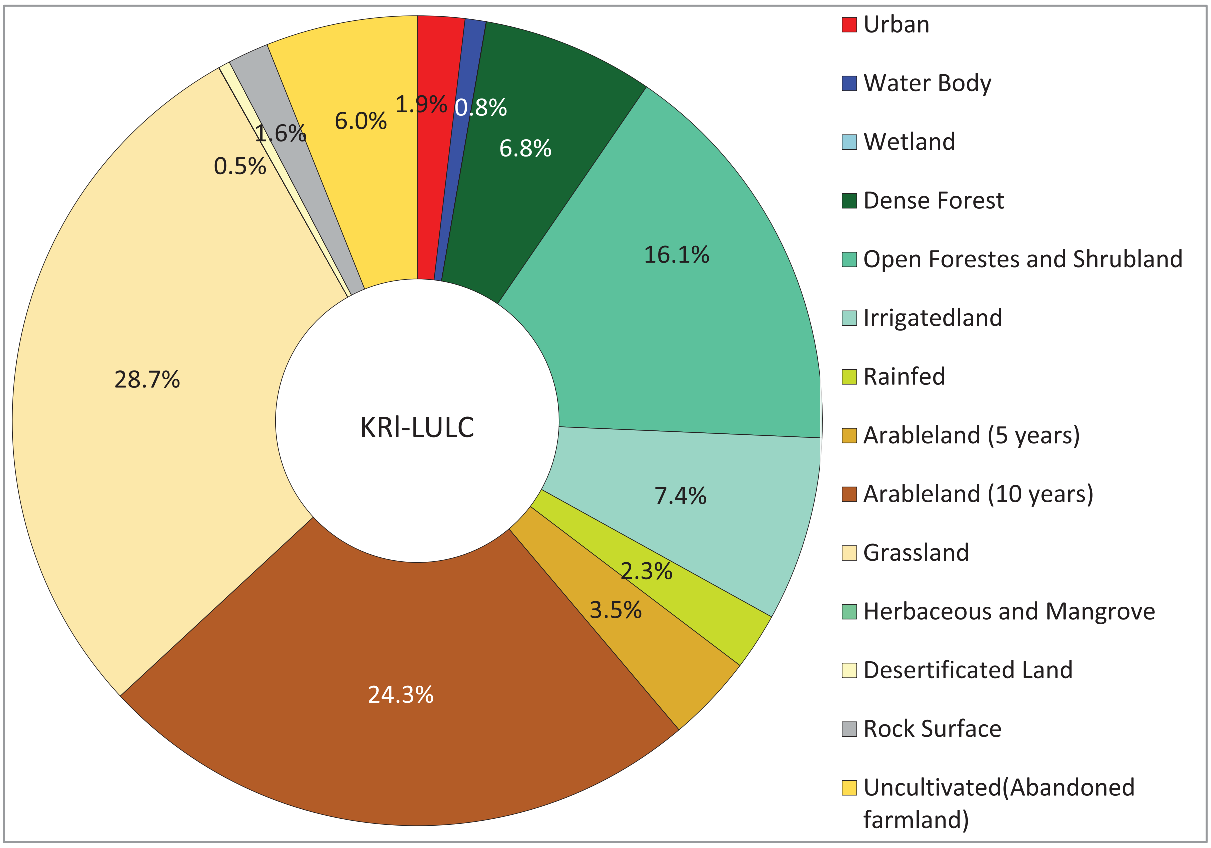


Figure 4: Land use and land cover (LULC) map produced for Kurdistan Region of Iraq

Table 1: Kurdistan Region of Iraq Land use and land cover (LULC) Classifications area km^2 and Percent

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	875.7	87566.9	1.9
Water Body	388.8	38876.9	0.8
Wetland	4.1	412.0	0.01
Dense Forest	3179.5	317953.2	6.8
Open Forests and Shrubland	7483.3	748333.2	16.1
Palm Tree	0.0	1.0	0
Irrigated land	3425.0	342502.9	7.4
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Desertificated Land	212.3	21233.1	0.5
Rock Surface	759.3	75934.2	1.6
Uncultivated (Abandoned farmland)	2810.9	281085.6	6.0
Total area	46465.1	4646505.7	100

5.2. Erbil Province

Erbil province is the capital city of the Kurdistan Region of Iraq, with an area of 14690.9 km2. The LULC map for the province shows various classes, including arable land (10 years), grassland, shrublands, tree cover, irrigated lands, and urban classes (Figure 5, Figure 6 and Table 2). The area of Built-Up (buildings and cities) is around 345 km2, which is equivalent to %2.3 of the area of Erbil. Arable lands (10 years) occupy the largest area of KRI's total are with %27, which is equivalent to around 3966 km2. Grasslands and natural pastures are the second-largest land area in Erbil, covering %23.7 of the province's area, which is equivalent to 3481 km2. The study used satellite images to determine the land area used for cultivating crops during both winter and summer seasons. The land area cultivated with summer crops was found to be 1451.2 km2, which is %9.8 of the total area of Erbil. In addition to the above, the study also calculated the surface material areas, including roads, industrial facilities, minerals, and rocky lands that are not suitable for cultivation. The importance of each LULC class in Erbil province depends on various factors, such as the economic and environmental significance of the class. However, some of the most important LULC classes in Erbil province are arable land, grassland, open forests, shrublands, dense forest, irrigated lands, and urban classes.

Urban: The urban class is an important LULC class in Erbil province because it includes the city and its infrastructure, it covers 345 km(%2.3) 2. Erbil is the capital of the Kurdistan Region of Iraq and is one of the fastest-growing cities in Kurdistan and Iraq. The urban class is essential for providing housing, services, and employment opportunities to the residents of Erbil.

Tree Cover: The dense forest occupies %8 (1170.2 km2) of the total area of Erbil province class is an important LULC class in the region because it includes forests and woodlands, which are crucial for the environment and the economy. Forests provide various ecological services, such as carbon sequestration, water regulation, biodiversity conservation and reducing negative effects of climate change. They are also a source of timber, fuelwood, and non-timber forest products.

Shrubland: The shrubland class is an important LULC class in Erbil province because it includes savannas and scrublands, which are essential for the local ecosystems and the economy. Shrublands cover %17.6 (2149 km2) of Erbil's total area and they provide habitat for various wildlife species, such as birds and mammals, and are a source of forage for livestock. They are also important for soil conservation and preventing desertification of Erbil lands.

Arable land (10 years): The arable land (10 years) class is the largest land use (3699 ,%27 km2) and an important LULC class in Erbil province because it includes areas that are cultivated for crops and are rotated at least once within the last 10 years. Agriculture is an important sector in Erbil province, and crops such as wheat, barley, and fruits are grown in the area. Arable land provides food and income for the local population and is crucial for regional food security.

Agricultural LULC classes, including irrigated land, rainfed, arable land (5 years), and arable land (10 years) are important classes in Erbil provinces which cover approximately %41 (6061 km2) of Erbil’s total area. These classes represent areas where crops are grown and can have significant economic and social importance for the region. The irrigated land class represents areas where crops are grown using irrigation systems. These areas are often associated with intensive agriculture and higher crop yields. In Erbil province, the main crops grown on irrigated land include wheat, barley, corn, vegetables, and fruits. The agriculture sector is an important source of income for many farmers in the region. Rainfed areas are those where crops are grown without any additional irrigation and rely solely on rainfall for crop growth. Rainfed agriculture is prevalent in the semi-arid and arid regions of Erbil province. The main crops grown in rainfed areas include wheat, barley, and legumes. Arable lands represent areas where crops were cultivated at least once within the last 10 or 5 years, mainly including wheat, barley, and legumes.

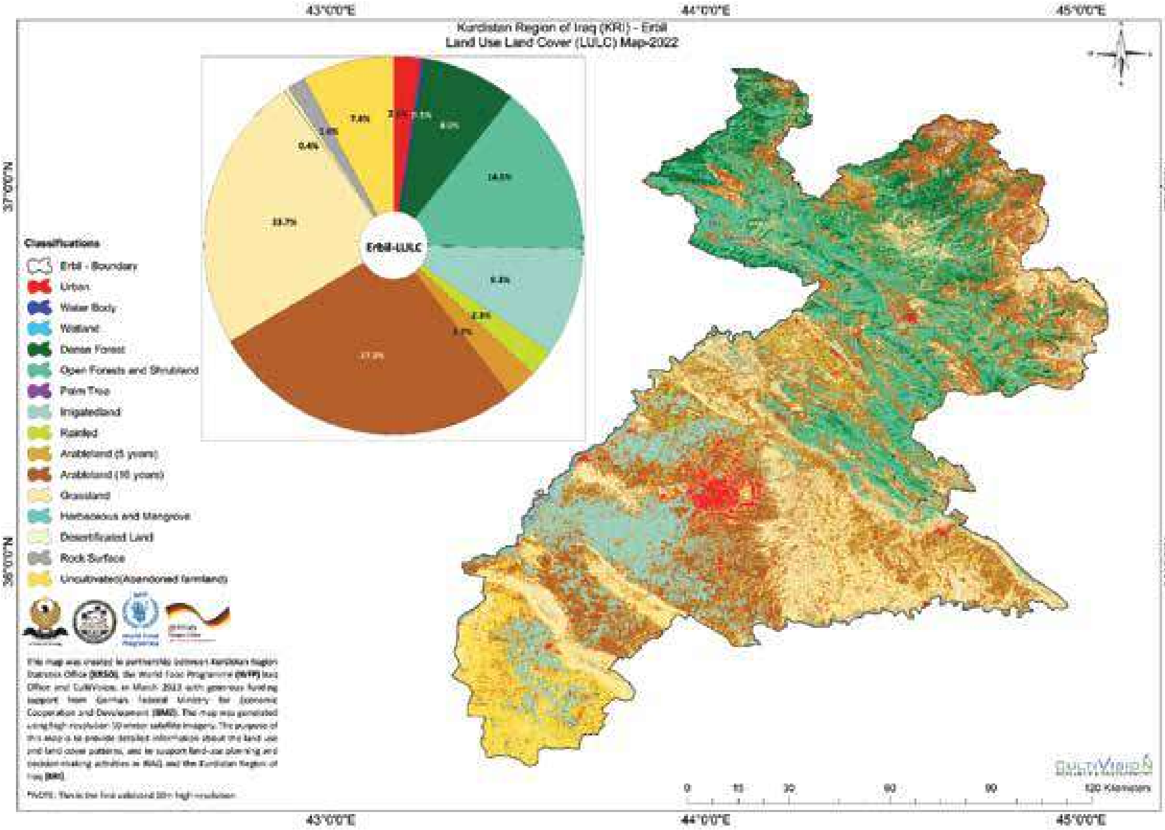

Figure 5: The spatial distribution of land use and land cover of Erbil province for 2022

The water body class in Erbil province includes all surface water bodies, such as rivers, streams, lakes, ponds, and reservoirs. The total area of the water body class in Erbil province is approximately 46.9 km2, which represents %0.3 of the total area of the province. The water bodies in Erbil province play a crucial role in providing water resources for various uses, such as irrigation, domestic, and industrial purposes. They also provide habitats for aquatic plants and animals and contribute to the region's biodiversity. One of the most important water bodies in Erbil province is the Greater Zab River. The river is a primary water source for irrigation and domestic uses in the region. It also provides habitat for various fish species and supports recreational activities such as fishing and boating.

Overall, the LULC classes of Erbil's province play important roles in the economic, ecological, and social systems, and their sustainable management is essential for the region's future development.

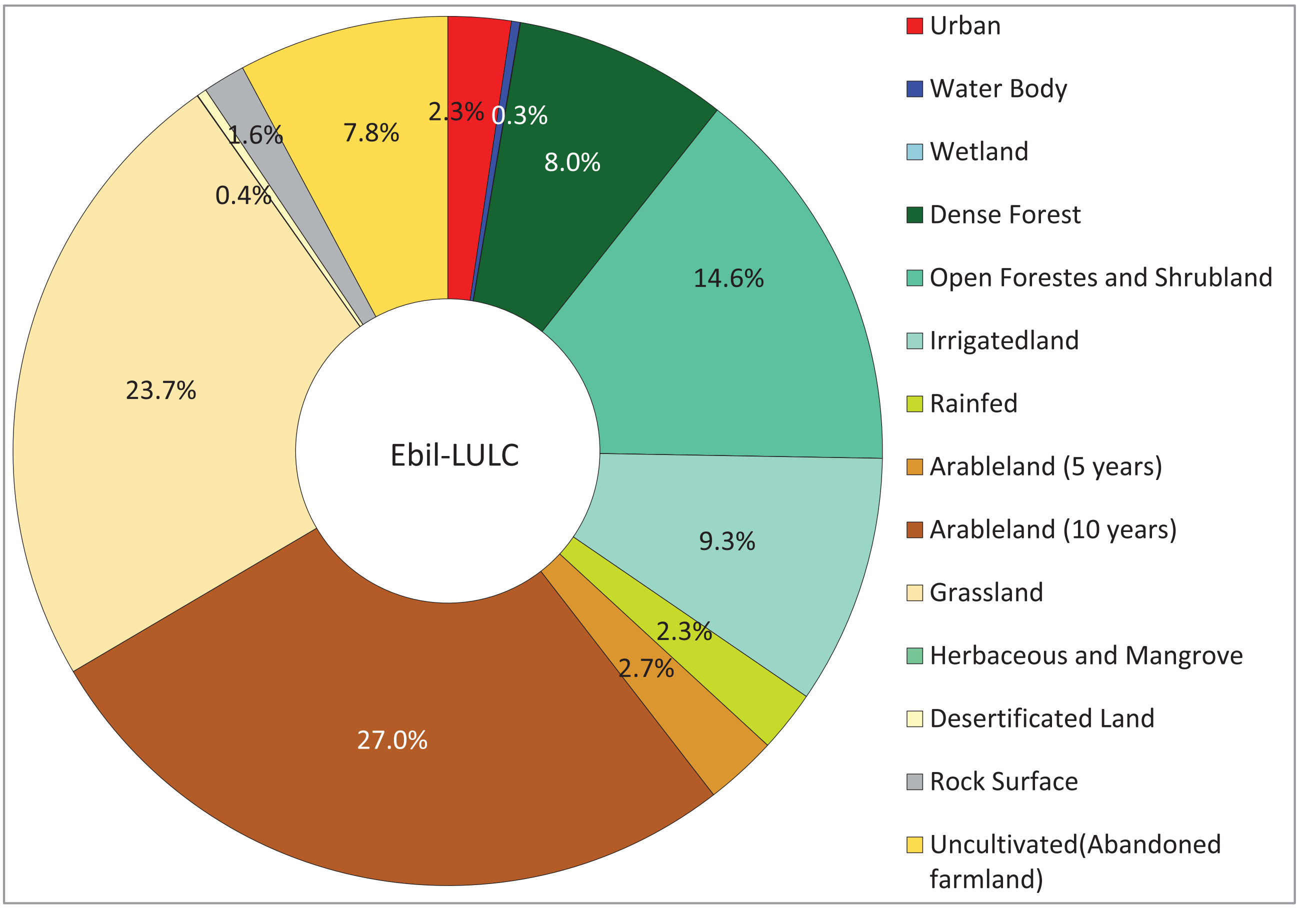

Figure 6: Land use and land cover (LULC) map produced for Erbil province

Table 2: Erbil Land use and land cover (LULC) Classifications Area in km2 and percentag

No.	LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
1	Urban	344.4	34442.3	2.3
2	Water Body	46.9	4686.7	0.3
3	Wetland	2.6	260.8	0.0
4	Dense Forest	1170.2	117019.2	8.0
5	Open Forests and Shrubland	2148.6	214857.8	14.6
6	Palm Tree	0.0	0.1	0.0
7	Irrigated land	1363.9	136392.6	9.3
8	Rainfed	335.6	33561.5	2.3
9	Arableland (5 years)	394.9	39490.6	2.7
10	Arableland (10 years)	3966.4	396637.0	27.0
11	Grassland	3481.4	348136.5	23.7
12	Herbaceous and Mangrove	2.9	288.3	0.0
13	Desertificated Land	52.4	5244.8	0.4
14	Rock Surface	231.4	23144.4	1.6
15	Uncultivated (Abandoned farmland)	1149.3	114931.1	7.8
	Total area	**14690.9**	**1469093.7**	**100**

5.3. Al-Sulaymaniyah Province

Sulaymaniyah Province is the largest city in the Kurdistan region, covering an area of 19966 km2, along with the independent administration of Garmyan. The province is bounded by Iran to the east, Kirkuk Province to the west, Salahalddin Province to the southwest, and Diyala Province to the south. It comprises 15 districts, including Sulaimaniyah, Qaradagh, Sharazure, Saidsadiq, Penjwin, Darbandikhan, Kalar, Khanaqin, Kifri, Chamchamal, Dukan, Sharbazher (Mawat), Ranya, and Pishdar.

The region's land use and land cover (LULC) map portrays different classes along with their corresponding areas and percentages, including Grassland, Arable land (10 years), open forest and shrublands, uncultivated (abandoned farmland), irrigated lands, dense forest, and urban classes (Figure 7, Figure 8 and Table 3). The most dominant land use classes in Al-Sulaymaniyah province are grassland, followed by arable land (10 years) and shrubland. The classification of the region shows that the Built-up area covers 319 km2, which is equivalent to %1.6 of the area of Sulaimaniyah, and water bodies cover 225 km^2, equivalent to %1.1 of the area of Sulaymaniyah because the province contains two main dams, Dokan and Darbandikhan. Arable lands cover the largest area, occupying 5124 km2, which is equivalent to %26 of the governorate's area. The area of land covered with dense trees is 581.4 km2, equivalent to %2.9. The urban areas, water bodies, and wetlands cover a small percentage of the total area. Grasslands are essential for the region's livestock industry and provide grazing lands for animals. The urban areas, water bodies, and wetlands cover a small percentage of the total area. The economic and environmental significance of each LULC class in Al-Sulaymaniyah province depends on various factors. The most important land use and land cover (LULC) classes in Al-Sulaymaniyah province are:

- **Grassland:** With an area of 7669 km(%38.4) 2, grassland is the largest LULC class in the province. It is an important source of fodder for livestock and plays a significant role in the local economy.
- **Arable land (10 years):** With an area of 4505 km(%22.6) 2, arable land is the second largest LULC class in the province. It is used for growing crops such as wheat, barley, and vegetables within the last 10 years.
- **Shrubland:** With an area of 2522 km(%12.6) 2, shrubland is an important LULC class in the province. It provides habitat for a variety of wildlife and is important for soil conservation.
- **Uncultivated (Abandoned farmland):** With an area of 1574 km2 (%7.9), this class represents abandoned farmland that is no longer in use for agriculture. It may contain natural vegetation or may be left fallow for soil restoration.
- **Urban:** With an area of 319 km(%1.6) 2, urban areas are a relatively small but important LULC class in the province. They are centres of economic activity and provide housing, services, and infrastructure for the local population.

The water body class in Al-Sulaymaniyah province covers an area of 224.7 km2, which is %1.1 of the total area. This class includes all surface water features such as rivers, lakes, and reservoirs. Water bodies are important natural resources that play a critical role in sustaining the environment and supporting human activities in the province. In Al-Sulaymaniyah, water bodies provide essential resources for various activities such as agriculture, industry, and domestic use. The most significant water body in the region is the Dokan Lake, which is located in the northeast of the province and covers a large area in the province.

Al-Sulaymaniyah province has several agricultural classes, including irrigated land, rain-fed land, arable land (5 and 10 years), and Grasslands which together approximately cover %72 (14,300 km2) of Al-Sulaymaniyah's province total area. The region has five primary land classes: Irrigated Land, Rain-fed Land, Arable Land (5 years), Arable Land (10 years) and Grasslands. Irrigated Land accounts for %5.3 of the total area and is crucial for agricultural production in the region. It is mainly irrigated using surface water and groundwater. Rainfed Land covers %2.3 of the total area and is mainly found in mountainous areas where there is sufficient rainfall for crop production. Arable Lands (10 and 5 years) makeup %22.6 and %3.1 of the total area and consist of fields where crops are cultivated within the last 10 and 5 years. Finally, the Grasslands represent a large area of Al-Sulaymaniyah with %38.5 (7669 km2), it is an important natural resource for livestock grazing, fodder for wild animals and other migrant and local birds and animals. These land classes provide valuable insights into the agricultural landscape of the region and highlight the different factors that affect crop production and sustainability in Al-Sulaymaniyah province.

In summary, the most important LULC classes in Al-Sulaymaniyah province depend on the specific context of the study or analysis being conducted. However, the grassland, shrubland, urban, tree cover, and irrigated land classes are all important for various reasons, ranging from ecological significance to economic and social importance for the province.

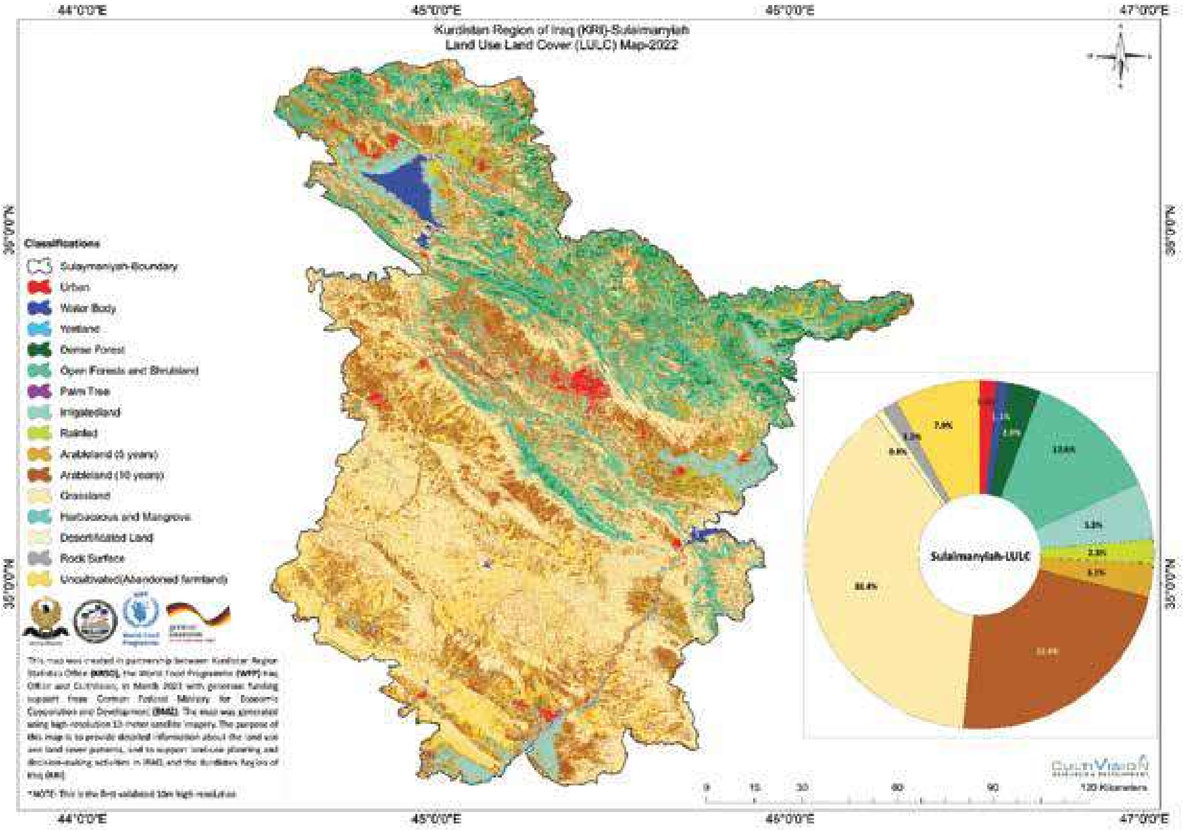

Figure 7: The spatial distribution of land use and land cover of Al-Sulaymaniyah province for 2022

Table 3: Al-Sulaymaniyah Land use and land cover (LULC) Classifications Area in km2 and Percentage

No.	LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
1	Urban	318.8	31876.8	1.6
2	Water Body	224.7	22467.5	1.1
3	Wetland	1.1	109.0	0.0
4	Dense Forest	581.4	58137.1	2.9
5	Open Forests and Shrubland	2522.4	252242.2	12.6
6	Palm Tree	0.0	0.8	0.0
7	Irrigatedland	1057.7	105772.8	5.3
8	Rainfed	449.8	44980.3	2.3
9	Arableland (5 years)	619.6	61962.7	3.1
10	Arableland (10 years)	4504.5	450449.8	22.6
11	Grassland	7668.6	766855.0	38.4
12	Herbaceous and Mangrove	2.3	230.5	0.0
13	Desertificated Land	149.8	14981.4	0.8
14	Rock Surface	291.4	29137.0	1.5
15	Uncultivated(Abandoned farmland)	1574.2	157420.3	7.9
	Total area	19966.2	1996623.2	100.0

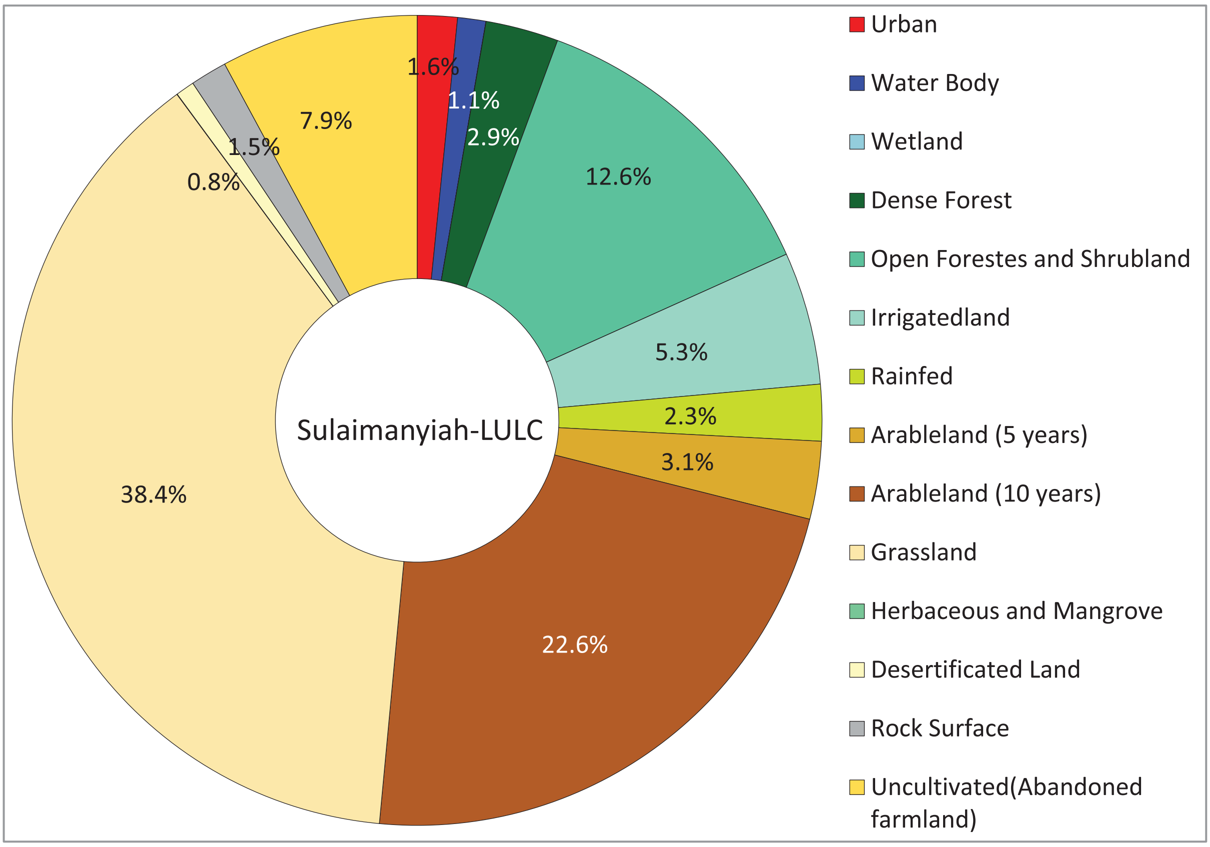

Figure 8: Land use and land cover (LULC) map produced for Al-Sulaymaniyah province

5.4. Duhok Province

Duhok province is situated in the north-western part of the Kurdistan Region and spans approximately 10,919.1 km2, with an elevation of 430 to 2,500 meters above sea level. It shares borders with Turkey to the north, Syria to the west, Ninewa Governorate to the south, and Erbil Governorate to the east. The province is divided into seven districts: Duhok, Semel, Zakho, Amedi, Akre, Shekhan, and Bardarash. The area is surrounded by the Bekher Mountains to the north and the Zawa Mountains to the south, resulting in a climate influenced by the Mediterranean region. The project employed efficient approaches to identify land use and land cover classes in the area, which were categorized into fifteen classes including urban areas, barren land, areas of vegetation, and water bodies. The Duhok province is mountainous, with only %1.8 of the area being built-up and %0.9 (101 km2) covered by water bodies. The study aimed to identify changes in land use classes.

Duhok province in Iraq has a diverse range of land use and land cover (LULC) classes that play a crucial role in shaping the region's ecological and socioeconomic systems (Figure 9, Figure 10 and Table 4).
The LULC classes in Duhok province can be broadly classified into urban, agricultural, forested, and natural vegetation classes.

- Urban areas cover approximately %1.8 (195 km2) of the total area in Duhok province, indicating that the province is still largely rural. The presence of urban areas implies an increase in population and economic activity, which might lead to environmental degradation and increased pressure on natural resources.
- Agricultural lands, including irrigated and rainfed land, cover around %9.9 (1074 km2) of Duhok province. This highlights the importance of agriculture as a major livelihood source in the region. The province has both arable and non-arable land, with arable lands comprising around %29.8 (3251 km2) of the total area of Duhok province.
- Forested areas in the province consist of dense forests and open forests and shrubland, covering around %37.3 (4064 km2) of the total area. The tree cover class is dominated by natural forests and includes a mix of deciduous and coniferous trees, while the shrubland class is dominated by bushes and shrubs. The presence of forested areas in the region is vital for maintaining the ecological balance, soil, and water conservation, and supporting biodiversity in Duhok province.
- Natural vegetation classes, such as grasslands cover around %17.5 (1907 km2) of the total area.
- These natural grassland classes provide important ecological services, such as carbon sequestration, water purification, and flood control, livestock grazing, and support a range of plant and animal species that existed in the province.

The water body class in Duhok province covers approximately %1 (101.2 km2) of the total area and includes natural and artificial surface water bodies such as rivers, lakes, and reservoirs. The primary water body in Duhok province is the Greater Zab River, which originates in Turkey and flows through Duhok and Sulaymaniyah provinces before joining the Tigris River. The river is an important source of freshwater for irrigation, domestic use, and hydropower generation, supporting aquatic species, including fish, amphibians, and waterfowl. In addition to the Greater Zab River, there are several smaller rivers and streams in the province, including the Lesser Zab River and the Khabur River, which support local ecosystems and provide water for irrigation and drinking purposes. Duhok Lake, which is an artificial reservoir created by the Duhok Dam on the Duhok River is a paramount water body in the province. Duhok dam is two kilometres north of Duhok city, between latitudes 52°36′ to 54°36′N and longitudes 59°42′ to 00°43′E. The location of Duhok was characterized climate strategic location on international transportation lines connecting Iraq's Kurdistan Region to Turkey and Syria.

Overall, the distribution of LULC classes in Duhok province highlights the region's diverse natural resources and the importance of balancing their sustainable use and conservation. Proper management of these resources is essential for sustaining the region's socio-economic development and ensuring the well-being of its inhabitants in Duhok province.

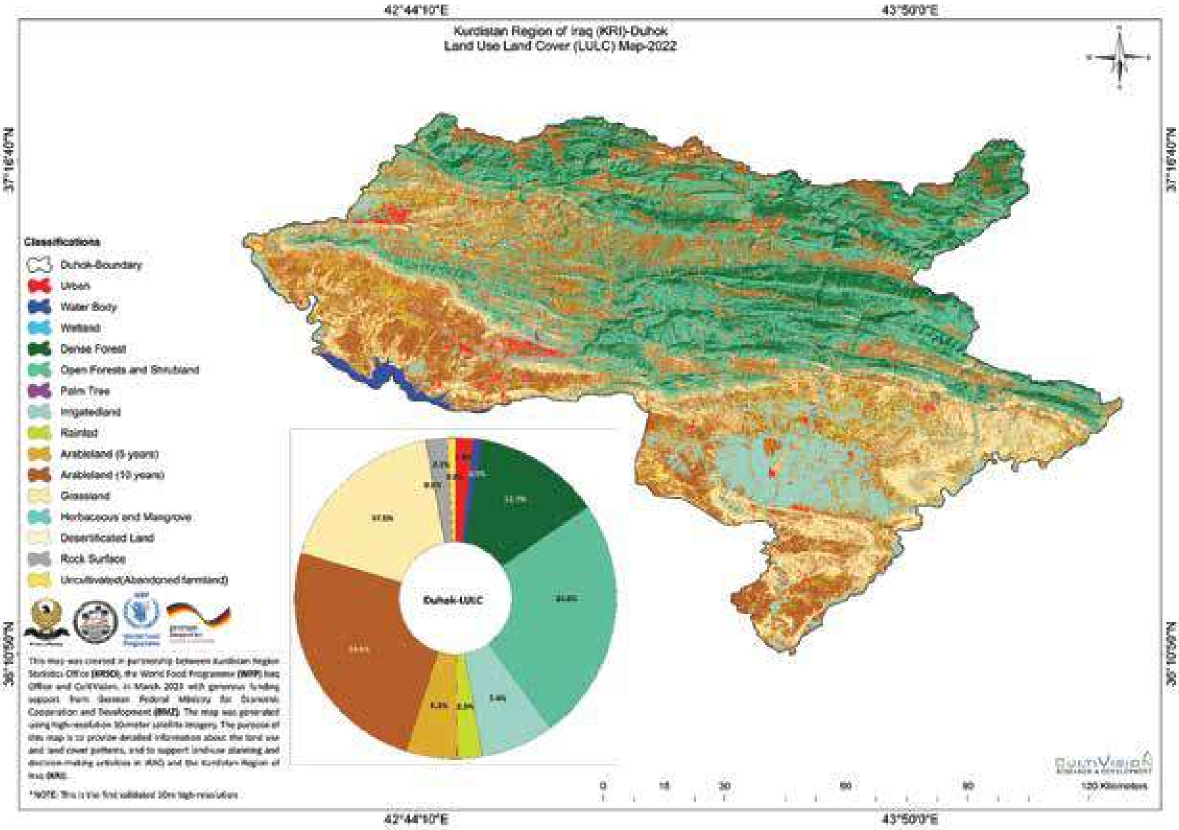

Figure 9: The spatial distribution of land use and land cover of Duhok province for 2022

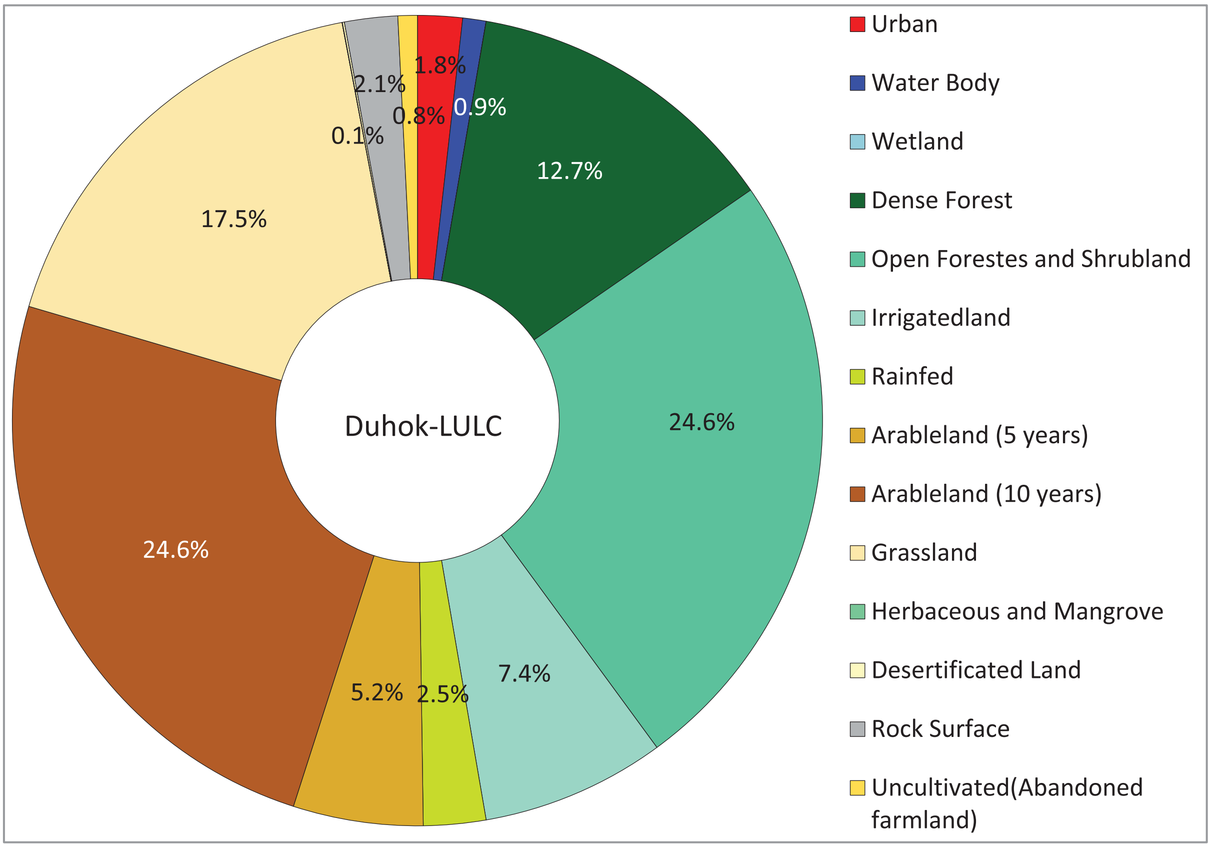

Figure 10: Land use and land cover (LULC) map produced for Duhok province

Table 4: Duhok Land use and land cover (LULC) Classifications area in km^2 and percentage

No.	LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
1	Urban	194.8	19482.0	1.8
2	Water Body	101.2	10123.8	0.9
3	Wetland	0.4	41.0	0.0
4	Dense Forest	1381.9	138190.8	12.7
5	Open Forests and Shrubland	2682.0	268201.0	24.6
6	Palm Tree	0.0	0.1	0.0
7	Irrigated land	802.8	80284.2	7.4
8	Rainfed	271.4	27137.3	2.5
9	Arableland (5 years)	565.9	56592.7	5.2
10	Arableland (10 years)	2685.5	268547.4	24.6
11	Grassland	1907.4	190741.0	17.5
12	Herbaceous and Mangrove	1.6	155.4	0.0
13	Desertificated Land	8.6	858.0	0.1
14	Rock Surface	231.0	23097.0	2.1
15	Uncultivated(Abandoned farmland)	84.5	8453.6	0.8
	Total area	10919.1	1091905.3	100

5.5. Halabja Province

The land use and land cover (LULC) classes of Halabja Province in the Kurdistan Region represent the distribution of various land uses and vegetation types in the region. Halabja province spans an area of 888.95 km2. Halabja is the smallest province in Kurdistan Region of Iraq in terms the area. Within this province, the total area occupied by built-up structures is 17.7 km2, which represents only %2 of the entire area of Halabja. Additionally, the area covered by water bodies in this region is 16 km2, accounting for %1.8 of the total area of Halabja. The classes include urban, water bodies, dense forests, open forests and shrubland, irrigated land, rainfed land, arable land, grassland, desertified land, rock surface, and uncultivated land.

The urban class represents the built-up areas of the province, such as cities and towns, and it covers %2 (17.7 km2) of the total area. The water body class includes natural and artificial bodies of water, such as rivers, lakes, and reservoirs, and it covers %1.8 (16 km2) of the total area. Darbandikhan lake and Sirwan River are the major surface water for Halabja province.

The dense forest, open forests and shrubland, and grassland classes represent the natural vegetation of the region, and they cover %50 (473 km2) of the total area. The dense forest class covers %5.2 (~46 km2) of the total area and includes areas with high tree canopy coverage. The open forest and shrubland class cover %14.7 (130 km2) of the total area and includes areas with lower tree canopy coverage and more shrubs and bushes.

The irrigated land class represents areas where crops are grown using irrigation, and it covers %22.6 (200.5 km2) of the total area. The rainfed land class represents areas where crops are grown using rainwater (precipitation), and it covers only %0.4 of the total area. The arable land classes represent areas where crops are grown, and they cover %18.9 (168 km2) of the total area. The arable land (5 years) class represents areas where crops are grown within last five years, while the arable land (10 years) class represents areas where crops are grown within the last ten years. The grassland class represents areas dominated by grasses and other herbaceous plants, and it covers the largest area of Halabja %33.4 (297 km2) of the total area. The desertified land class represents areas where the natural vegetation has been lost or degraded, and it covers only %0.2 (1.5 km2) of the total area. The rock surface class represents areas dominated by rocks and stones, and it covers %0.6 (5.6 km2) of the total area. The uncultivated land class represents a very small area that was once used for agriculture but has been abandoned, and it covers %0.3 (2.8 km2) of the total area. In summary, the LULC classes of Halabja Province represent the distribution of various land uses and vegetation types in the region, ranging from urban areas to natural forests and grasslands to agricultural land and desertified areas. The different classes have different ecological, economic, and social significance and play an important role in the overall functioning of the province's ecosystems and the livelihoods of its people.

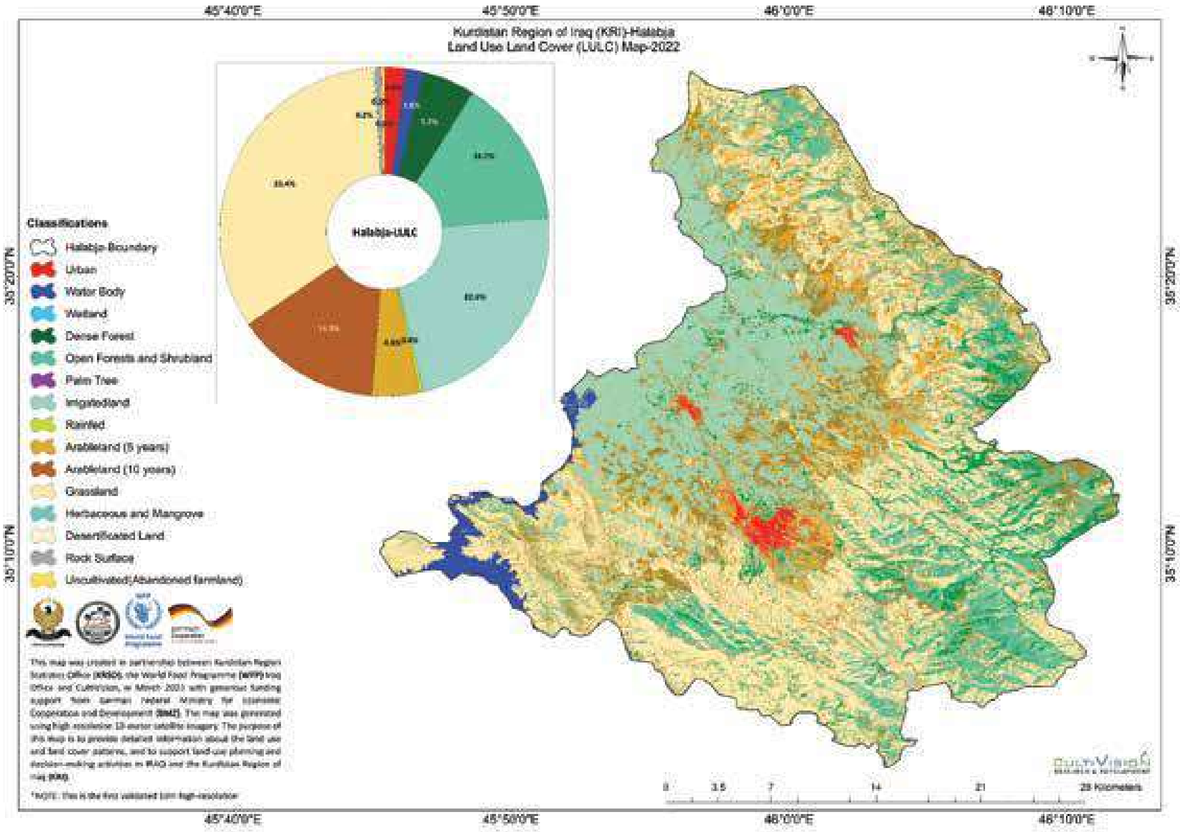

Figure 10: The spatial distribution of land use and land cover of Halabja province for 2022

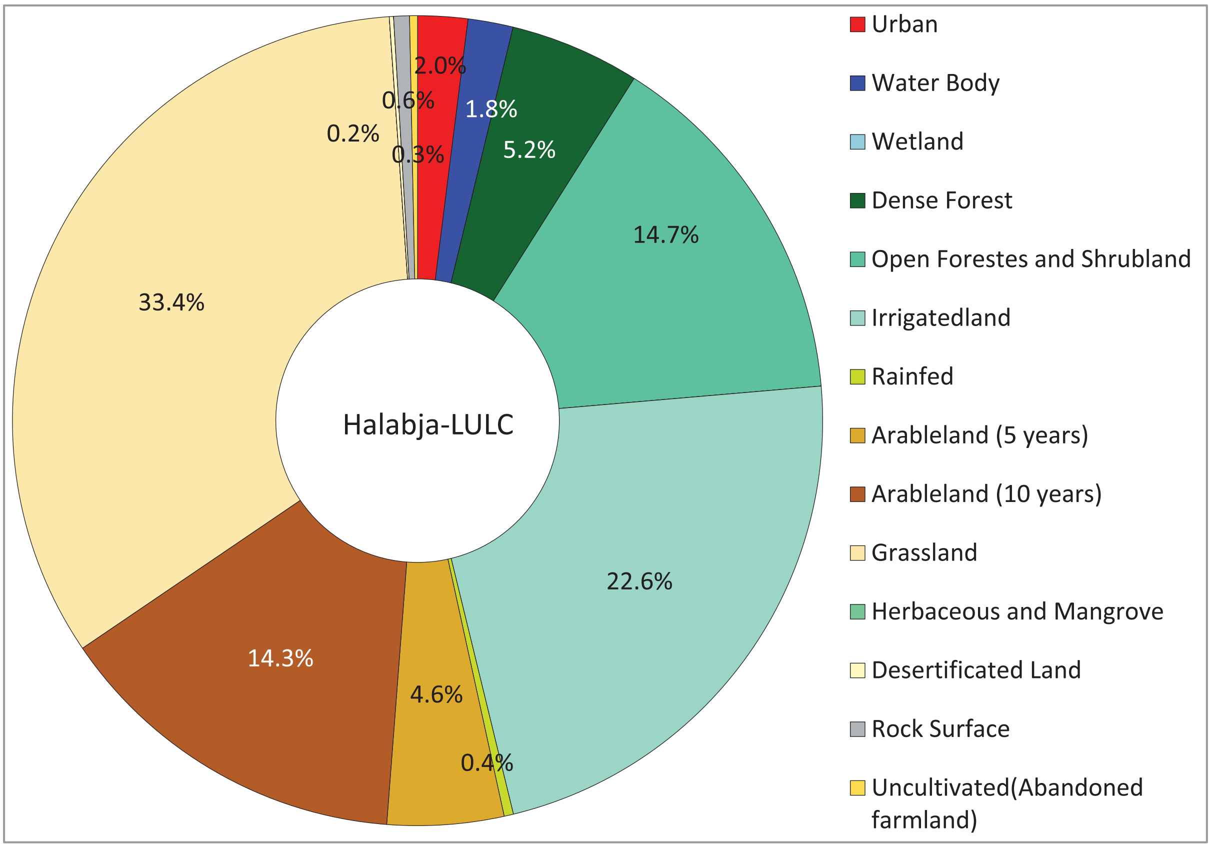

Figure 11: Land use and land cover (LULC) map produced for Halabja province

Table 5: Halabja Land use and land cover (LULC) Classifications Area in km^2 and percentage

No.	LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
1	Urban	17.7	1765.8	2.0
2	Water Body	16.0	1598.9	1.8
3	Wetland	0.0	1.2	0.0
4	Dense Forest	46.1	4606.1	5.2
5	Open Forestes and Shrubland	130.3	13032.2	14.7
6	Palm Tree	0.0	0.0	0.0
7	Irrigatedland	200.5	20053.3	22.6
8	Rainfed	3.3	331.4	0.4
9	Arableland (5 years)	41.3	4129.4	4.6
10	Arableland (10 years)	127.0	12703.6	14.3
11	Grassland	296.7	29674.9	33.4
12	Herbaceous and Mangrove	0.0	1.3	0.0
13	Desertificated Land	1.5	148.9	0.2
14	Rock Surface	5.6	555.8	0.6
15	Uncultivated(Abandoned farmland)	2.8	280.6	0.3
	Total area	888.8	88883.5	100.

6. Discussion

Erbil governorate is one of the major governorates in the Republic of Iraq, with seven administrative districts, and it is the political and economic capital of the KRI in the north of Iraq (Hakzi, 2022). In this study, GIS and remote sensing were used to monitor and quantify LULC changes spatially and temporarily. There have been significant LULC changes specifically to urban development, particularly in the north of the city. However, these developments come at the cost of other landscape fabrics, for example, agricultural land and barren land. The classification of the Kurdistan region into fifteen Land Use Land Cover (LULC) categories is an essential component in assessing the distribution and extent of various land cover types in the region and it is relevance to decision-making in various fields. The results of the land use land cover (LULC) classification showed that the Built-Up class covered %1.9 of the total area of the Kurdistan Region of Iraq (KRI), while the Water Body class covered %0.9 of the total area. The Built-Up class mainly consists of human-made structures such as buildings, roads, bridges, parking lots, and other infrastructure, while the Water Body class represents any surface water feature such as lakes, rivers, streams, ponds, reservoirs, and wetlands.

The land use and land cover changes in the Kurdistan region have been driven by population growth, urbanization, and economic development (Ibrahim et al., 2016). The Built-Up class provides valuable information for urban planning and management, and by monitoring changes in this class over time, decision-makers can identify areas where development is occurring rapidly and where there may be a need for infrastructure improvements, services, or policies to manage urban growth sustainably. This is consistent with the Kurdistan Statistics Office (KRSO) (published in February 2021) about population analysis in the Kurdistan region, which highlighted the need for sustainable urban planning and management in the Kurdistan region to address the challenges of rapid urbanization and promote sustainable development.

The Water Body class is also important, as it provides crucial insights into the hydrological cycle, ecological diversity, recreational activities, and water resource management. Water resources in the Kurdistan region are under threat from anthropogenic activities such as urbanization, agriculture, and dam construction (Abdullah et al., 2016). The Water Body class can be used by environmental managers to assess the impact of human activities on surface water features and to design policies and management strategies that promote sustainable water resource use.

The occupation of arable land is a significant aspect of land use in the Kurdistan region (KRI), covering 12905 km2 or ~%28 of the region's total area. Arable land is an important subset of agricultural land, as it refers to land suitability for crop cultivation and is crucial for food and fibre production. This classification is essential as it provides information on the potential for agricultural production in Kurdistan region provinces, which is significant for both economic and food security reasons. Furthermore, it can help identify areas where land use practices need to be changed to promote sustainable agriculture and protect soil health. The classification of arable land can also be used to identify areas where land use change is occurring, such as the conversion of agricultural land to urban or industrial uses. This understanding is critical for policymakers and land managers to plan and manage land use effectively.

Grassland and natural pastures cover a vast area of the Kurdistan region of Iraq, equivalent to 13354 km2, which is %29 of the region's area and is the second rank in terms of land area in the Kurdistan region (Figure 3 and Table 1). Grassland is an important land cover category in LULC analysis. It is often used for grazing livestock, wildlife habitat, and recreational activities and can affect the local climate, hydrology, and biodiversity (Yang et al., 2020). Monitoring changes in grassland cover over time can help identify trends in land use practices, climate change impacts, and other environmental factors. Changes in grasslands can have significant implications for regional food security and biodiversity (Liu et al., 2020). Understanding the distribution and dynamics of Grassland cover is essential for effective land management and conservation planning, and for addressing important environmental and socio-economic issues in Kurdistan. Developing techniques to measure spatially past, current, and future changes provide invaluable information for decision-makers, and biodiversity conservationists, and assists in identifying ecologically degraded areas concerning the landscape's total area.

Dense forests are a significant land use in the Kurdistan region, covering an area of 3180 km2, which is %6.8 of the region's total land area. They are essential in preserving biodiversity, supporting livelihoods through the provision of forest products, and providing ecological services like water filtration and carbon sequestration. Dense forests are characterised by high tree canopy cover and density, resulting in a closed canopy that blocks sunlight and promotes carbon sequestration, biodiversity conservation, and ecosystem services. However, the sustainability of forest and tree cover is threatened by human activities, particularly deforestation, agricultural expansion, and urbanization in Kurdistan provinces. Deforestation is a significant cause of forest loss and contributes significantly to global greenhouse gas emissions. These activities pose challenges to sustainable development, and initiatives have been developed to address them. These initiatives include afforestation and reforestation programs, sustainable forest management, and natural forest conservation.

Promoting sustainable forest and tree cover requires a balance between economic development and conservation. Policies and practices that promote sustainable resource use are necessary in the Kurdistan region to prevent overexploitation of natural resources. The involvement of local communities in decision-making processes related to forest management is also vital to promote sustainability and equity. Community awareness and community-based forest management approaches that empower local communities can lead to more sustainable outcomes for natural resources in the region. The implementation of these initiatives requires the cooperation of all stakeholders, including governments, private sector actors, civil society organizations, and local communities to sustain and promote forest and tree cover areas in the Kurdistan Region of Iraq.

Open forests are characterised by a relatively low tree canopy cover, allowing for more light penetration and diverse vegetation with a variety of plant species. Open forests and shrublands cover a relatively large area of the Kurdistan region, equivalent to 7483 km2, which is %16 of the region's area and is the third rank in terms of land area in the Kurdistan region. They provide several ecological benefits, such as carbon sequestration, soil conservation, and water regulation, as well as supporting a range of wildlife in the region. Open forests can be found in different ecosystems and are often associated with natural disturbances, like bushfires or grazing. Some open forests are managed thoughtfully for agricultural purposes through traditional land-use practices, such as agroforestry or shifting cultivation. Shrublands are areas dominated by shrubs and provide many ecological, economic, and social benefits.

Ecologically, they provide habitat for a diverse range of plant and animal species and are essential for soil conservation. Economically, they provide resources like timber, fuelwood, and non-timber forest products. Socially, they are significant for their cultural and visual values and can provide important cultural resources for tribal and Kurdish communities in mountainous areas and rangelands. However,the conversion of shrublands to other land uses can have negative impacts on the environment and society, and sustainable management is crucial to sustaining shrublands in the region. Open forests and shrublands are also vulnerable to many natural and anthropogenic factors such as human activities such as urbanisation, overgrazing, logging, and agricultural expansion, which can result in soil erosion, loss of biodiversity, and reduced ecosystem services, negatively impacting human well-being (Bartley et al., 2023).

To promote sustainable management of open forests and shrublands, various initiatives have been developed, including community-based forest management education, authorities' policies, and schemes for sustainable forest/shrubland management. These initiatives aim to balance economic, social, and environmental objectives and involve the participation of local communities, civil society, and the private sector as well as national and international organisations in decision-making processes.

Desertification creates significant risks to the Kurdistan Region of Iraq due to having arid and semi-arid conditions. The degradation of land due to factors such as climate change, overgrazing, deforestation, and unsustainable land-use practices likely led to a reduction in soil health, reduced biodiversity, and the decline of ecosystem services. This process can have severe social, economic, and environmental consequences, particularly in developing countries (for example, Iraq including the Kurdistan region) where agriculture is the main source of livelihood for many people.
Although the desertified lands in the Kurdistan region is relatively low with only

%0.5 (212 km2, mainly impacted Al-Sulaymaniyah and Erbil provinces), The impacts of desertification are particularly critical in the Kurdistan Region of Iraq, where the agricultural sector is an essential contributor to the region's economy after extraction of the petroleum industry. To address the risks of desertification in the Kurdistan Region of Iraq, there is a need for a comprehensive approach that involves multiple stakeholders to establish strategies that assist in combating desertification risks. The United Nations Convention to Combat Desertification (UNCCD) provides a framework for promoting sustainable land management practices, restoring degraded land, and enhancing the resilience of ecosystems and communities in drylands. The implementation of these essential strategies requires adequate financial and technical resources, as well as effective governance and institutional frameworks in the region.Successful implementation of strategies to combat desertification in the Kurdistan Region of Iraq would improve soil health, increase vegetation cover, and enhance groundwater recharge. This would contribute to sustainable development, poverty elimination, and climate change adaptation and mitigation. However, there is a need for long-term strategies and frameworks, interdisciplinary collaboration, and active participation of local communities, the private sector as well as relevant authorities in the Kurdistan region to obtain these goals.

7. Accuracy assessment of LULC classes

Accuracy assessment is a vital step in any remote sensing analysis or machine-learning project, as it ensures the accuracy and reliability of the results. There are different methods of validation, and in this project, the accuracy of LULC classes was verified. The accuracy assessment method involved randomly selecting %30 of the data for validation purposes, while the remaining %70 was used for training the model. A confusion matrix was used to evaluate the model's performance, which showed the number of correctly and incorrectly classified pixels for each class in JavaScript. The overall accuracy of the model was reported to be %95, which means of the pixels were correctly classified for all classes with high confidence.

This validation provides a comprehensive assessment of the accuracy and reliability of the results. Accuracy assessment helps evaluate the performance of the model. It also allows us to ensure that the analysis is reliable and accurate and that the results can be used with confidence.

Ground-truth validation is another important validation method that involves comparing the results obtained from the analysis with actual ground-truth data collected in the field. This method is particularly useful when dealing with complex or heterogeneous landscapes where it can be difficult to accurately classify or estimate parameters from remote sensing data alone. The field points have been collected by KRSO employees, which were 275 points, then, they have been compared with the estimated LULC generated throughout GEE. The overall accuracy of this process was %89.

8. Conclusion:

The land use and land cover (LULC) classes of the Kurdistan Region of Iraq have been analysed and presented in this research technical report. This report reveals that the largest LULC classes in the region are grassland, arable land (10 years), and open forests and shrubland, which together account for nearly %70 of the total area. The other significant LULC classes in the region include irrigated land, dense forest, and urban areas. The results of this study provide valuable information about the current LULC patterns in the Kurdistan Region, which can be used to develop effective strategies for land management and conservation. For example, the high proportion of grassland in the region indicates that grazing and livestock farming are important economic activities. Therefore, sustainable grazing practices can be promoted to ensure the long-term productivity of these grasslands. Additionally, the high proportion of arable land (10 years) highlights the importance of agriculture in the region's economy. However, it also indicates that there may be a need for sustainable farming practices to prevent soil degradation and loss of biodiversity. Furthermore, the large area of open forests and shrubland emphasizes the need for forest management practices that balance economic development with conservation goals which play a critical role in mitigating climate change by sequestering carbon dioxide from the atmosphere, regulating the water cycle, and supporting biodiversity.

In conclusion, this project report provides a comprehensive understanding of the LULC patterns in the Kurdistan Region, which is essential for sustainable land management and conservation practices. The results of this study can be used to develop effective policies and strategies that support economic development while maintaining the ecological integrity of the region's natural resources.

9. Recommendations

Based on the findings of the report, the following recommendations are made:
Key Policy Recommendations and Programs:

•Integrated Land Use Planning:
Implementing a comprehensive and integrated land use planning framework is essential to address the challenges of land use and land cover (LULC). This should involve collaboration between government agencies, local communities, and stakeholders to develop land use policies that are sustainable, inclusive, and responsive to local needs.

•Climate Change Adaptation and Mitigation:
Incorporating climate change adaptation and mitigation strategies into land use planning is crucial for building resilience and reducing greenhouse gas emissions. Encourage the adoption of sustainable land management practices

such as afforestation, reforestation, and agroforestry to enhance carbon sequestration, protect biodiversity, and promote sustainable agriculture.

Urban Planning and Smart Growth:
Prioritize compact and efficient urban development to minimize urban sprawl and preserve agricultural land, forests, and open spaces.

•Conservation and Protected Areas:
Strengthen the establishment and management of conservation areas and protected lands to safeguard biodiversity, natural habitats, and ecosystem services. Enhance the enforcement of protected area regulations and support community-based conservation initiatives.

•Land Use Data and Monitoring:
Data collection, mapping, and monitoring systems to provide accurate and up-to-date information for evidence-based decision making.

Users and Purpose of LULC Data:

•Government Agencies:
LULC data is vital for government agencies responsible for land management, urban planning, environmental protection, agriculture, forestry, and disaster management. It helps them assess the current state of land resources, identify areas of concern, formulate policies, and monitor changes over time. This data enables evidence-based decision making and effective resource allocation.

•Researchers and Academia:
Researchers and academia utilize LULC data to study land dynamics, assess environmental impacts, analyze urbanization patterns, evaluate habitat fragmentation, and explore the socioeconomic implications of land use changes. It serves as a valuable resource for scientific studies, modeling, and

forecasting future scenarios.

•Conservation Organizations:

Conservation organizations use LULC data to monitor habitat loss, and prioritize conservation efforts. This data helps them design effective strategies for protecting endangered species, preserving critical ecosystems, and advocating for sustainable land use practices.

•Private Sector:

The private sector, including real estate developers, infrastructure companies, and agricultural enterprises, can utilize LULC data for site selection, feasibility studies, and impact assessments. It enables them to make informed decisions about land acquisition, infrastructure development, and sustainable business practices.

•Community Organizations and NGOs:

Community organizations and non-governmental organizations (NGOs) can leverage LULC data to engage local communities in land management, conservation, and participatory planning processes. It facilitates community-based monitoring, empowers grassroots initiatives, and promotes sustainable land use practices at the local level.

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10. Appendices

A1- LULC Classification (Km^2) of Kurdistan Region/Iraq-Erbil districts

no.	LULC Classes	Erbil (City Center)(Km^2)	%
0	Urban	145.1	12.7
1	Water Body	0.8	0.1
2	Wetland	0.1	0.0
3	Tree Cover	2.4	0.2
4	Shrubland	0.8	0.1
5	Palm Tree	0.0	0.0
6	Irrigatedland	465.4	40.9
7	Rainfed	48.6	4.3
8	Arableland (5 years)	35.2	3.1
9	Arableland (10 years)	274.5	24.1
10	Grassland	94.9	8.3
13	Herbaceous and Mangrove	0.1	0.0
14	Desertificated Land	0.5	0.0
16	Rock Surface	44.2	3.9
17	Uncultivated(Abandoned farmland)	26.2	2.3
	Total	**1139.0**	**100.0**

no.	LULC Classes	Erbil Province(Km^2)	%
0	Urban	344.4	2.3
1	Water Body	46.9	0.3
2	Wetland	2.6	0.0
3	Tree Cover	1170.2	8.0
4	Shrubland	2148.6	14.6
5	Palm Tree	0.0	0.0
6	Irrigatedland	1363.9	9.3
7	Rainfed	335.7	2.3
8	Arableland (5 years)	395.0	2.7
9	Arableland (10 years)	3966.4	27.0
10	Grassland	3481.4	23.7
13	Herbaceous and Mangrove	2.9	0.0
14	Desertificated Land	52.4	0.4
16	Rock Surface	230.6	1.6
17	Uncultivated(Abandoned farmland)	1149.3	7.8
	Total	**14690.1**	**100.0**

no.	LULC Classes	Choman(Km^2)	%
0	Urban	8.3	1.0
1	Water Body	2.9	0.3
2	Wetland	1.2	0.1
3	Tree Cover	93.4	10.9
4	Shrubland	136.6	15.9
5	Palm Tree	0.0	0.0
6	Irrigatedland	4.4	0.5
7	Rainfed	0.2	0.0
8	Arableland (5 years)	2.2	0.3
9	Arableland (10 years)	285.2	33.3
10	Grassland	293.2	34.2
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.0	0.0
16	Rock Surface	11.4	1.3
17	Uncultivated(Abandoned farmland)	17.8	2.1
	Total	**856.8**	**100.0**

no.	LULC Classes	Dashti hawler(Km^2)	%
0	Urban	52.0	4.0
1	Water Body	1.3	0.1
2	Wetland	0.1	0.0
3	Tree Cover	0.3	0.0
4	Shrubland	7.2	0.6
5	Palm Tree	0.0	0.0
6	Irrigatedland	161.2	12.5
7	Rainfed	36.7	2.9
8	Arableland (5 years)	32.9	2.6
9	Arableland (10 years)	535.7	41.6
10	Grassland	370.6	28.8
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	7.7	0.6
16	Rock Surface	29.7	2.3
17	Uncultivated(Abandoned farmland)	51.2	4.0
	Total	**1286.7**	**100.0**

no.	LULC Classes	Xabat(Km²)	%
0	Urban	28.7	4.1
1	Water Body	6.5	0.9
2	Wetland	0.0	0.0
3	Tree Cover	1.1	0.2
4	Shrubland	2.5	0.4
5	Palm Tree	0.0	0.0
6	Irrigatedland	144.3	20.5
7	Rainfed	44.5	6.3
8	Arableland (5 years)	29.2	4.1
9	Arableland (10 years)	203.4	28.9
10	Grassland	202.9	28.9
13	Herbaceous and Mangrove	0.3	0.0
14	Desertificated Land	0.2	0.0
16	Rock Surface	24.8	3.5
17	Uncultivated(Abandoned farmland)	14.2	2.0
	Total	**702.7**	**100.0**

no.	LULC Classes	Koysenjeq(Km²)	%
0	Urban	18.2	0.9
1	Water Body	5.0	0.2
2	Wetland	0.1	0.0
3	Tree Cover	25.6	1.3
4	Shrubland	150.6	7.4
5	Palm Tree	0.0	0.0
6	Irrigatedland	40.9	2.0
7	Rainfed	43.3	2.1
8	Arableland (5 years)	117.2	5.7
9	Arableland (10 years)	523.4	25.6
10	Grassland	940.3	46.0
13	Herbaceous and Mangrove	0.1	0.0
14	Desertificated Land	4.4	0.2
16	Rock Surface	32.3	1.6
17	Uncultivated(Abandoned farmland)	142.3	7.0
	Total	**2043.8**	**100.0**

no.	LULC Classes	Mergaswr(Km^2)	%
0	Urban	9.3	0.5
1	Water Body	6.9	0.4
2	Wetland	0.1	0.0
3	Tree Cover	491.2	25.5
4	Shrubland	836.0	43.4
5	Palm Tree	0.0	0.0
6	Irrigatedland	15.1	0.8
7	Rainfed	1.2	0.1
8	Arableland (5 years)	18.8	1.0
9	Arableland (10 years)	319.8	16.6
10	Grassland	212.5	11.0
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.3	0.0
16	Rock Surface	11.3	0.6
17	Uncultivated(Abandoned farmland)	2.0	0.1
	Total	**1924.4**	**100.0**

no.	LULC Classes	Rawanduz(Km^2)	%
0	Urban	5.2	1.0
1	Water Body	0.6	0.1
2	Wetland	0.0	0.0
3	Tree Cover	68.0	12.9
4	Shrubland	226.4	43.0
5	Palm Tree	0.0	0.0
6	Irrigatedland	0.9	0.2
7	Rainfed	0.3	0.1
8	Arableland (5 years)	3.5	0.7
9	Arableland (10 years)	128.2	24.3
10	Grassland	88.5	16.8
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.2	0.0
16	Rock Surface	3.9	0.7
17	Uncultivated(Abandoned farmland)	1.2	0.2
	Total	**526.8**	**100.0**

no.	LULC Classes	Shaqlawa(Km^2)	%
0	Urban	23.8	1.6
1	Water Body	4.2	0.3
2	Wetland	0.1	0.0
3	Tree Cover	58.4	4.0
4	Shrubland	331.2	22.5
5	Palm Tree	0.0	0.0
6	Irrigatedland	25.7	1.7
7	Rainfed	75.0	5.1
8	Arableland (5 years)	76.6	5.2
9	Arableland (10 years)	430.4	29.2
10	Grassland	407.0	27.7
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	2.2	0.1
16	Rock Surface	30.3	2.1
17	Uncultivated(Abandoned farmland)	6.9	0.5
	Total	**1471.9**	**100.0**

no.	LULC Classes	Maxmoor(Km^2)	%
0	Urban	30.7	1.2
1	Water Body	7.5	0.3
2	Wetland	0.1	0.0
3	Tree Cover	1.0	0.0
4	Shrubland	1.2	0.0
5	Palm Tree	0.0	0.0
6	Irrigatedland	499.8	19.1
7	Rainfed	83.4	3.2
8	Arableland (5 years)	50.0	1.9
9	Arableland (10 years)	586.0	22.4
10	Grassland	427.0	16.3
13	Herbaceous and Mangrove	2.4	0.1
14	Desertificated Land	36.7	1.4
16	Rock Surface	21.7	0.8
17	Uncultivated(Abandoned farmland)	866.9	33.2
	Total	**2614.2**	**100.0**

A2- LULC Classification of Kurdistan Region/Iraq-Sulaymaniyah and Halabja districts.

no.	LULC Classes	Chamchamal(Km^2)	%
0	Urban	32.1	0.9
1	Water Body	6.3	0.2
2	Wetland	0.2	0.0
3	Tree Cover	2.4	0.1
4	Shrubland	49.1	1.4
5	Palm Tree	0.0	0.0
6	Irrigatedland	15.1	0.4
7	Rainfed	53.7	1.5
8	Arableland (5 years)	137.4	3.9
9	Arableland (10 years)	860.9	24.7
10	Grassland	1925.5	55.3
13	Herbaceous and Mangrove	0.2	0.0
14	Desertificated Land	28.2	0.8
16	Rock Surface	21.4	0.6
17	Uncultivated(Abandoned farmland)	351.4	10.1
	Tottal	**3483.7**	**100.0**

no.	LULC Classes	Darbandixan(Km^2)	%
0	Urban	10.7	1.9
1	Water Body	26.4	4.7
2	Wetland	0.1	0.0
3	Tree Cover	1.3	0.2
4	Shrubland	50.3	8.9
5	Palm Tree	0.0	0.0
6	Irrigatedland	13.9	2.4
7	Rainfed	12.3	2.2
8	Arableland (5 years)	9.2	1.6
9	Arableland (10 years)	104.7	18.5
10	Grassland	299.2	52.9
13	Herbaceous and Mangrove	0.1	0.0
14	Desertificated Land	2.0	0.4
16	Rock Surface	11.6	2.0
17	Uncultivated(Abandoned farmland)	24.0	4.2
	Tottal	**565.7**	**100.0**

no.	LULC Classes	Halabja(Km^2)	%
0	Urban	17.7	2.0
1	Water Body	16.0	1.8
2	Wetland	0.0	0.0
3	Tree Cover	46.1	5.2
4	Shrubland	130.3	14.7
5	Palm Tree	0.0	0.0
6	Irrigatedland	200.5	22.6
7	Rainfed	3.3	0.4
8	Arableland (5 years)	41.3	4.6
9	Arableland (10 years)	127.0	14.3
10	Grassland	296.7	33.4
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	1.5	0.2
16	Rock Surface	5.6	0.6
17	Uncultivated(Abandoned farmland)	2.8	0.3
	Tottal	**888.8**	**100.0**

no.	LULC Classes	Kalar(Km^2)	%
0	Urban	22.8	1.3
1	Water Body	2.0	0.1
2	Wetland	0.1	0.0
3	Tree Cover	0.3	0.0
4	Shrubland	4.7	0.3
5	Palm Tree	0.0	0.0
6	Irrigatedland	19.5	1.1
7	Rainfed	11.2	0.7
8	Arableland (5 years)	33.9	2.0
9	Arableland (10 years)	335.0	19.7
10	Grassland	951.0	56.0
13	Herbaceous and Mangrove	0.1	0.0
14	Desertificated Land	2.9	0.2
16	Rock Surface	31.1	1.8
17	Uncultivated(Abandoned farmland)	284.0	16.7
	Tottal	**1698.5**	**100.0**

no.	LULC Classes	Kfri(Km²)	%
0	Urban	17.1	0.6
1	Water Body	5.0	0.2
2	Wetland	0.1	0.0
3	Tree Cover	0.4	0.0
4	Shrubland	0.1	0.0
5	Palm Tree	0.0	0.0
6	Irrigatedland	146.0	5.4
7	Rainfed	17.5	0.6
8	Arableland (5 years)	66.6	2.5
9	Arableland (10 years)	543.6	20.1
10	Grassland	1064.8	39.4
13	Herbaceous and Mangrove	1.2	0.0
14	Desertificated Land	94.6	3.5
16	Rock Surface	21.5	0.8
17	Uncultivated(Abandoned farmland)	721.9	26.7
	Tottal	**2700.4**	**100.0**

no.	LULC Classes	Mawat(Km²)	%
0	Urban	5.1	1.1
1	Water Body	0.6	0.1
2	Wetland	0.0	0.0
3	Tree Cover	46.5	10.0
4	Shrubland	164.7	35.5
5	Palm Tree	0.0	0.0
6	Irrigatedland	7.2	1.6
7	Rainfed	1.8	0.4
8	Arableland (5 years)	2.4	0.5
9	Arableland (10 years)	105.5	22.7
10	Grassland	122.5	26.4
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.0	0.0
16	Rock Surface	6.8	1.5
17	Uncultivated(Abandoned farmland)	1.4	0.3
	Tottal	**464.5**	**100.0**

no.	LULC Classes	Penjween(Km²)	%
0	Urban	11.8	1.1
1	Water Body	0.4	0.0
2	Wetland	0.0	0.0
3	Tree Cover	155.9	14.0
4	Shrubland	401.9	36.0
5	Palm Tree	0.0	0.0
6	Irrigatedland	121.8	10.9
7	Rainfed	46.4	4.2
8	Arableland (5 years)	16.2	1.5
9	Arableland (10 years)	207.6	18.6
10	Grassland	146.5	13.1
13	Herbaceous and Mangrove	0.2	0.0
14	Desertificated Land	0.1	0.0
16	Rock Surface	5.2	0.5
17	Uncultivated(Abandoned farmland)	1.5	0.1
	Tottal	**1115.5**	**100.0**

no.	LULC Classes	Pshdar(Km²)	%
0	Urban	17.7	1.3
1	Water Body	4.8	0.4
2	Wetland	0.1	0.0
3	Tree Cover	92.5	7.0
4	Shrubland	301.3	22.8
5	Palm Tree	0.0	0.0
6	Irrigatedland	27.4	2.1
7	Rainfed	73.9	5.6
8	Arableland (5 years)	32.2	2.4
9	Arableland (10 years)	340.5	25.8
10	Grassland	385.2	29.2
13	Herbaceous and Mangrove	0.1	0.0
14	Desertificated Land	0.8	0.1
16	Rock Surface	33.1	2.5
17	Uncultivated(Abandoned farmland)	10.5	0.8
	Tottal	**1319.9**	**100.0**

no.	LULC Classes	Qaradax(Km^2)	%
0	Urban	3.7	0.5
1	Water Body	0.3	0.0
2	Wetland	0.0	0.0
3	Tree Cover	16.4	2.3
4	Shrubland	190.7	26.6
5	Palm Tree	0.0	0.0
6	Irrigatedland	25.4	3.5
7	Rainfed	1.1	0.1
8	Arableland (5 years)	25.9	3.6
9	Arableland (10 years)	130.6	18.2
10	Grassland	312.6	43.6
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.4	0.1
16	Rock Surface	6.7	0.9
17	Uncultivated(Abandoned farmland)	3.6	0.5
	Tottal	**717.2**	**100.0**

no.	LULC Classes	Ranya(Km^2)	%
0	Urban	25.2	3.0
1	Water Body	72.8	8.6
2	Wetland	0.0	0.0
3	Tree Cover	52.5	6.2
4	Shrubland	159.5	18.7
5	Palm Tree	0.0	0.0
6	Irrigatedland	114.1	13.4
7	Rainfed	15.9	1.9
8	Arableland (5 years)	16.4	1.9
9	Arableland (10 years)	212.4	25.0
10	Grassland	152.4	17.9
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.2	0.0
16	Rock Surface	22.2	2.6
17	Uncultivated(Abandoned farmland)	7.4	0.9
	Tottal	**851.1**	**100.0**

no.	LULC Classes	Said Sadiq(Km^2)	%
0	Urban	11.2	1.6
1	Water Body	0.3	0.0
2	Wetland	0.0	0.0
3	Tree Cover	20.5	2.9
4	Shrubland	115.6	16.6
5	Palm Tree	0.0	0.0
6	Irrigatedland	136.9	19.7
7	Rainfed	39.0	5.6
8	Arableland (5 years)	38.4	5.5
9	Arableland (10 years)	129.0	18.6
10	Grassland	196.0	28.2
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.2	0.0
16	Rock Surface	6.2	0.9
17	Uncultivated(Abandoned farmland)	1.7	0.2
	Tottal	**695.0**	**100.0**

no.	LULC Classes	Sharazwr(Km^2)	%
0	Urban	8.1	2.4
1	Water Body	2.1	0.6
2	Wetland	0.0	0.0
3	Tree Cover	0.4	0.1
4	Shrubland	16.9	5.1
5	Palm Tree	0.0	0.0
6	Irrigatedland	49.9	15.1
7	Rainfed	52.1	15.8
8	Arableland (5 years)	23.6	7.1
9	Arableland (10 years)	103.4	31.3
10	Grassland	70.0	21.2
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.2	0.1
16	Rock Surface	3.1	0.9
17	Uncultivated(Abandoned farmland)	0.9	0.3
	Tottal	**330.6**	**100.0**

no.	LULC Classes	Sharbazher(Km²)	%
0	Urban	13.8	1.1
1	Water Body	1.0	0.1
2	Wetland	0.0	0.0
3	Tree Cover	112.8	9.3
4	Shrubland	504.7	41.7
5	Palm Tree	0.0	0.0
6	Irrigatedland	15.4	1.3
7	Rainfed	20.7	1.7
8	Arableland (5 years)	13.5	1.1
9	Arableland (10 years)	250.1	20.6
10	Grassland	257.8	21.3
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.0	0.0
16	Rock Surface	18.0	1.5
17	Uncultivated(Abandoned farmland)	3.7	0.3
	Tottal	**1211.6**	**100.0**

no.	LULC Classes	Sulaymania-City Center(Km²)	%
0	Urban	108.5	7.7
1	Water Body	0.4	0.0
2	Wetland	0.3	0.0
3	Tree Cover	6.8	0.5
4	Shrubland	131.7	9.4
5	Palm Tree	0.0	0.0
6	Irrigatedland	119.8	8.5
7	Rainfed	33.4	2.4
8	Arableland (5 years)	102.0	7.2
9	Arableland (10 years)	360.5	25.6
10	Grassland	469.6	33.4
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	2.2	0.2
16	Rock Surface	58.1	4.1
17	Uncultivated(Abandoned farmland)	13.8	1.0
	Tottal	**1407.2**	**100.0**

no.	LULC Classes	Sulaymania-Province(Km²)	SU%
0	Urban	318.8	1.60
1	Water Body	224.7	1.13
2	Wetland	1.1	0.01
3	Tree Cover	581.4	2.91
4	Shrubland	2522.4	12.63
5	Palm Tree	0.0	0.00
6	Irrigatedland	1057.7	5.30
7	Rainfed	449.8	2.25
8	Arableland (5 years)	619.6	3.10
9	Arableland (10 years)	4504.5	22.56
10	Grassland	7668.6	38.41
13	Herbaceous and Mangrove	2.3	0.01
14	Desertificated Land	149.8	0.75
16	Rock Surface	291.4	1.46
17	Uncultivated(Abandoned farmland)	1574.2	7.88
	Tottal	**19966.3**	**100.00**

no.	LULC Classes	Xanaqin(Km²)	%
0	Urban	13.2	0.8
1	Water Body	4.7	0.3
2	Wetland	0.1	0.0
3	Tree Cover	4.8	0.3
4	Shrubland	60.2	3.7
5	Palm Tree	0.0	0.0
6	Irrigatedland	103.3	6.4
7	Rainfed	27.9	1.7
8	Arableland (5 years)	45.9	2.8
9	Arableland (10 years)	363.4	22.4
10	Grassland	830.8	51.2
13	Herbaceous and Mangrove	0.5	0.0
14	Desertificated Land	17.8	1.1
16	Rock Surface	12.3	0.8
17	Uncultivated(Abandoned farmland)	136.1	8.4
	Tottal	**1621.1**	**100.0**

A3- LULC Classification of Kurdistan Region/Iraq -Duhok districts

no.	LULC Classes	Duhok(City Center)(Km^2)	%
0	Urban	36.0	3.6
1	Water Body	2.0	0.2
2	Wetland	0.1	0.0
3	Tree Cover	98.2	9.7
4	Shrubland	384.1	38.0
6	Irrigatedland	13.0	1.3
7	Rainfed	24.9	2.5
8	Arableland (5 years)	23.1	2.3
9	Arableland (10 years)	244.5	24.2
10	Grassland	127.9	12.7
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.2	0.0
16	Rock Surface	54.3	5.4
17	Uncultivated(Abandoned farmland)	2.3	0.2
	Total	**1010.6**	**100.0**

no.	LULC Classes	Duhok province(Km^2)	%
0	Urban	191.5	1.8
1	Water Body	101.2	0.9
2	Wetland	0.4	0.0
3	Tree Cover	1381.8	12.7
4	Shrubland	2682.0	24.6
6	Irrigatedland	802.8	7.4
7	Rainfed	271.4	2.5
8	Arableland (5 years)	565.9	5.2
9	Arableland (10 years)	2685.4	24.6
10	Grassland	1907.4	17.5
13	Herbaceous and Mangrove	1.6	0.0
14	Desertificated Land	8.6	0.1
16	Rock Surface	231.0	2.1
17	Uncultivated(Abandoned farmland)	84.5	0.8
	Total	**10915.5**	**100.0**

no.	LULC Classes	Amedi(Km^2)	%
0	Urban	17.5	0.6
1	Water Body	3.9	0.1
2	Wetland	0.1	0.0
3	Tree Cover	813.9	29.6
4	Shrubland	1199.2	43.7
6	Irrigatedland	14.8	0.5
7	Rainfed	12.8	0.5
8	Arableland (5 years)	16.0	0.6
9	Arableland (10 years)	520.7	19.0
10	Grassland	130.4	4.7
13	Herbaceous and Mangrove	0.0	0.0
14	Desertificated Land	0.2	0.0
16	Rock Surface	16.5	0.6
17	Uncultivated(Abandoned farmland)	1.1	0.0
	Total	**2747.0**	**100.00**

no.	LULC Classes	Akre(Km^2)	%
0	Urban	15.2	0.9
1	Water Body	3.8	0.2
2	Wetland	0.1	0.0
3	Tree Cover	201.6	11.4
4	Shrubland	419.5	23.7
6	Irrigatedland	94.7	5.4
7	Rainfed	68.9	3.9
8	Arableland (5 years)	63.7	3.6
9	Arableland (10 years)	343.5	19.4
10	Grassland	509.9	28.8
13	Herbaceous and Mangrove	0.1	0.0
14	Desertificated Land	0.7	0.0
16	Rock Surface	39.6	2.2
17	Uncultivated(Abandoned farmland)	8.5	0.5
	Total	**1769.9**	**100.0**

no.	LULC Classes	Bardarash(Km^2)	%
0	Urban	27.8	2.4
1	Water Body	4.8	0.4
2	Wetland	0.0	0.0
3	Tree Cover	1.6	0.1
4	Shrubland	0.6	0.1
6	Irrigatedland	308.6	26.9
7	Rainfed	51.6	4.5
8	Arableland (5 years)	59.5	5.2
9	Arableland (10 years)	332.6	29.0
10	Grassland	319.0	27.8
13	Herbaceous and Mangrove	0.9	0.1
14	Desertificated Land	0.8	0.1
16	Rock Surface	20.3	1.8
17	Uncultivated(Abandoned farmland)	18.5	1.6
	Total	**1146.6**	**100.0**

no.	LULC Classes	Semil(Km^2)	%
0	Urban	38.3	2.8
1	Water Body	82.1	6.0
2	Wetland	0.1	0.0
3	Tree Cover	4.9	0.4
4	Shrubland	44.0	3.2
6	Irrigatedland	43.8	3.2
7	Rainfed	35.6	2.6
8	Arableland (5 years)	214.7	15.6
9	Arableland (10 years)	527.3	38.3
10	Grassland	314.7	22.8
13	Herbaceous and Mangrove	0.1	0.0
14	Desertificated Land	4.3	0.3
16	Rock Surface	42.0	3.0
17	Uncultivated(Abandoned farmland)	26.1	1.9
	Total	**1377.9**	**100.0**

no.	LULC Classes	Shexan(Km²)	%
0	Urban	23.0	1.6
1	Water Body	0.4	0.0
2	Wetland	0.0	0.0
3	Tree Cover	73.1	5.2
4	Shrubland	229.6	16.2
6	Irrigatedland	279.9	19.8
7	Rainfed	27.7	2.0
8	Arableland (5 years)	109.7	7.7
9	Arableland (10 years)	357.9	25.3
10	Grassland	273.3	19.3
13	Herbaceous and Mangrove	0.2	0.0
14	Desertificated Land	2.3	0.2
16	Rock Surface	15.5	1.1
17	Uncultivated(Abandoned farmland)	24.1	1.7
	Total	**1416.8**	**100.0**

no.	LULC Classes	Zaxo(Km²)	%
0	Urban	33.9	2.3
1	Water Body	4.2	0.3
2	Wetland	0.1	0.0
3	Tree Cover	188.6	13.0
4	Shrubland	405.0	28.0
6	Irrigatedland	47.9	3.3
7	Rainfed	49.8	3.4
8	Arableland (5 years)	79.3	5.5
9	Arableland (10 years)	358.7	24.8
10	Grassland	232.2	16.0
13	Herbaceous and Mangrove	0.2	0.0
14	Desertificated Land	0.1	0.0
16	Rock Surface	42.8	3.0
17	Uncultivated(Abandoned farmland)	3.9	0.3
	Total	**1446.7**	**100.0**

Appendix. Table 1: Validation in remote sensing analysis and machine-learning projects to ensure that the results obtained from the analysis or model are accurate and reliable for 275 locations.

NO	LATITUDE	LONGITUDE	REAL	ESTIMATED	RESULT
1	36.634139	44.885750	URBAN	SURFACEMATERIAL	AGREE
2	36.626889	44.880611	TREE	TREE	AGREE
3	36.626833	44.881639	WATER	WATER	AGREE
4	36.615083	44.867861	GRASSLAND	GRASSLAND	AGREE
5	36.610611	44.834056	WATER	WATER	AGREE
6	36.603778	44.819889	GRASSLAND	GRASSLAND	AGREE
7	36.596500	44.728250	CULTIVATED	CULTIVATED	AGREE
8	36.710389	44.548639	GRASSLAND	GRASSLAND	AGREE
9	36.723528	44.567528	GRASSLAND	SURFACEMATERIAL	DISAGREE
10	36.722500	44.573889	SHRUBLAND	SHRUBLAND	AGREE
11	36.698222	44.535639	CULTIVATED	CULTIVATED	AGREE
12	36.670111	44.542278	URBAN	BUILTUP	AGREE
13	36.663194	44.581389	URBAN	BUILTUP	AGREE
14	36.626667	44.465667	WATER	WATER	AGREE
15	36.584139	44.400083	SHRUBLAND	SHRUBLAND	AGREE
16	36.578278	44.404000	CULTIVATED	CULTIVATED	AGREE
17	36.578861	44.404750	TREE	TREE	AGREE
18	36.579083	44.404833	ARABLE	ARABLE	AGREE
19	35.818670	43.630080	URBAN	SURFACEMATERIAL	AGREE
20	35.797890	43.628780	URBAN	BUILTUP	AGREE
21	35.794920	43.631750	URBAN	BUILTUP	AGREE
22	35.795390	43.633220	ARABLE	ARABLE	AGREE
23	35.798580	43.642190	ARABLE	ARABLE	AGREE
24	35.798250	43.641220	TREE	TREE	DISAGREE
25	35.809860	43.661470	ARABLE	ARABLE	AGREE
26	35.727060	43.661420	URBAN	GRASSLAND	DISAGREE
27	35.727220	43.689440	GRASSLAND	GRASSLAND	AGREE
28	35.831360	43.694920	WATER	WATER	AGREE
29	35.867220	43.761170	TREE	TREE	AGREE
30	35.867470	43.761610	ARABLE	ARABLE	AGREE
31	35.876190	43.808890	URBAN	ARABLE	DISAGREE
32	35.877420	43.810560	URBAN	SURFACEMATERIAL	AGREE
33	35.898000	43.810390	SHRUBLAND	SHRUBLAND	AGREE
34	35.905360	43.829810	SHRUBLAND	SHRUBLAND	AGREE
35	35.907970	43.796080	GRASSLAND	GRASSLAND	AGREE
36	35.953890	43.877940	ARABLE	ARABLE	AGREE
37	35.979030	43.896970	WATER	WATER	AGREE
38	36.010390	43.912640	SHRUBLAND	SHRUBLAND	AGREE
39	36.095690	43.958530	GRASSLAND	GRASSLAND	AGREE
40	36.095560	43.892000	GRASSLAND	GRASSLAND	AGREE
41	36.095060	43.958610	CULTIVATED	CULTIVATED	AGREE
42	36.031222	44.036500	ARABLE	ARABLE	AGREE
43	36.024083	44.036861	ARABLE	ARABLE	AGREE
44	36.004194	44.033417	URBAN	SURFACEMATERIAL	AGREE
45	35.996028	44.036667	URBAN	BUILTUP	AGREE
46	35.985306	44.039889	URBAN	ARABLE	DISAGREE
47	35.979444	44.037222	URBAN	BUILTUP	AGREE
48	35.975639	44.027639	ARABLE	ARABLE	AGREE
49	35.972722	44.029222	WATER	WATER	AGREE
50	36.006722	44.076111	ARABLE	ARABLE	AGREE
51	36.006139	44.151111	TREE	TREE	AGREE
52	36.012139	44.181083	ARABLE	ARABLE	AGREE
53	36.029306	44.190556	GRASSLAND	GRASSLAND	AGREE
54	36.028056	44.190667	GRASSLAND	GRASSLAND	AGREE
55	36.033806	44.193056	TREE	TREE	AGREE
56	36.039056	44.195250	GRASSLAND	GRASSLAND	AGREE
57	36.045333	44.198667	URBAN	BUILTUP	AGREE

58	36.053611	44.197889	GRASSLAND	GRASSLAND	AGREE
59	36.061361	44.190278	GRASSLAND	GRASSLAND	AGREE
60	36.008500	44.059278	URBAN	GRASSLAND	DISAGREE
61	36.014222	44.038250	TREE	TREE	AGREE
62	36.219065	44.178446	TREE	TREE	AGREE
63	36.217760	44.171327	SHRUBLAND	SHRUBLAND	AGREE
64	36.214788	44.180697	TREE	TREE	AGREE
65	36.215484	44.178886	GRASSLAND	GRASSLAND	AGREE
66	36.214234	44.175892	TREE	TREE	AGREE
67	36.205907	44.142675	URBAN	ARABLE	DISAGREE
68	36.181555	44.134571	URBAN	BUILTUP	AGREE
69	36.161284	44.128902	SHRUBLAND	SHRUBLAND	AGREE
70	36.157625	44.138112	ARABLE	ARABLE	AGREE
71	36.156520	44.136712	ARABLE	ARABLE	AGREE
72	36.149833	44.103180	URBAN	BUILTUP	AGREE
73	36.155104	44.080569	URBAN	BUILTUP	AGREE
74	36.125983	44.047093	URBAN	BUILTUP	AGREE
75	36.068589	44.034516	SHRUBLAND	SHRUBLAND	AGREE
76	36.044614	44.039040	ARABLE	ARABLE	AGREE
77	36.013997	44.036168	SHRUBLAND	SURFACEMATERIAL	DISAGREE
78	36.015159	44.036283	ARABLE	ARABLE	AGREE
79	36.004049	44.033840	URBAN	BUILTUP	AGREE
80	36.005611	44.063153	CULTIVATED	CULTIVATED	AGREE
81	36.003444	44.146031	WATER	ARABLE	DISAGREE
82	36.331060	44.198644	TREE	TREE	AGREE
83	36.402628	44.339538	URBAN	BUILTUP	AGREE
84	36.320981	44.164892	SHRUBLAND	SHRUBLAND	AGREE
85	36.332997	44.168338	SHRUBLAND	SHRUBLAND	AGREE
86	36.490421	44.375465	TREE	TREE	AGREE
87	36.502062	44.346429	URBAN	ARABLE	DISAGREE
88	36.569159	44.295789	ARABLE	ARABLE	AGREE
89	36.568954	44.296236	URBAN	CULTIVATED	DISAGREE
90	36.579116	44.326138	URBAN	SURFACEMATERIAL	AGREE
91	36.579223	44.322642	GRASSLAND	GRASSLAND	AGREE
92	36.545690	44.348773	URBAN	SURFACEMATERIAL	AGREE
93	36.507839	44.384448	ARABLE	ARABLE	AGREE
94	36.508411	44.384754	GRASSLAND	GRASSLAND	AGREE
95	36.509542	44.383645	ARABLE	ARABLE	AGREE
96	36.480959	44.398352	ARABLE	ARABLE	AGREE
97	36.494877	44.395657	ARABLE	ARABLE	AGREE
98	36.493896	44.396191	ARABLE	ARABLE	AGREE
99	36.430197	44.367445	URBAN	ARABLE	DISAGREE
100	36.411201	44.328131	GRASSLAND	GRASSLAND	AGREE
101	36.410473	44.328344	URBAN	ARABLE	DISAGREE
102	36.411768	44.313685	TREE	TREE	AGREE
103	36.411768	44.313685	TREE	TREE	AGREE
104	35.798141	43.641274	TREE	TREE	AGREE
105	36.095020	43.958825	ARABLE	ARABLE	AGREE
106	36.095564	43.958833	ARABLE	ARABLE	AGREE
107	36.095704	43.958373	CULTIVATED	CULTIVATED	AGREE
108	36.010057	43.912331	SHRUBLAND	SHRUBLAND	AGREE
109	35.979044	43.896935	WATER	ARABLE	DISAGREE
110	35.958323	43.874171	ARABLE	ARABLE	AGREE
111	35.953883	43.878124	ARABLE	ARABLE	AGREE
112	35.905763	43.829378	GRASSLAND	GRASSLAND	AGREE
113	35.905409	43.829868	ARABLE	ARABLE	AGREE
114	35.897998	43.810381	GRASSLAND	GRASSLAND	AGREE
115	35.877505	43.810658	URBAN	GRASSLAND	DISAGREE
116	35.876171	43.808879	URBAN	ARABLE	DISAGREE
117	35.867437	43.761533	ARABLE	ARABLE	AGREE
118	35.867237	43.761277	SHRUBLAND	SHRUBLAND	AGREE
119	35.831144	43.694738	WATER	ARABLE	DISAGREE
120	35.827350	43.689555	ARABLE	ARABLE	AGREE
121	35.810382	43.661334	ARABLE	ARABLE	AGREE
122	35.809806	43.663810	CULTIVATED	CULTIVATED	AGREE
123	35.798466	43.642058	ARABLE	ARABLE	AGREE

124	35.795315	43.633040	ARABLE	ARABLE	AGREE
125	35.794879	43.632992	URBAN	BUILTUP	AGREE
126	35.797339	43.630104	URBAN	BUILTUP	AGREE
127	35.797623	43.629333	URBAN	BUILTUP	AGREE
128	35.797151	43.628723	URBAN	BUILTUP	AGREE
129	36.345225	44.004963	TREE	TREE	AGREE
130	36.339427	44.006786	SHRUBLAND	SHRUBLAND	AGREE
131	36.339427	44.006786	SHRUBLAND	SHRUBLAND	AGREE
132	36.338882	44.006194	SHRUBLAND	SHRUBLAND	AGREE
133	36.338613	44.005082	WATER	WATER	AGREE
134	36.338112	44.005016	ARABLE	ARABLE	AGREE
135	36.337692	44.018492	GRASSLAND	GRASSLAND	AGREE
136	36.337563	44.018584	TREE	TREE	AGREE
137	36.337303	44.022102	URBAN	BUILTUP	AGREE
138	36.330946	44.025720	SHRUBLAND	SHRUBLAND	AGREE
139	36.330037	44.025291	SHRUBLAND	SHRUBLAND	AGREE
140	36.319940	44.029264	URBAN	BUILTUP	AGREE
141	36.278887	44.002544	TREE	TREE	AGREE
142	36.339094	44.007052	ARABLE	ARABLE	AGREE
143	36.342965	44.003997	TREE	TREE	AGREE
144	36.350521	44.001990	URBAN	GRASSLAND	DISAGREE
145	36.126917	44.444701	ARABLE	ARABLE	AGREE
146	36.119318	44.457950	GRASSLAND	GRASSLAND	AGREE
147	36.118470	44.459733	ARABLE	ARABLE	AGREE
148	36.104176	44.477867	ARABLE	ARABLE	AGREE
149	36.102632	44.479440	WATER	WATER	AGREE
150	36.079164	44.539753	ARABLE	ARABLE	AGREE
151	36.077561	44.546264	GRASSLAND	GRASSLAND	AGREE
152	36.074929	44.570129	SHRUBLAND	SHRUBLAND	AGREE
153	36.074544	44.576004	GRASSLAND	GRASSLAND	AGREE
154	36.077070	44.600472	URBAN	ARABLE	DISAGREE
155	36.074942	44.599644	SHRUBLAND	SHRUBLAND	AGREE
156	36.089880	44.629730	URBAN	BUILTUP	AGREE
157	36.029164	44.759429	GRASSLAND	GRASSLAND	AGREE
158	36.026624	44.761108	ARABLE	ARABLE	AGREE
159	36.005586	44.786356	ARABLE	ARABLE	AGREE
160	35.987839	44.797983	ARABLE	ARABLE	AGREE
161	35.986094	44.799789	ARABLE	ARABLE	AGREE
162	35.973882	44.804095	ARABLE	ARABLE	AGREE
163	35.970747	44.806158	GRASSLAND	GRASSLAND	AGREE
164	35.970369	44.807908	CULTIVATED	CULTIVATED	AGREE
165	35.930934	44.826352	GRASSLAND	GRASSLAND	AGREE
166	35.926151	44.831429	ARABLE	ARABLE	AGREE
167	36.904680	43.141510	TREE	TREE	AGREE
168	36.905970	43.146660	URBAN	BUILTUP	AGREE
169	37.024410	43.145580	ARABLE	ARABLE	AGREE
170	37.033580	43.096870	URBAN	BUILTUP	AGREE
171	37.015530	43.042550	ARABLE	ARABLE	AGREE
172	37.033600	43.277780	WATER	WATER	AGREE
173	37.098540	43.384280	URBAN	BUILTUP	AGREE
174	37.174076	43.772078	TREE	TREE	AGREE
175	37.090640	43.486290	URBAN	BUILTUP	AGREE
176	36.647790	43.384000	ARABLE	ARABLE	AGREE
177	36.901360	43.740300	TREE	TREE	AGREE
178	36.712280	43.919050	GRASSLAND	GRASSLAND	AGREE
179	36.763060	43.904710	GRASSLAND	GRASSLAND	AGREE
180	35.924555	44.916934	SHRUBLAND	SHRUBLAND	AGREE
181	35.926821	44.920610	URBAN	SURFACEMATERIAL	AGREE
182	35.931752	44.910736	GRASSLAND	GRASSLAND	AGREE
183	35.929546	44.917975	URBAN	SURFACEMATERIAL	AGREE
184	35.930863	44.918361	GRASSLAND	GRASSLAND	AGREE
185	35.929211	44.927948	GRASSLAND	GRASSLAND	AGREE
186	35.929514	44.939388	ARABLE	ARABLE	AGREE
187	35.928918	44.938873	GRASSLAND	GRASSLAND	AGREE
188	35.932517	44.950962	GRASSLAND	GRASSLAND	AGREE
189	35.924639	44.962586	WATER	WATER	AGREE

190	35.920262	44.975724	ARABLE	ARABLE	AGREE
191	35.917686	44.978942	ARABLE	ARABLE	AGREE
192	35.863152	45.041290	TREE	TREE	AGREE
193	35.861314	45.044420	URBAN	GRASSLAND	DISAGREE
194	35.861910	45.045044	CULTIVATED	CULTIVATED	AGREE
195	35.848631	45.062295	CULTIVATED	CULTIVATED	AGREE
196	35.840192	45.077809	GRASSLAND	GRASSLAND	AGREE
197	35.728738	45.151118	URBAN	SURFACEMATERIAL	AGREE
198	35.662703	45.212810	CULTIVATED	CULTIVATED	AGREE
199	35.628163	45.224229	URBAN	SURFACEMATERIAL	AGREE
200	35.633068	45.217010	ARABLE	ARABLE	AGREE
201	35.584959	45.279140	SHRUBLAND	SHRUBLAND	AGREE
202	35.581262	45.377841	WATER	WATER	AGREE
203	35.579393	45.376721	WATER	WATER	AGREE
204	35.587396	45.381866	WATER	WATER	AGREE
205	35.589318	45.382371	TREE	TREE	AGREE
206	35.580792	45.468090	URBAN	SURFACEMATERIAL	AGREE
207	35.585645	45.468499	WATER	WATER	AGREE
208	35.582565	45.468309	TREE	TREE	AGREE
209	35.593956	45.466021	TREE	TREE	AGREE
210	35.600143	45.466100	TREE	TREE	AGREE
211	35.601644	45.472126	GRASSLAND	GRASSLAND	AGREE
212	35.600651	45.474696	TREE	TREE	AGREE
213	35.576877	45.487849	GRASSLAND	GRASSLAND	AGREE
214	35.577072	45.488296	GRASSLAND	GRASSLAND	AGREE
215	35.400000	45.642000	CULTIVATED	CULTIVATED	AGREE
216	35.385000	45.748000	TREE	TREE	AGREE
217	35.365000	45.819000	URBAN	SURFACEMATERIAL	AGREE
218	35.298180	45.036890	URBAN	SURFACEMATERIAL	AGREE
219	35.349000	45.911000	CULTIVATED	SURFACEMATERIAL	DISAGREE
220	35.353220	45.882500	SHRUBLAND	SHRUBLAND	AGREE
221	35.354000	45.872000	GRASSLAND	GRASSLAND	AGREE
222	35.377000	45.832000	WATER	WATER	AGREE
223	35.380000	45.829000	TREE	TREE	AGREE
224	35.382000	45.826000	GRASSLAND	GRASSLAND	AGREE
225	35.422200	45.556900	URBAN	GRASSLAND	DISAGREE
226	35.467000	45.508000	SHRUBLAND	SHRUBLAND	AGREE
227	34.815000	45.510000	GRASSLAND	GRASSLAND	AGREE
228	34.782000	45.429000	ARABLE	ARABLE	AGREE
229	34.769000	45.467000	URBAN	ARABLE	DISAGREE
230	34.727000	45.457000	ARABLE	ARABLE	AGREE
231	34.701000	45.434000	URBAN	SURFACEMATERIAL	AGREE
232	34.655000	45.383000	URBAN	BUILTUP	AGREE
233	34.650000	45.259000	URBAN	BUILTUP	AGREE
234	34.716000	45.127000	ARABLE	ARABLE	AGREE
235	34.725000	45.032000	SHRUBLAND	SHRUBLAND	AGREE
236	34.677000	44.996000	ARABLE	ARABLE	AGREE
237	34.679000	44.949000	URBAN	SURFACEMATERIAL	AGREE
238	34.714000	44.972000	SHRUBLAND	SHRUBLAND	AGREE
239	34.722000	44.974000	WATER	WATER	AGREE
240	34.718000	44.966000	ARABLE	ARABLE	AGREE
241	34.697000	45.053000	ARABLE	ARABLE	AGREE
242	34.734000	45.076000	ARABLE	ARABLE	AGREE
243	34.732000	45.102000	URBAN	ARABLE	DISAGREE
244	34.711000	45.136000	TREE	TREE	AGREE
245	34.683000	45.178000	ARABLE	ARABLE	AGREE
246	34.678000	45.207000	ARABLE	ARABLE	AGREE
247	34.692000	45.210000	ARABLE	ARABLE	AGREE
248	34.721000	45.198000	ARABLE	ARABLE	AGREE
249	34.754000	45.195000	SHRUBLAND	SHRUBLAND	AGREE
250	34.930000	45.195000	GRASSLAND	GRASSLAND	AGREE
251	34.889000	45.088000	GRASSLAND	GRASSLAND	AGREE
252	35.011000	45.124000	ARABLE	ARABLE	AGREE
253	35.025000	45.112000	GRASSLAND	GRASSLAND	AGREE
254	35.283000	45.186000	URBAN	ARABLE	DISAGREE
255	35.310000	45.245000	GRASSLAND	GRASSLAND	AGREE

256	35.335000	45.253000	GRASSLAND	GRASSLAND	AGREE
257	34.342000	45.277000	GRASSLAND	GRASSLAND	AGREE
258	35.339000	45.306000	SHRUBLAND	SHRUBLAND	AGREE
259	35.340000	45.310000	WATER	WATER	AGREE
260	35.249100	45.939000	TREE	TREE	AGREE
261	35.255000	45.937000	URBAN	URBAN	AGREE
262	35.228000	46.008000	ARABLE	ARABLE	AGREE
263	35.229000	46.011000	CULTIVATED	CULTIVATED	AGREE
264	35.227000	46.117000	TREE	TREE	AGREE
265	35.207000	46.134000	TREE	TREE	AGREE
266	35.214070	46.187500	TREE	TREE	AGREE
267	35.217030	46.188930	GRASSLAND	GRASSLAND	AGREE
268	35.199620	46.151130	URBAN	URBAN	AGREE
269	35.206200	46.134000	GRASSLAND	GRASSLAND	AGREE
270	35.226000	46.093000	ARABLE	ARABLE	AGREE
271	35.305000	46.065000	GRASSLAND	GRASSLAND	AGREE
272	35.306780	46.063150	WATER	WATER	AGREE
273	35.296330	46.058040	CULTIVATED	CULTIVATED	AGREE
274	35.308000	46.004000	WATER	WATER	AGREE
275	35.313000	46.000000	ARABLE	ARABLE	AGREE

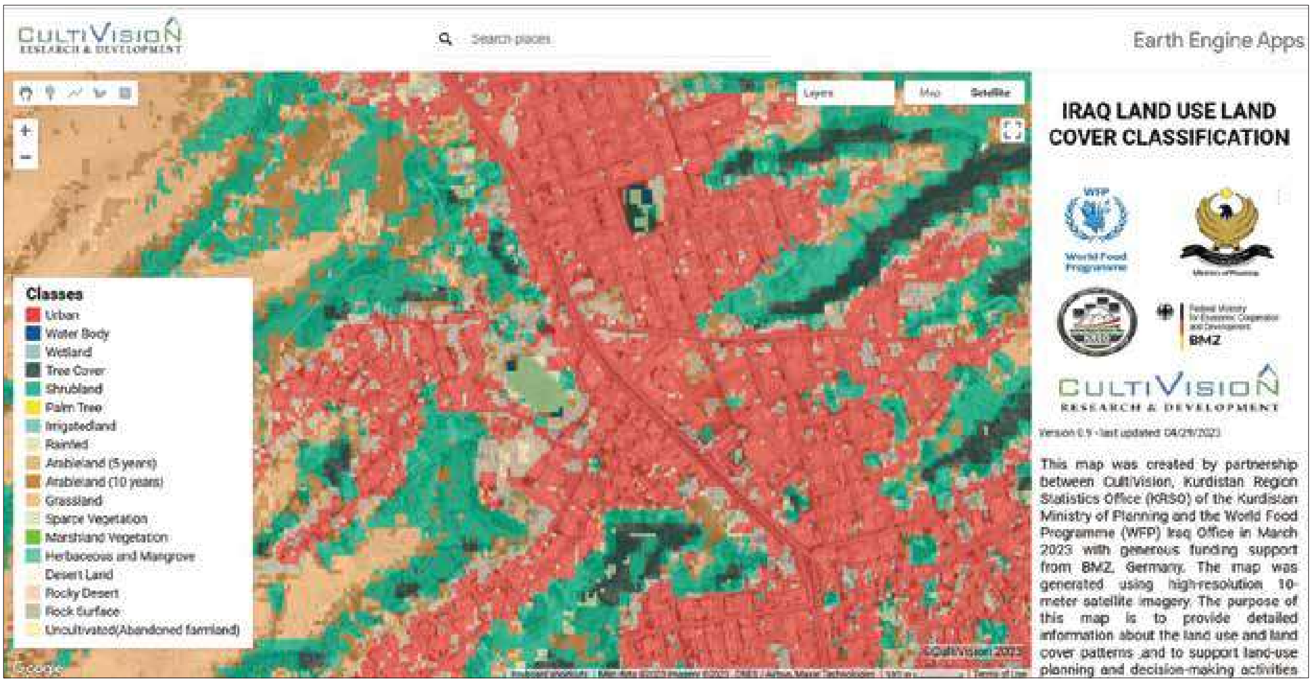
Note. Image satellite high-resolution (HR) and LULC (Land Use and Land Cover) based on Sentinel are two different approaches for obtaining information about the earth's surface. High-resolution satellite images are obtained by capturing images of the earth's surface from space using satellites. These images provide high spatial resolution, allowing us to see detailed features on the ground, such as roads, buildings, and vegetation. High-resolution satellite images can be used for various applications such as urban planning, disaster management, and environmental monitoring.

On the other hand, LULC classification based on Sentinel is a process of categorizing the land surface into different types of land use and land cover based on data obtained from the Sentinel satellite. This approach uses data from different spectral bands to classify the land surface into various categories such as forests, water bodies, and urban areas.

The main difference between the two approaches is that high-resolution satellite images provide more detailed information about the earth's surface, while LULC classification based on Sentinel provides information about the distribution of different land use and land cover types. High-resolution satellite images are suitable for applications where detailed information about the earth's surface is required, while LULC classification based on Sentinel is suitable for applications that require information about the distribution of land use and land cover types over a large area.

Appendix. Figure A

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).



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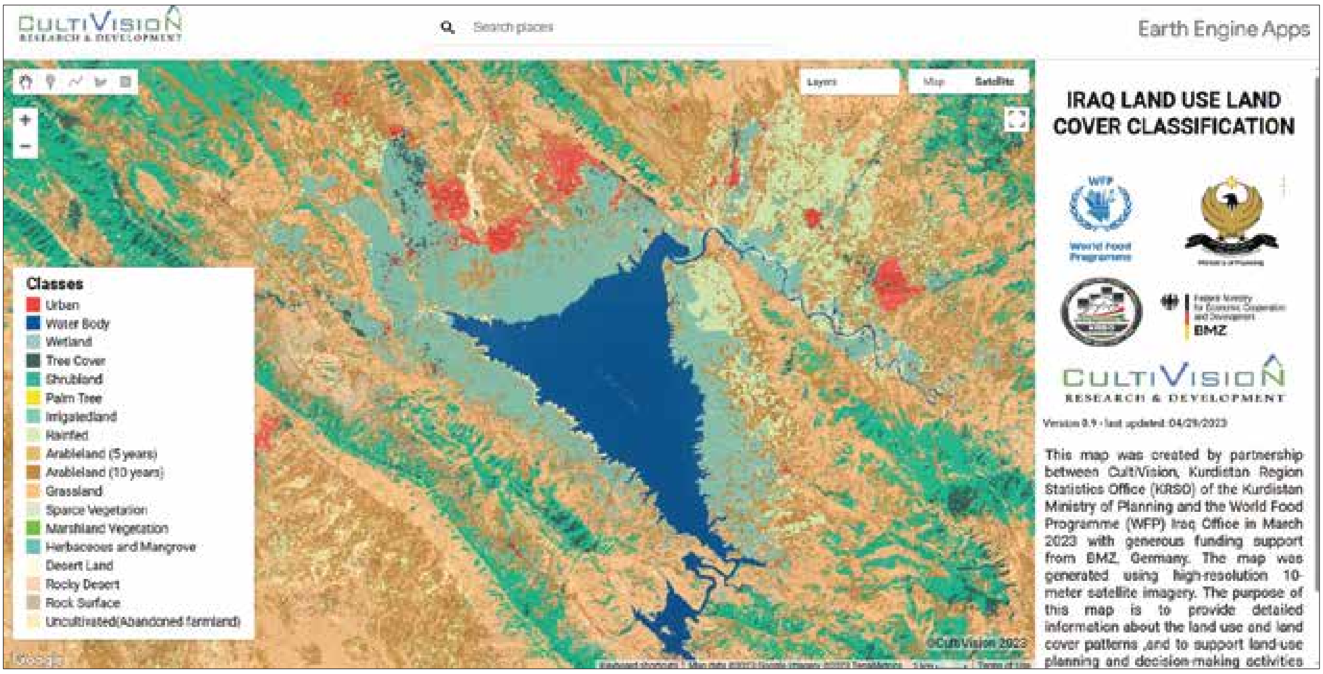
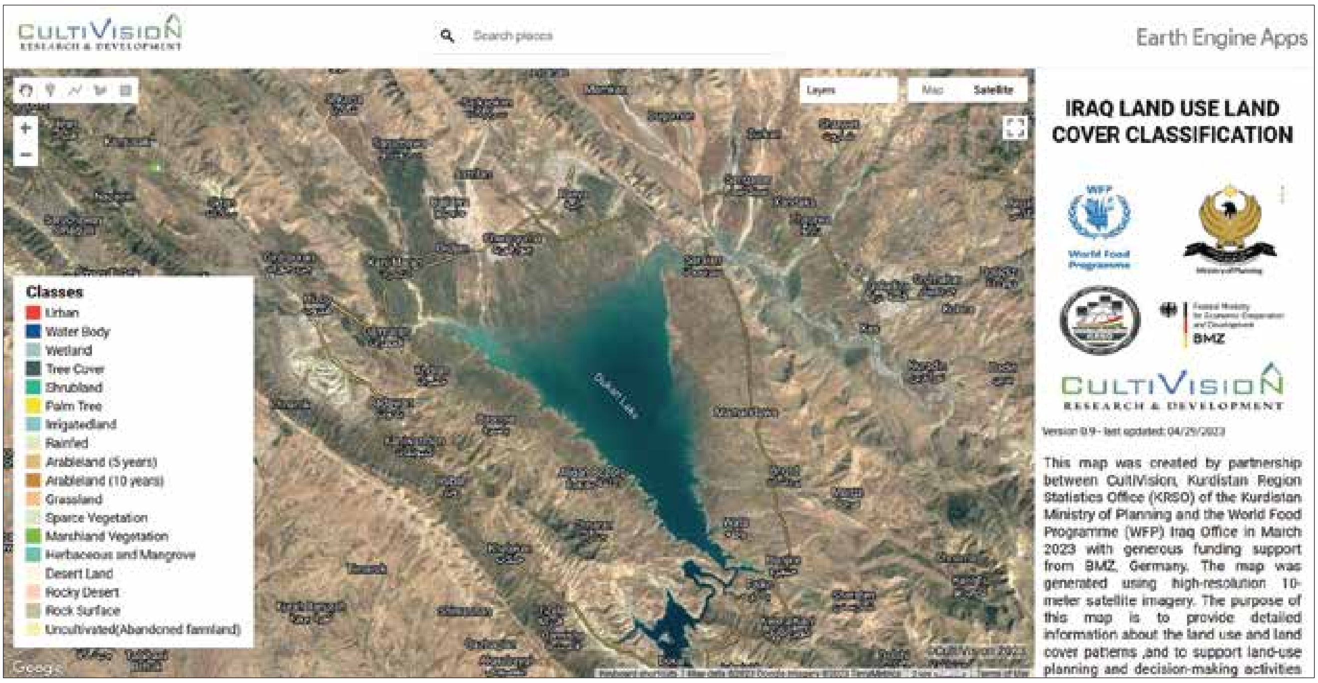
Appendix. Figure B

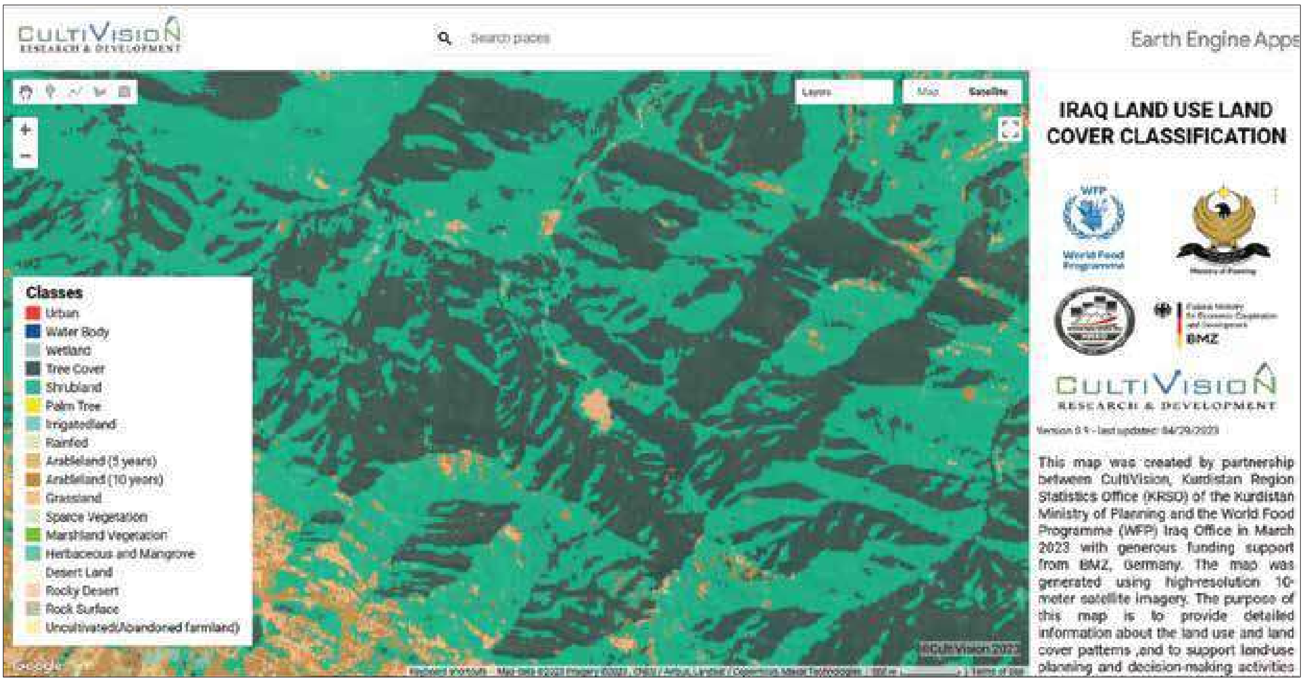
Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).

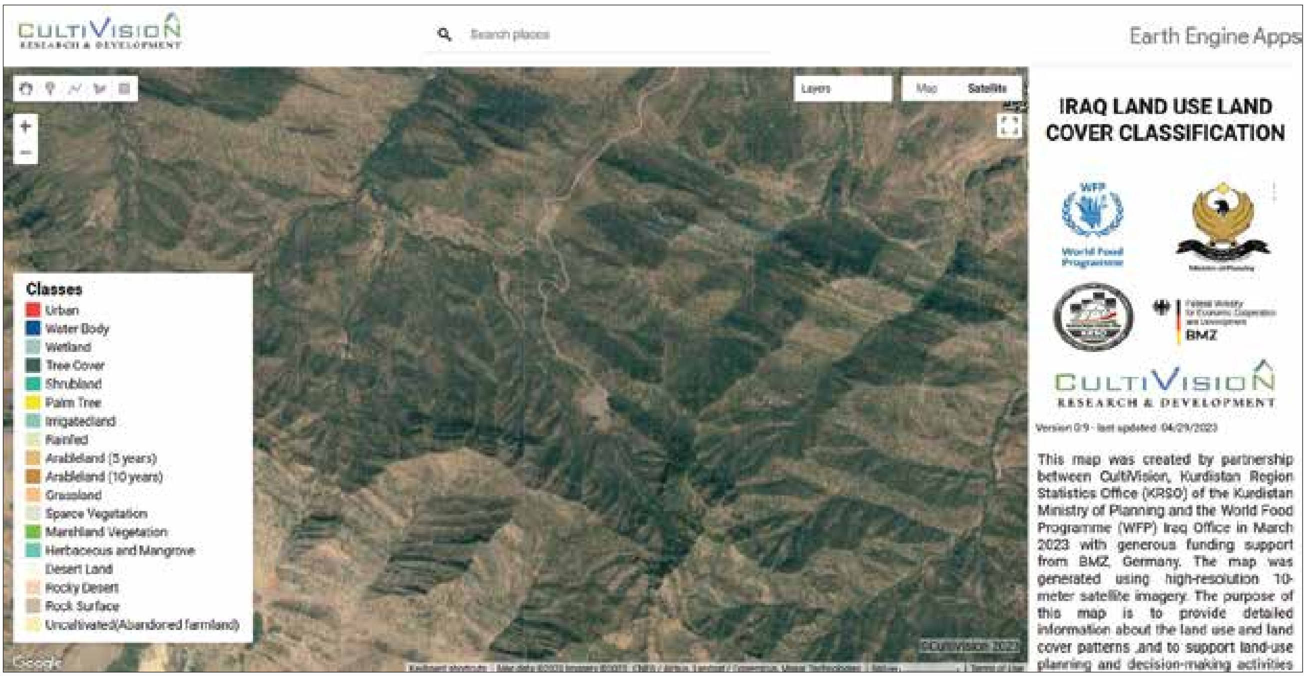




Appendix. Figure C

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).



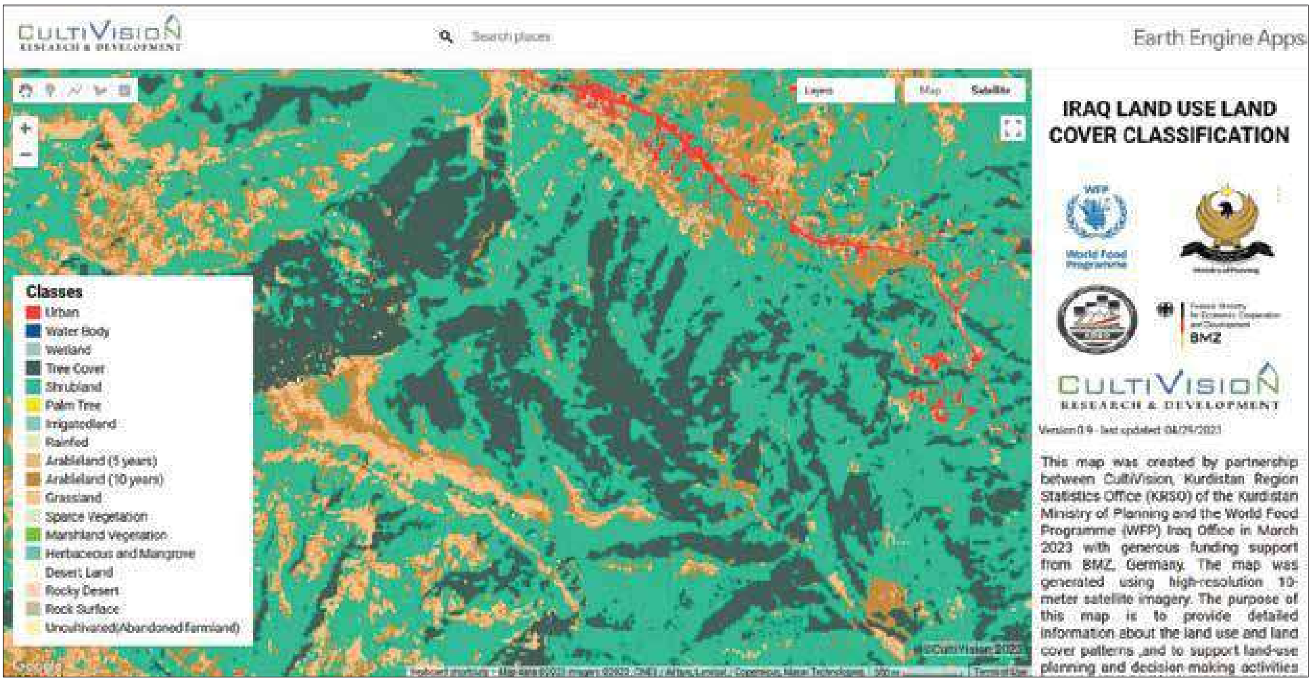


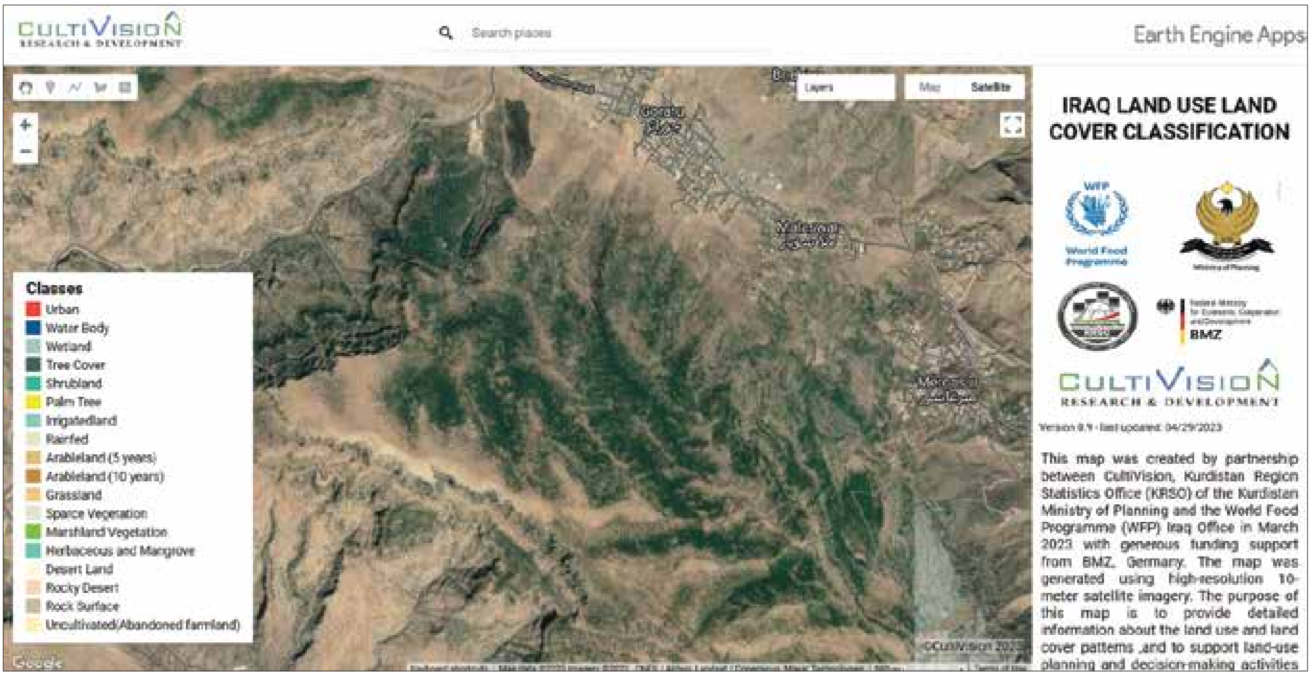
Appendix. Figure D

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).

Appendix. Figure E

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).





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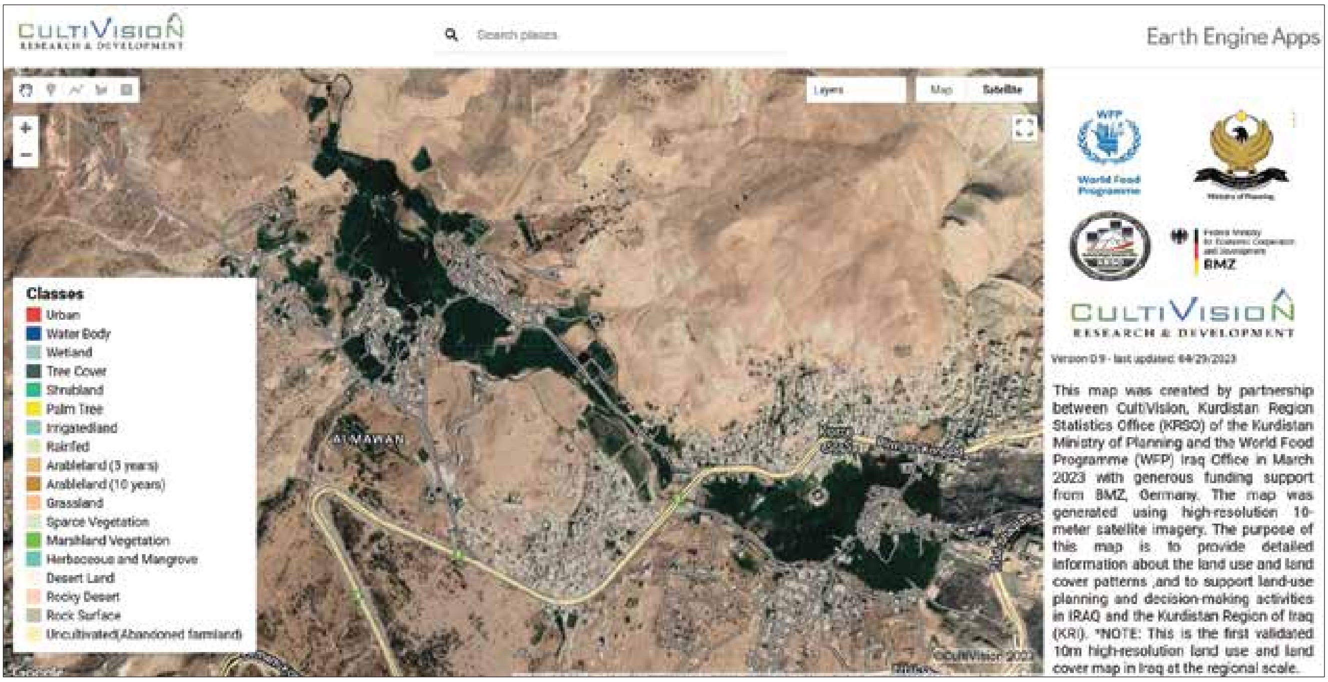
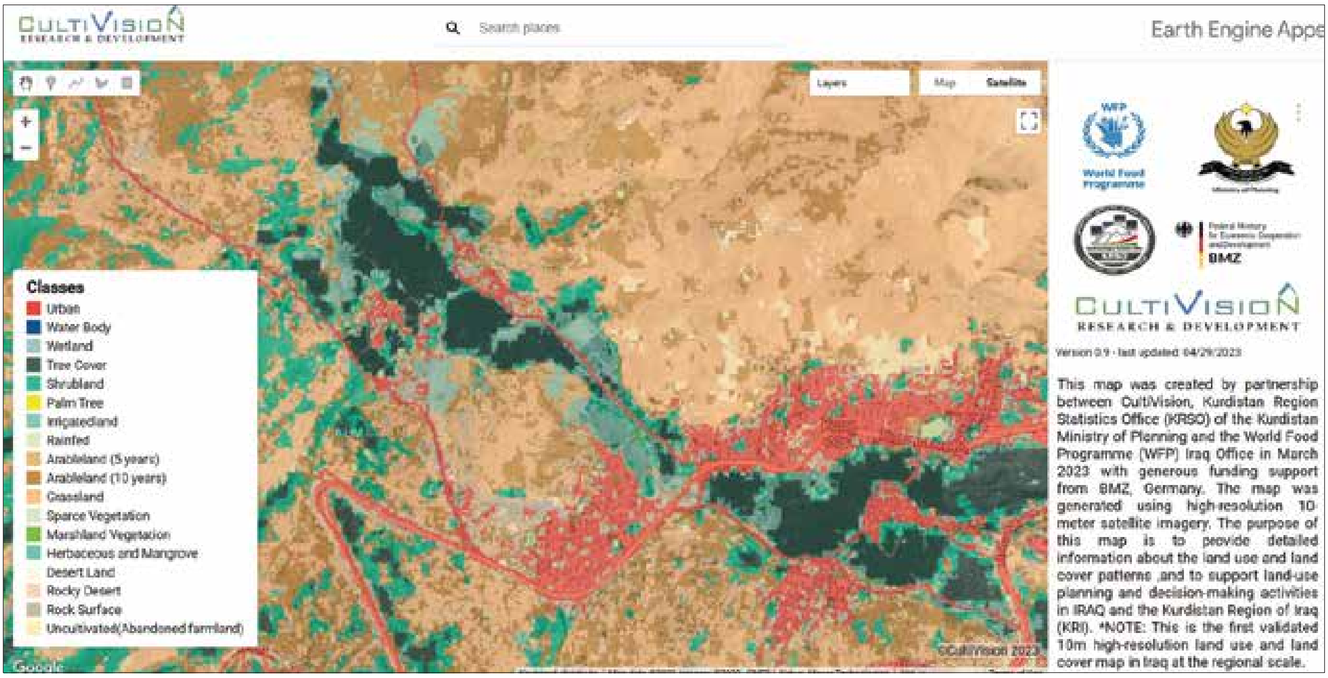
Appendix. Figure F

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).



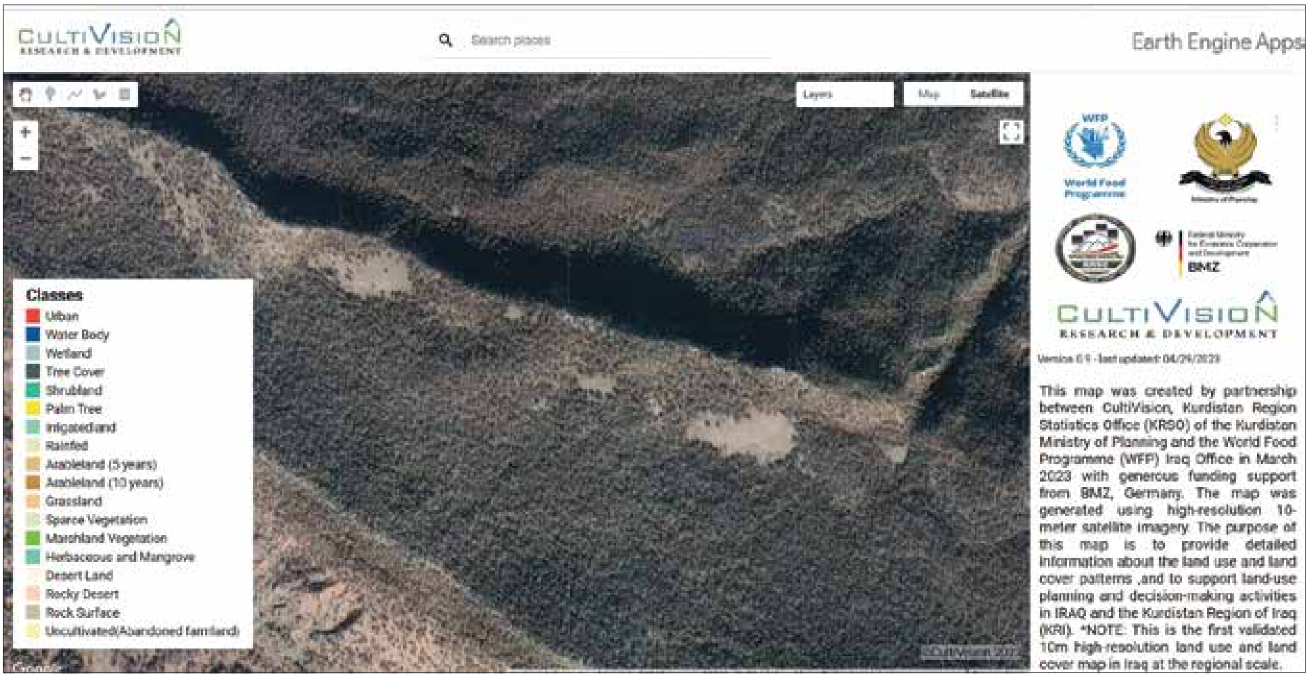


Appendix. Figure G

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).

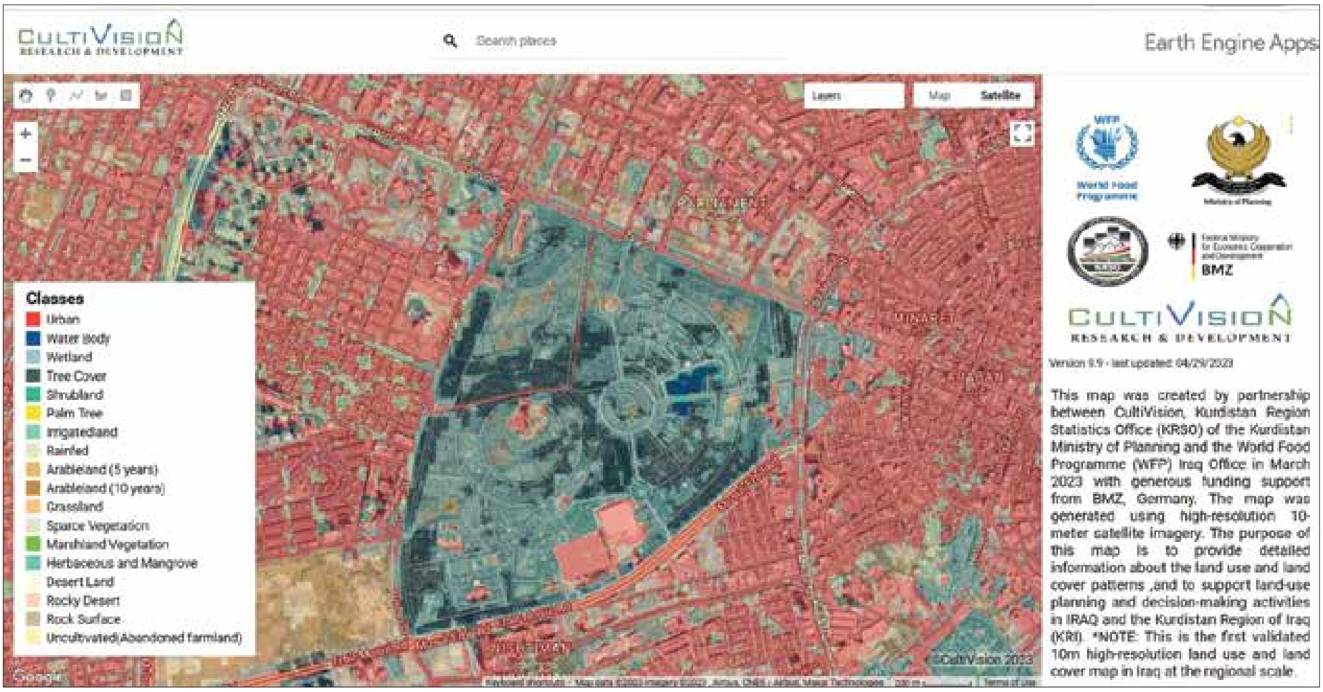
Appendix. Figure H

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).



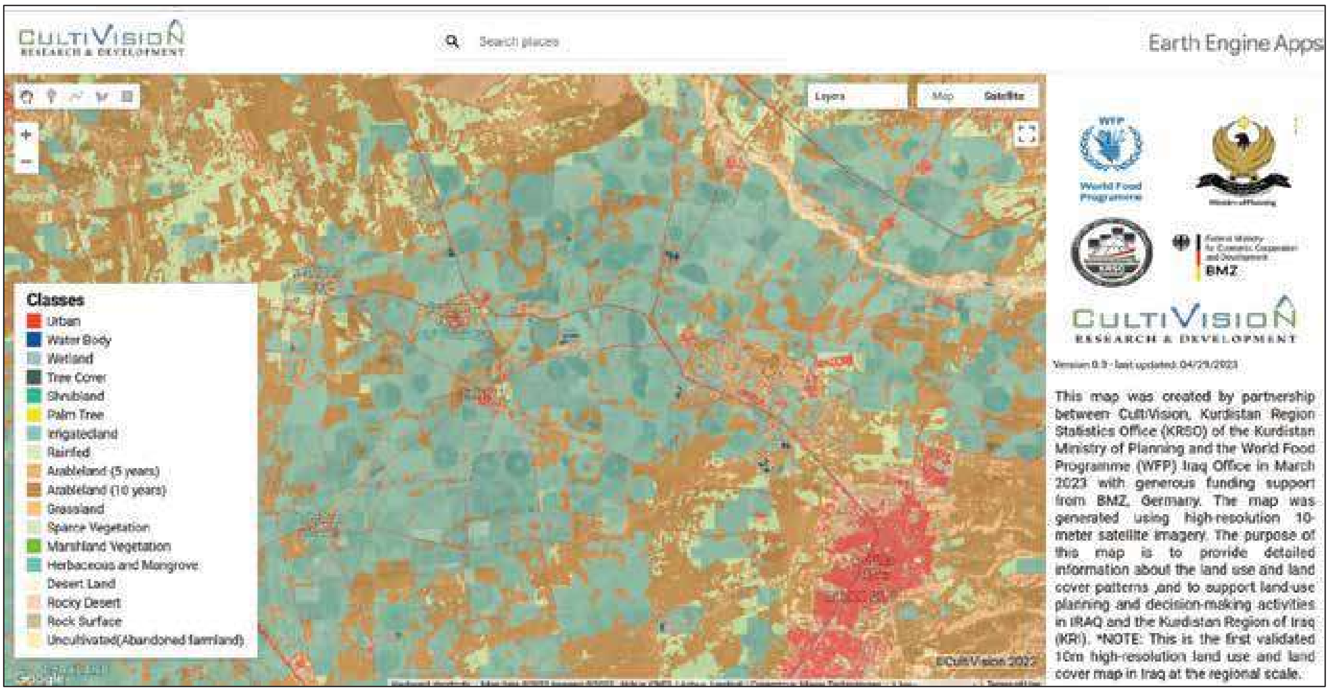
Appendix. Figure I

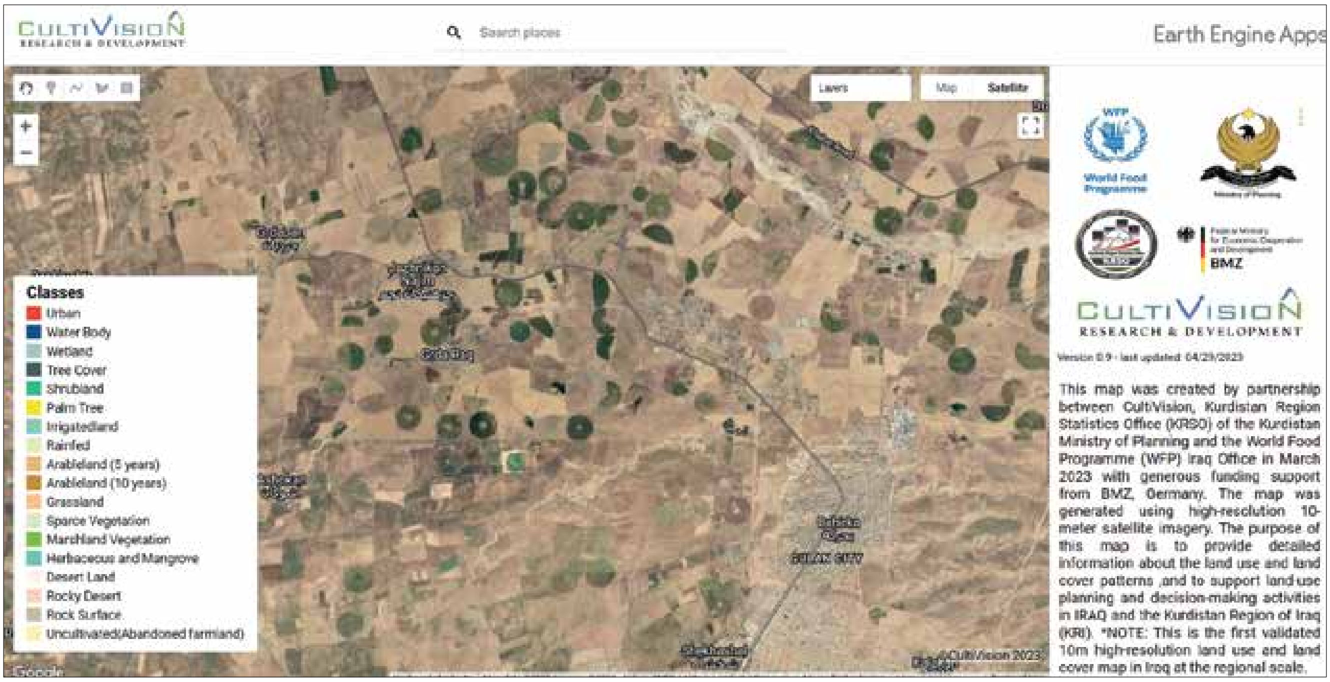
Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).



Appendix. Figure J

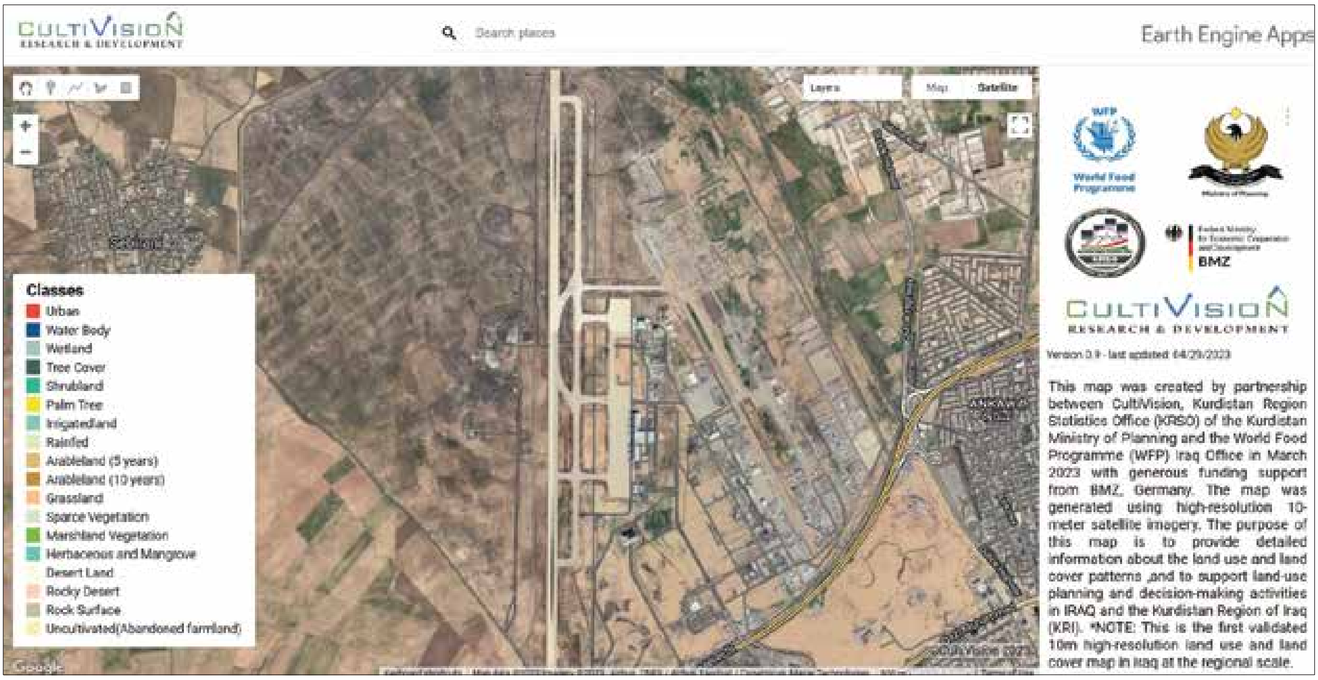
Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).





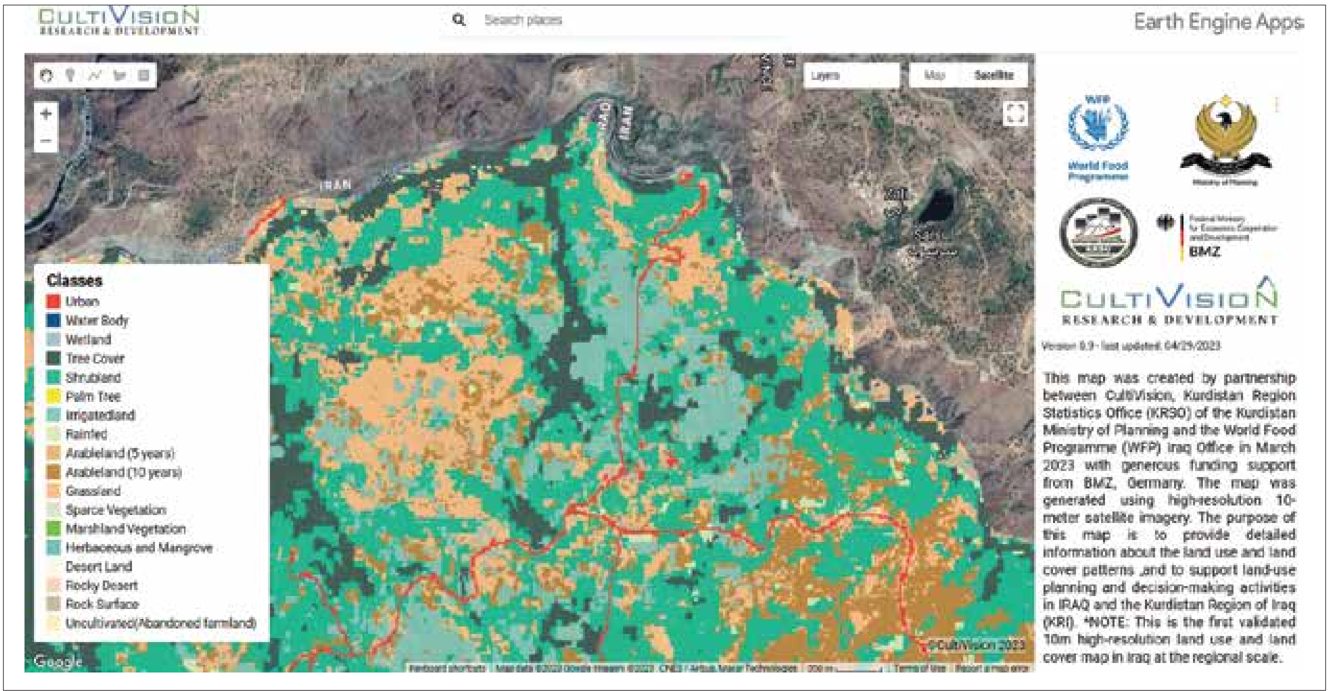
Appendix. Figure K

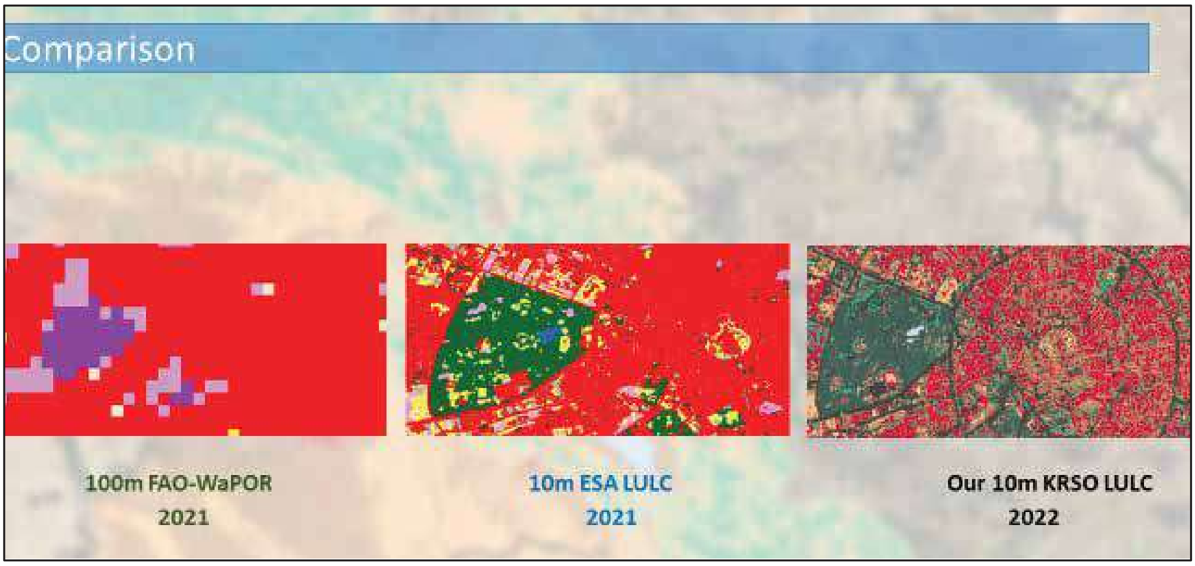
Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).

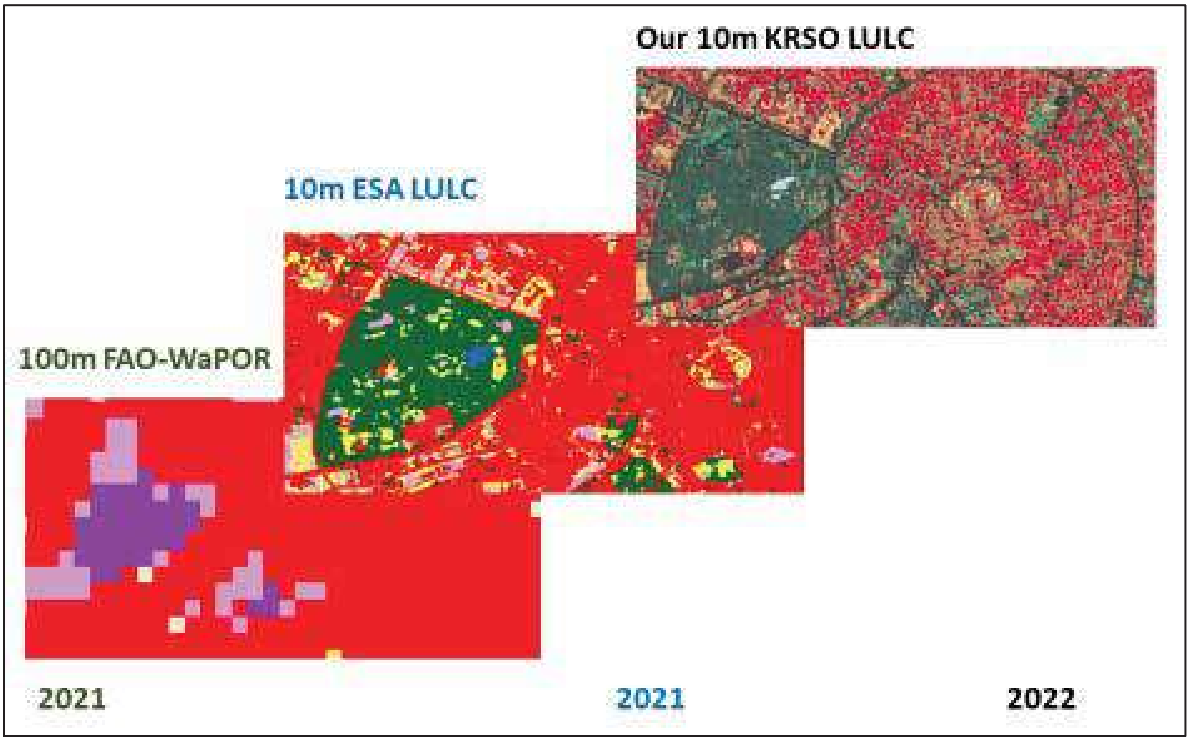


Appendix. Figure L

Comparing the accuracy of the results between satellite images and land classification images in Urban, Water Body, Wetland, Tree Cover, Shrubland, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparce Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).




Comparison
100m FAO-WaPOR
2021
10m ESA LULC
2021
Our 10m KRSO LULC
2022


Our 10m KRSO LULC
10m ESA LULC
100m FAO-WaPOR
2021
2021
2022

Note: Field data collection is an important component of LULC analysis, as it provides critical information that cannot be obtained through remote sensing alone.

Field data collection about Land Use Land Cover (LULC) is an important process for obtaining accurate and up-to-date information about the spatial distribution and characteristics of different land cover types in a given area. Here are some general steps that taken to collect field data on LULC:
Define study area: In the first, the area selected a location that represents the extent of the analysis.

Develop a sampling plan: Developed a sampling plan that outlines the location and number of sample points within the study area.
Collect ground truth data: At each sample point, collected ground truth data on the land cover types present in the area. This done using a combination of field observations and measurements, including visual interpretation of aerial or satellite imagery, direct measurements of vegetation cover.

Record data: The data obtained at each sample point, including the land cover type, vegetation cover, and any other relevant information.

Analyze data: The data collected to create a detailed map of the LULC in the study area. This was done using GIS software or other mapping tools.

Validate the results: Validate the accuracy of the LULC map by comparing it with existing data sources or by conducting additional fieldwork to confirm the results.

Appendix. Figure O

Field data collection about Land Use Land Cover (LULC) process by KRSO Team

Appendix. Figure P

Field data collection about Land Use Land Cover (LULC) process by KRO Team

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