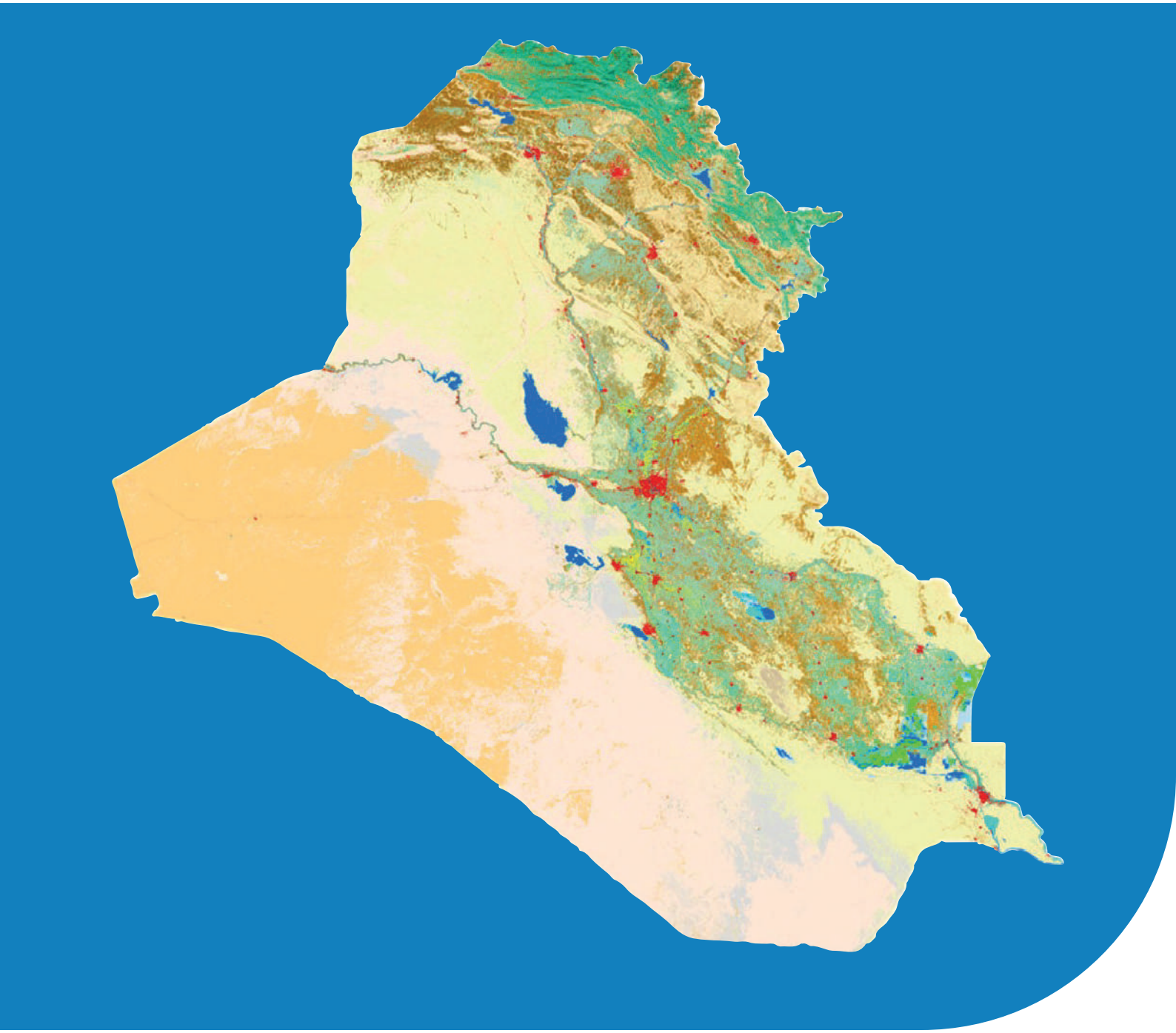
REMOTE SENSING & MACHINE LEARNING BASED HIGH-RESOLUTION LAND

Use Land Cover Classification Map for Iraq
A Step towards Improved Land and Water Management for Food Security



FINAL REPORT

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Project Title: Remote Sensing and Machine Learning-Based High-Resolution Land Use Land Cover Classification Map for Iraq: A Step towards Improved Land and Water Management for Food Security

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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

Foreword

On the occasion that coincides with the World Earth Day and the Climate Summit, we are pleased to launch the results of the Iraqi Land Use and Land Cover Classification Project which is an outcome of framework of joint coordination and cooperation between Government institutions and research centers and with financial and technical support from international agencies working in Iraq. The data and information issued by the Central Statistics Organization (CSO (and the ministries (Ministry of Agriculture and Ministry of Water Resources) contributed to enriching this important and interesting project related to the environment and society. The efforts of the World Food Program (WFP) and (CultiVision) for Research and Development Foundation have joined efforts with (GIZ) Organization to work on identifying and documenting lands and their use on the surface of the Earth in order to be able to know cultivated lands, grassland, forests, deserts, marshland vegetation , cities and other different categories. The results of this project will help to understand environmental changes, human impacts on natural resources, and the extent to which agricultural lands are affected by desertification, erosion, and drought. In addition, this project will enable to identify forested, abandoned or irrigated areas suitable for agriculture, and estimating the effects of urban expansion on those areas due to population expansion and the resulting impact on the quality of life, health and security of the residents of those areas that are not prepared for housing.

Ladies and gentlemen.

The results showed that the largest part of Iraq's area is classified as desert at a rate of approximately %42, and abandoned agricultural lands occupy the second largest area at a rate of %22.2, while irrigated lands for agriculture amount to only %5.7 of the total area; while grasslands and scattered plants together constitute %10.3, which are important areas for livestock herders.

As we present the results of this first-of-its-kind project in Iraq using geographic information systems to support decision-makers and researchers for sustainable planning and management of the land, the most important recommendations and suggestions emerging from those in charge of this work are as follows:

1. Improving the ability to monitor, evaluate and forecast to confront climate and environmental changes and reduce human impacts on them.

2. Work on land sustainability in a way that achieves a balance between preserving the environment and meeting human and economic needs.

3. The importance of using modern technological means such as geographic information systems to provide comprehensive and updated data on land use in various regions.

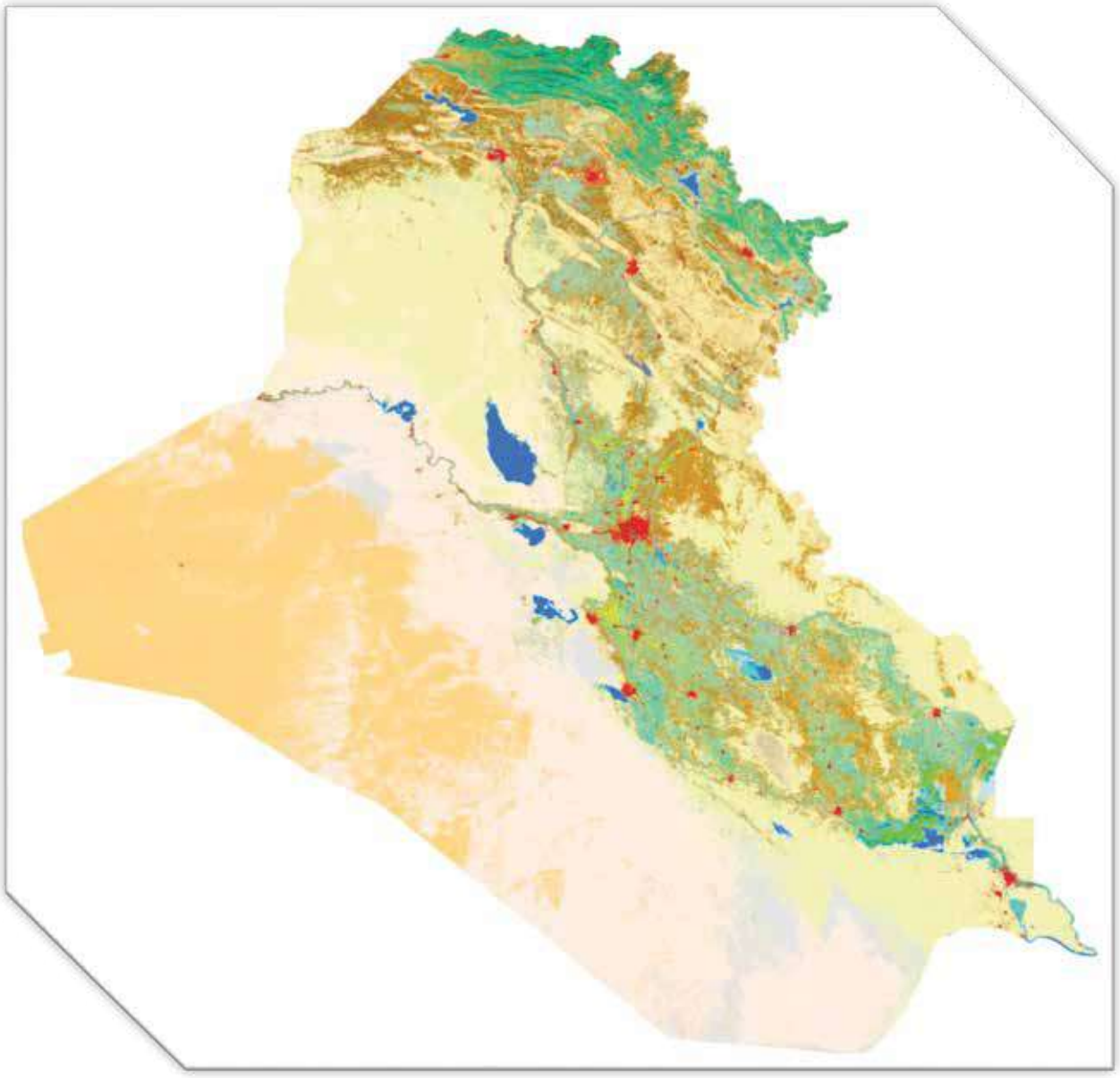
4. The need to disseminate environmental awareness and increase knowledge of environmental and development commitments in a way that serves the threat of achieving the sustainable development goals and the United Nations Convention to Combat Desertification and the Paris Climate Agreement.

5. Assuming responsibility between various governmental and civil authorities, organizations and research centers to enhance knowledge exchange of advanced global methodologies related to the project.

In conclusion, I can only appreciate with great pride all the contributors to this distinguished effort and the true partnership between the World Food Program (WFP) and the project sponsor from the (GIZ) organization and the close cooperation between the ministries involved in this project. Thanks also are due to Dr. Haiman from the (CultiVision) Research Foundation and development.

Dr. Dhia Khadum
Ministry of Planning
CSO Chairman

Remote Sensing and Machine Learning-Based High-Resolution Land Use Land Cover Classification Map for Iraq: A Step towards Improved Land and Water Management for Food Security



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Abstract

The land use and land cover (LULC) classes for Iraq have been produced, analysed and presented in this research project. The analysis provides insights into the distribution of different land use types and their corresponding areas within each province of Iraq. The LULC classes in Iraq include urban, water bodies, wetlands, dense forests, open forests, palm trees, irrigated land, rainfed land, arable land for 5 years, arable land for 10 years, grassland, sparse vegetation, marshland vegetation, herbaceous and mangrove, desert land, rocky desert, rocky surface, and uncultivated or abandoned farmland.

The largest areas of land in Iraq are covered by desert land and rocky desert, which together occupy %41.89 of the total land area of the country. The desert land is characterized by sandy or rocky terrain with sparse vegetation and minimal human settlements. Rocky desert areas are dominated by rocky outcrops with little or no vegetation.

Urban areas cover only %1.29 of the total land area of Iraq. Water bodies occupy %1.25 of the land area, with the Tigris and Euphrates rivers being the major sources. Wetlands cover only %0.26 of the total land area, but are important for biodiversity conservation and provide habitats for many species of birds and animals. Irrigated land is crucial for agriculture in Iraq, and it covers %5.78 of the total land area. Rainfed land covers %0.55 of the land area, and is used for cultivation of crops that require less water. Arable land for 5 years and arable land for 10 years which are usually rainfed lands cover %3.1 and %7.58 of the land area, respectively. Grassland and sparse vegetation together occupy %10.36 of the total land area, providing important grazing areas for livestock for local communities. Marshland vegetation covers only %0.28 of the total land area, but it is a critical habitat for biodiversity conservation. Herbaceous and mangrove areas cover %1.42 of the land area, providing important habitats for aquatic and terrestrial species.

Finally, abandoned farmland occupies the second largest area of land among all LULC classes in Iraq, covering %22.21 of the total land area. This reflects the challenges faced by farmers in the country, such as water scarcity, poor soil health, and lack of agricultural inputs and support.

In conclusion, the LULC classes in Iraq reflect the diverse geography and ecological zones of the country. The analysis of LULC classes provides useful information for land use planning, natural resource management, and conservation efforts in Iraq.

1. Executive summary

This project report provides a detailed analysis of the land use and land cover (LULC) classes in Iraq, highlighting the challenges and opportunities in managing the country's natural resources. The report reveals that desert land and rocky desert dominate the country's land area, covering nearly %42. Urban areas, water bodies, and wetlands occupy a small fraction of the land area, while abandoned farmland covers over %22. Based on the findings of the report, the following recommendations are made:

- Promote sustainable agricultural practices: Given the challenges faced by farmers in Iraq, there is a need to promote sustainable agricultural practices that can help in improving soil health, conserving water resources, and increasing crop yields.
- Conservation of wetlands and marshland vegetation: Despite occupying a small portion of the land area, wetlands and marshland vegetation are critical habitats for biodiversity conservation, they are also precious natural resources in Iraq. 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 %1 of the land area covered by Dense Forest (including Dense Forests and Open Forests, often present in the Kurdistan Region) and palm trees, there is a need to 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 country.
- Improve land use planning: The analysis of LULC classes provides useful information for land use planning, and it is important to use this information to guide the development and management of natural resources in each province and throughout Iraq. A better understanding of the country's LULC classes can help in identifying areas that are suitable for different land uses and prevent the misuse of natural resources.

In conclusion, the project report provides valuable insights into the distribution of different land use types in Iraq and their corresponding areas. The recommendations made in the report can help in promoting sustainable land use practices, conserving natural resources, and protecting biodiversity in Iraq.

The global land cover is progressively changing due to anthropogenic activities

2. Introduction

(i.e., urbanisation and agricultural expansion) and natural processes (e.g., flooding, natural bushfires) (Yang et al., 2020). These changes influence human life, and therefore effective monitoring mechanisms are required for the sustainable management and utilisation of natural resources (e.g., forests, land, and water). The development of satellite remote sensing technology has revolutionised the approaches to monitoring the natural resources and human activities on the Earth's surface, and this technology makes it possible to regularly monitor these resources. Information on land use and land cover (LULC) including forest cover, agronomic and human activities is important for the development of strategies for land planning and management.

Land use and land cover mapping have always been of interest to researchers, government authorities, land managers, and international organisations because of their association with ecological changes, hydrology, climate change, ecosystem services and socio-economic issues (Serra et al. 2014; Fei et al., 2018). The LULC is a significant and noticeable transformation to the Earth's surface, the dynamic nature of LULC needs the regular updating of LULC maps. LULC maps are valuable for illustrating the interactions between the Earth's land surface and atmosphere and portraying the connections between human activities and the natural environment. Precise geoinformation on these interactions is necessary for policymakers to establish sustainable development and planning policies. Remote Sensing (RS) systems collect useful datasets for a variety of applications (Mirmazloumi et al., 2022).

The primary categories of LULC are agricultural lands use and built-up lands. Areas with minimal human influence are typically classified as "land cover," including water bodies, rangeland, and bare land. Accurate assessment of LULC change at various geographic scales is essential in environmental conservation, resource management, land use planning, and sustainable development. To reduce the negative impacts of LULC change, detailed plans based on LULC data are necessary, which require 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 is necessary for achieving these goals, although the specific objectives may vary among producers and consumers (Mirmazloumi et al., 2022).

On a global and regional scale, human demands, climate change, and environmental, cultural, and economic constraints have significantly

influenced LULC change and the ability of biological systems to fulfil human needs. These changes are caused by human activities such as urbanisation, industrialisation, mismanaged agricultural practices, deforestation, and overgrazing, which can directly and indirectly stress natural resources and subsequently ecosystem degradation. Natural disasters such as heavy rainfall, extended drought, temperature rises, and flooding are also projected to wreak havoc on land cover, posing a threat to the provision of human resources on earth. To manage available resources and monitor environmental changes, LULC data is required to appropriately identify changes in the past and present and to plan for future sustainable development. Sustainable development solutions depend on regional and local variables, which makes LULC analysis critical. 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 land use classification.

Iraq (officially is the Republic of Iraq) is a populated country in Western Asia. It is bordered by Turkey, Iran, Jordan, Saudi Arabia and the Persian Gulf and Kuwait. The total area of Iraq is 437,072 Km2, about the size of California. Iraq's capital city is Baghdad, with other well-known cities Basra, Mosul, Najaf, Kerbala, Erbil, and Kirkuk. This land society has a rich history with many firsts, including the world's first cities, irrigation systems, states, empires, writing, monuments, and recorded religions. The Mesopotamian civilization was innovative but also brutal, creating hierarchies and classes that brought order and meaning to life. The Sumerians, Akkadians, Babylonians, and Assyrians built large and well-organized civilizations whose cultural contributions continue to influence Eastern and Western civilisations today. The legacy of these civilizations gives us a deeper understanding of our past and ourselves. (Fattah and Caso 2009). These civilizations participated in major land use and land cover alteration throughout the history of this land. Moreover, Iraq encountered various challenges in the last century such as social, economic, political and security instabilities including civilian displacement due to local conflicts and wars with neighbouring countries (Iraq-Iran war 1988–1980 and Iraq-Kuwait war in 1991–1990) (Ulrichsen 2013). The Islamic state organisation also caused millions of people to be displaced both internally and internationally (Dora

2021). Additionally, natural factors such as climate change, flooding, and increasing temperatures have also impacted the LULC changes in the area over this time frame. Therefore, the research project aims to analyse the LULC changes in the country of Iraq considering all of these factors.

3. Objectives and scope of the project

The availability of pertinent data on land cover and land use is evaluated globally. Land cover and land use data are typically accessible as category maps generated using semi-automated algorithms that rely on remote sensing imagery as the primary input. Land cover refers to the physical surface characteristics of land, including vegetation type and the presence of human-made structures. On the other hand, land use refers to the social and economic functions of land in fulfilling the demand for food, fibre, shelter, and natural resources. Although the two concepts are interrelated, their connection is intricate. For instance, 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 areas (Diogo and Koomen, 2016).
In this report, we will differentiate between land cover and land use when applicable. Preferably, land cover and land use data from Earth observation sources will be utilized. The report outlines the following characteristics of Earth observation-based data:

- Data capture: The procedures for measuring, gathering, and examining the data.
- Reliability: The quality, accuracy, and comprehensiveness of the dataset.
- Geographical coverage: The extent of the dataset's geographical area.
- Format: Whether the dataset is in raster or vector form.
- Spatial resolution: The smallest features captured and the size of the dataset's spatial elements.

In 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. On the other hand, in vector format, the resolution is often 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 - the frequency with which datasets are produced as well as the years for which datasets are available;
- Thematic resolution - the categories of land cover or socioeconomic use distinguished in the dataset, including the classification used;

- Data source - the institution responsible for providing the dataset and how the data may be accessed.

These characteristics will be examined in depth for each dataset below. The discussion will begin 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.

4. 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.

4.1. 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 has statistical data on land resources, planning decisions become more informed, you have a greater knowledge of the broader picture, and you can incorporate the requirements of many rather than just one.

a) It allows us to know what land classes you have.
b) It identifies where each class is located.

c) It identifies the proportion of each land class.

4.2. 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.

a) 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) LULC (land conversion), urban heat land, sustainable design.
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.

4.3. 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 you may improve our knowledge of land use classes.

4.4. The Digital Image Classification & Analysis to Detect Features Based on:

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

Notes: 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.

Notes: 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.

5. Study area and methods of LULC classification

5.1. Study area

The Republic of Iraq was selected as the study area in this project, including the Kurdistan region. Iraq is situated in Western Asia, north of the Persian Gulf, and has a land area of 435,052 km^2 with a coastline of 58 km. Iraq is situated between latitudes 29.5° and 37.5° N and longitudes 38.45° and 48.45° E in the northern Arab world, southwest of central Asia. The majority (%71) of Iraq's population lives in urban areas, and almost one-fifth of the population resides in Baghdad.

Iraq has a relatively low average elevation of 312 meters above sea level, with the highest mountain peak, Zagros- Halgurd Mountain in the Kurdistan region, reaching 3,611 meters (Figure 1B). It shares national borders with six neighbouring countries: Iran, Jordan, Kuwait, Saudi Arabia, Syria, and Turkey. The country of Iraq is characterized by two prominent rivers, the Tigris and Euphrates, which flow from the north towards the Arabian Gulf, dividing the fertile region between them. This area has been known by various names in history, such as Al-Jazirah, or "the island," in Arabic and Mesopotamia in Greek. Despite its rich cultural heritage, Iraq has challenging living conditions, with %40 of its land covered by rocky deserts and %30 being mountainous and bitterly cold in winter. However, the fertile plains along the Tigris and Euphrates provide suitable living conditions for most Iraqis. Throughout history, Iraq has been a hub of human civilization, and the Tigris and Euphrates rivers have played a significant role in its development. Sumer, Babil, and Assyria are some ancient civilizations that flourished in this region and have left their mark on the country.

Iraq is characterised by a desert climate and a vast expanse of desert which covers most of its territory. The desert region is mainly divided into two major types, namely: the sandy desert and the rocky desert.

1- The sandy desert, also known as the Arabian Desert, covers the southern and western regions of Iraq and is characterized by constantly changing sand dunes that are shaped by the wind. The temperature in this desert can reach up to 50°C during the day and drops to 0°C at night. The sandy desert is further divided into (three smaller types), including: A) Hamad Desert, is a flat and barren region that covers the southern part of Iraq. B) The Nefud Desert, which is a large desert region covering the northern part of Saudi Arabia and the

eastern part of Iraq, and the C) Rub' al Khali, which is the largest sand desert in the world, covering the southern part of Saudi Arabia and the north-western part of Iraq.

The rocky desert, also known as the Syrian Desert, covers the central and eastern regions of Iraq and is characterized by a terrain mainly composed of gravel, stones, and small rocks. The temperature in the rocky desert can reach up to 45°C during the day and drops to -5°C at night. In general, the desert regions in Iraq are challenging environments that require specific adaptation and survival strategies for both the human population and wildlife that inhabit them.

The climate in Iraq is a subtropical climate, which means that it can get very hot and dry for much of the year, with a few rainy months. The temperatures you mentioned are also quite extreme, ranging from an average of 17°C to 46°C during the day, with some areas reaching up to 48 °C. In the colder months, temperatures can drop significantly, with an average of 6°C depending on the region, where snowing can occur in Kurdistan region areas. This can be quite a contrast to the hot and dry weather experienced during the rest of the year. It's important to note that these temperatures are averages, and temperatures can fluctuate and vary depending on the specific location and time of year.

The climate and weather patterns in Iraq can have significant impacts on the environment, agriculture, and daily life of its residents. The country receives 650 mm of rain on average each year, the precipitation starts from October to May, with variations in the north and south of 1200 mm and less than 100 mm, respectively. Typically, less than 100 mm of rain falls annually in the nation's western desert. As a result, the climate is semi-arid in the north with relatively cold winters, while it is arid in the south and centre with a mild winter and an exceptionally hot summer (Figure 1A) (Mohammed and Scholz 2023). Kurdistan region from the north side is Affected by a Mediterranean climate, which is cold and rainy in winter and hot and dry in summer (Gaznayee etal.2022). In general, in the Kurdistan region, the precipitation starts from October to May, with 350 mm in the southwestern parts to more than 1200 mm in the northern and north-eastern parts (Mustafa and Negm, 2022)

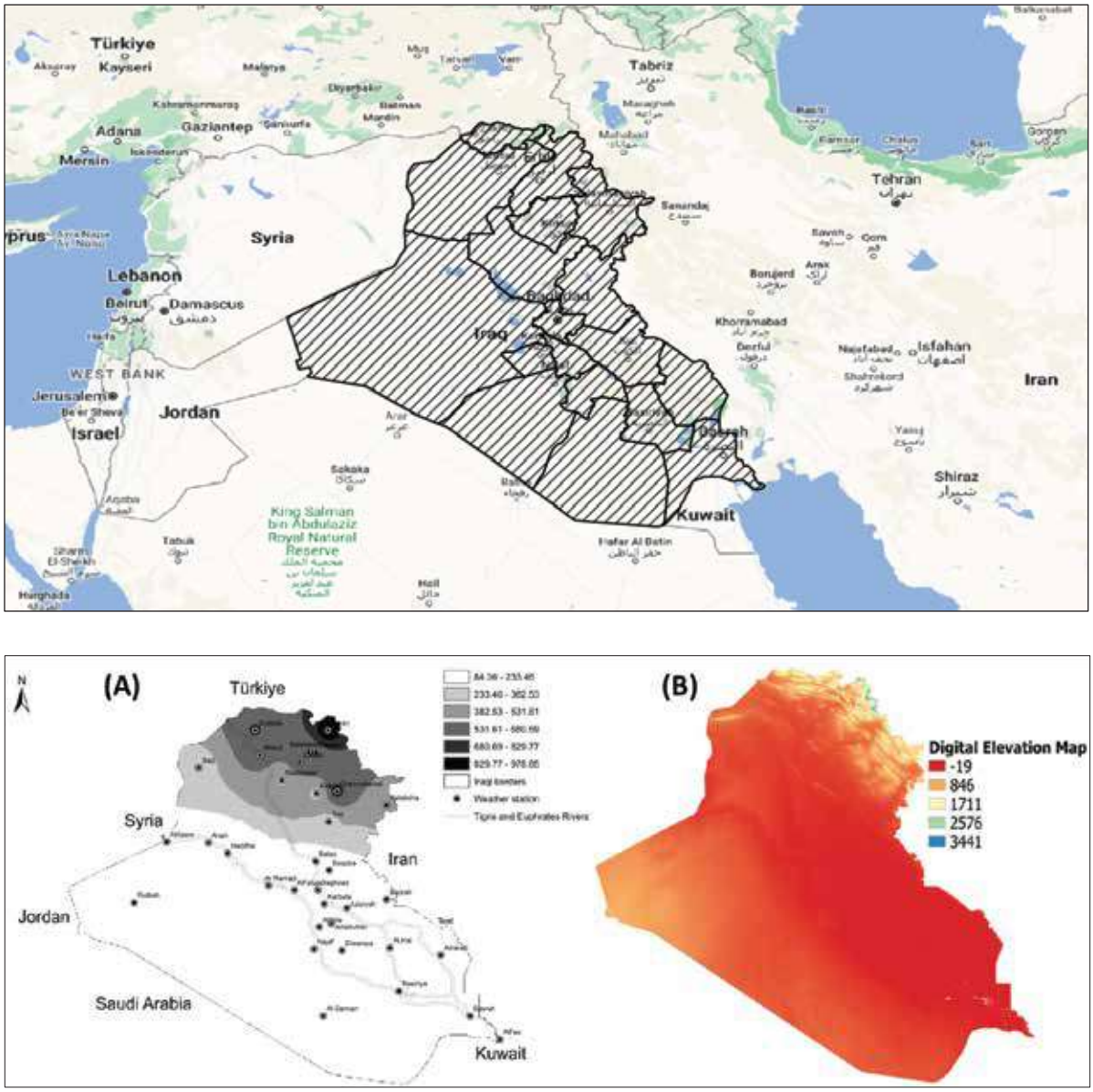

Figure 1. Location map of the study area with the meteorological stations map and the long-term spatial distribution of the annual precipitation (mm/year) over Iraq (Mohammed and Scholz 2023, and Gaznayee eatal.2022) and Digital Elevation Model (DEM).

5.2. Provinces in Iraq

Iraq is made up of 19 governorates or provinces, which can potentially form an autonomous region according to the Iraqi constitution. The Kurdistan Region is made up of four of these governorates, namely Erbil, Sulaymaniyah and Duhok. Baghdad and Basra are the oldest provinces in Iraq and have the largest populations. Ninawa, also known as Nineveh, is the

second most populous province and is located in the northwest with a cooler climate. The governorates are further divided into districts and sub-districts.

5.2.1. Baghdad Province

Baghdad, the capital city of Iraq, is situated on the Tigris River and was designated as the capital of the Abbasid Caliphate in 762 CE. It became a significant cultural, commercial, and intellectual hub of the Muslim world and housed important academic institutions.The city's diverse population of different ethnicities and religions earned it a reputation as the "Center of Learning."

Baghdad experiences a hot desert climate, with extremely hot and dry summers, and mild to cool, slightly wet winters. During the summer months, temperatures can reach a maximum of 44°C, and dust storms from the west are common. The winter temperatures are typical of hot desert climates, with maximum temperatures averaging 16 to 19°C. Freezing temperatures occur a few times a year on average. Annual rainfall is primarily limited to the period from November through March, with an average of about 150 mm.

5.2.2. Basra Province

The Basra Governorate, also known as Basra Province, is situated in the southern part of Iraq, adjacent to Kuwait in the south and Iran in the east, on the Arabian Peninsula. It encompasses various districts, including Al-Basrah, Al-Qurna, Al-Zubair, Al-Midaina, Shatt Al-Arab, Abu Al-Khaseeb, and Al-Faw, with Al-Basrah being the capital city. Notably, Basra Province is the sole Province in Iraq that has a shoreline, specifically on the Arabian Gulf. This feature gives it a distinct advantage in terms of potential economic opportunities.

Basra has a hot desert climate, similar to the surrounding areas, but it receives slightly more precipitation because it's near the coast. The city is consistently one of the hottest places on Earth during the summer months, with temperatures regularly going over 50°C in July and August. However, winters are mild with average high temperatures around 20°C, although minimum temperatures can drop below 0°C. High humidity is common due to the marshy Arabian Gulf.

5.2.3 Mosul Province

Mosul, which is located on the Tigris River in northern Iraq and serves as the capital of Nineveh Province, is the second largest city in Iraq both in terms of population and area, after Baghdad. The city's population is over 3.7 million, and it has expanded from the old city on the west side to encompass significant

areas on both the Left Bank (east side) and the Right Bank (west side) of the river. Nineveh city has a hot semi-arid climate that borders on the Mediterranean climate. The summers are extremely hot, dry, and long, with short and mild autumn and spring seasons, while the winters are relatively cool and moderately wet.

5.2.4. Al-Anbar Province

Al-Anbar Province, also known as Anbar Province, is the biggest province in Iraq in terms of land area. It is situated in the western part of the country, sharing borders with Syria, Jordan, and Saudi Arabia.

The climate in Al-Anbar is arid and mostly desert, with some steppe areas. It is similar in topography to the Arabian Peninsula plateau, featuring small hills and wadis such as Wadi Hauran. The lack of natural vegetation and inadequate land preservation has resulted in severe erosion and exposure to the elements.

The region receives an average of 115 millimetres of rainfall each year, with summer temperatures reaching up to 52°C and dropping as low as 0°C in winter. The Euphrates River is the primary source of water for those residing in the Province, flowing through seven of its districts in a south-easterly direction.

5.2.5. Babil Province

Babil Province is a province situated in the centre of Iraq, with a land area of 5,119 square kilometres. As of 2023, the population is estimated to be 1,820,700. The provincial capital is Hillah, which is located on the Euphrates River, opposite the ancient city of Babil. Babil province is situated between 32° to 33.25° North latitude and 44° to 45° East longitude, with an elevation of 28.83 meters above sea level. The climate in Babil is considered a Subtropical desert, with an annual temperature of 28.45°C. The hottest month in Babil is July, with an average daily temperature of 45.8°C in the summer months. The average annual precipitation in Babil is around 100 millimetres.

5.2.6. Dhi-Qar Province

The Dhi Qar Province is located in southern Iraq on the Arabian Peninsula, with its capital city being Nasiriyah. It was formerly known as Muntafiq province until 1976. The region is renowned for being the birthplace of the ancient Sumerian civilization and is home to historical sites such as Ur, Eridu, Lagash, Larsa, Girsu, Umma, and Bad-tibia.

Additionally, the Mesopotamian Marshes in the south of the province have

been inhabited by the Marsh Arabs for centuries.

The governorate has a population of approximately 2,000,000. Its elevation is 5.06 meters above sea level, and it has a Subtropical desert climate characterized by hot and dry summers, with temperatures often exceeding 40°C and mild winters. The region only receives rainfall between November and April, and the average annual precipitation is 100 mm.

5.2.7. Al-Qadisiyah Province

The Al-Qadisiyah Governorate, also known as Al-Diwaniyah Governorate, is located in the plains of south-central Iraq and has a population of approximately 1.5 million people based on the 2014 census. Its capital is Al Diwaniyah, and it shares borders with the governorates of Muthanna, Najaf, Babil, Wassit, and Thi-Qar. The region has a fertile landscape, owing to the presence of the Euphrates and Shamiya rivers, but faces challenges due to its hot, dry climate with limited rainfall. The area's geography and population provide useful context for understanding the economic and social dynamics of the region.

5.2.8. Diyala Province

Diyala Governorate is located in the northeast of Baghdad, adjacent to Iran, and covers an area of 17,685 square kilometres. The Diyala River, a major tributary of the Tigris, flows through a significant portion of the province, making agriculture, particularly date farming, the primary industry.
The Hamrin Mountain range crosses the governorate's north, giving way to desert plains in the south, while the man-made Hamrin Lake, formed by a dam on the Diyala River, is located around 50 km northeast of the provincial capital, Baqubah. Diyala has a typical dry desert climate, with high summer temperatures exceeding 40°C and low annual rainfall averaging 248 mm, mostly occurring in winter and early spring. The relative humidity is about %44 (Al-Mashhadani and Al-Kubaisi 2023).

5.2.9. Kerbala Province

Kerbala, also known as Kerbala, is a city located in central Iraq, situated approximately 100 km southwest of Baghdad and east of Razzaza Lake. It serves as the capital of the Kerbala Governorate and has an estimated population of 1,218,732 individuals as of 2018.
The governorate is among the smallest in Iraq and can be found in the southwestern region of the country. The eastern part of Kerbala features irrigated farmland along the Euphrates River, while the western section is

made up of desert plains. Kerbala shares boundaries with the governorates of Al-Anbar, Babil, and Najaf. The city has a dry, desert climate, with temperatures frequently reaching 40°C or higher in the summer and very limited rainfall amounting to approximately 89 mm, mainly concentrated in the winter months (Kadum and Al-Ali, 2022).

5.2.10. Maysan Province

Maysan is a governorate situated in the south-eastern part of Iraq, sharing its borders with Iran. It has a population of approximately one million people and is bordered by Al-Basrah, Thi-Qar, and Wassit. The Tigris River flows through Maysan, providing water to the marshlands that used to cover two-thirds of the area. However, due to a drainage campaign in the 1990s, the marshes have shrunk significantly, and most of the drained land has turned into desert. The marshes have been partially reflooded since the 2003 invasion. Maysan experiences a typical desert climate, with hot summers exceeding 40°C and cooler winters. The area receives an average of 184.5 mm of rainfall annually, mainly concentrated in the winter months (Al-Kubaisi and Al-Ghurabi, 2016).

5.2.11. Muthanna Province

The governorate of Muthanna is situated in the southwestern region of Iraq with an estimated population of 682,500. It shares its borders with Saudi Arabia and other Iraqi governorates such as Najaf, Qadissya, Thi-Qar, and Al-Basrah. Muthanna's topography is mostly composed of desert plains, with a small area of irrigated farmland along the Euphrates River to the north. The capital city of Samawah is located near Lake Sawa, which is a Salt Lake located in the western part of the governorate. The climate in Muthanna is characterized by hot and dry conditions, with temperatures exceeding 40°C in summer and very limited rainfall, which typically occurs during the winter months with an average annual rainfall of 105.7mm.

5.2.12. Najaf Province

The governorate of Najaf is situated in the southwestern region of Iraq and is adjacent to Saudi Arabia, with an approximate population of 1.2 million inhabitants. Its neighbouring Iraqi governorates include Al-Anbar, Kerbala, Babil, Qadissiya, and Muthanna. The governorate's topography mainly consists of desert plains, while an irrigated farmland strip runs along the Euphrates River, intersecting the governorate's eastern border. Najaf experiences a typical dry desert climate characterised by hot and arid summers and negligible precipitation, which occurs solely during the winter months. The governorate has an average annual rainfall of only 99mm.

5.2.13. Salah al-Din Province

Salah al-Din is a central governorate in Iraq that shares borders with Kirkuk, Diyala, Al-Anbar, and Mosul. The estimated population in 2019 was 1,637,232. The weather in Salah al-Din is hot and dry, with temperatures that can go above 42°C in summer, and there is limited rainfall during the winter, with an average annual rainfall of 184mm.

5.2.14 Wassit Province

The Wassit Governorate is situated in eastern Iraq and shares a border with Iran. With a population of around 1.45 million. Al-Kut, Al-Hai, and Al-Suwaira are the major cities in the area. The Mesopotamian Marshes of Shuwayja, Al-Attariyah, and Hor Aldelmj are significant natural features of the region and have been historically inhabited by Marsh Arabs. The climate in the governorate is transitional and falls between the Mediterranean and desert hot dry climate. The area experiences an average annual rainfall of 238mm. The Governorate Centre is located in Kut city, which is 176km south of Baghdad. Wassit Governorate shares a border with Diyala and Baghdad in the north, Maysan and Thi-Qar in the south, and Babil and Diwaniyah in the west.

5.2.15. 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 380 mm. The governorate is bordered in North West by the Great Zab and Little Zab rivers in the south.

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. The economy of Erbil is diverse, with industries like oil and gas, agriculture, tourism, and construction contributing to its growth. Overall, Erbil Governorate is an essential and dynamic region within Kurdistan, with a thriving economy and a rich cultural heritage.

5.2.16. 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 (113°F) 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.

5.2.17. Kirkuk Province

The Kirkuk Province in northern Iraq that covers just %2.2 of the country's land area. It has a population of approximately 1.3 million people and is divided into four districts, with the city of Kirkuk serving as its capital. The governorate is characterized by its arable land, which is crucial for the local economy and sustenance of its residents who rely on agriculture.

Kirkuk is surrounded by the Lower Zab and Tigris rivers in the west, the Hamreen Mountains in the south, and the Sirwan river in the southwest. It is situated about 250 km from the capital city of Baghdad. The region experiences a hot semi-arid climate with hot and dry summers, and mild winters with moderate rainfall, which is around 300mm per year.

5.2.18. Duhok Province

Duhok Governorate is situated in the 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 makes 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 Cold winters. Precipitation is typically limited to the winter months and averages around 700 mm per year.

5.3. Methodology of Land 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. We developed an eleven-class scheme for the study area.

The methodology of this study involves several key phases:

I. 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 4 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.

5.3. 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. 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.

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 environmental 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 center 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. 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. 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. 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.

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.

Sparse Vegetation: Land with exposed soil, sand, or rock never has more than %10 vegetative cover at any time of the year.

Marshland vegetation: Seasonal and permanent aquatic vegetation in naturally saturated areas form part of this category.

Desert 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.

Rocky desert: Refers to rocky surfaces in the desert lands, naturally exposed rocks in the desert surface without soil cover, often with no presence of rock vegetation.

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. 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.

5.4. Data Collection

There are different remote sensing-based satellite data freely available for downloading and further analysis. Open source tools were 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.

5.4.1. 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 (,10

25 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.

5.4.2. 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), SWIR1 (11), and SWIR(12) 2), and three bands at 60 m (Aerosols (1), Water vapour (9), and Cloud mask (10)) spatial resolution. In this work, 12 images from bands ,2 4 ,3, and 8 from 2022 were used.

5.4.3. 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.

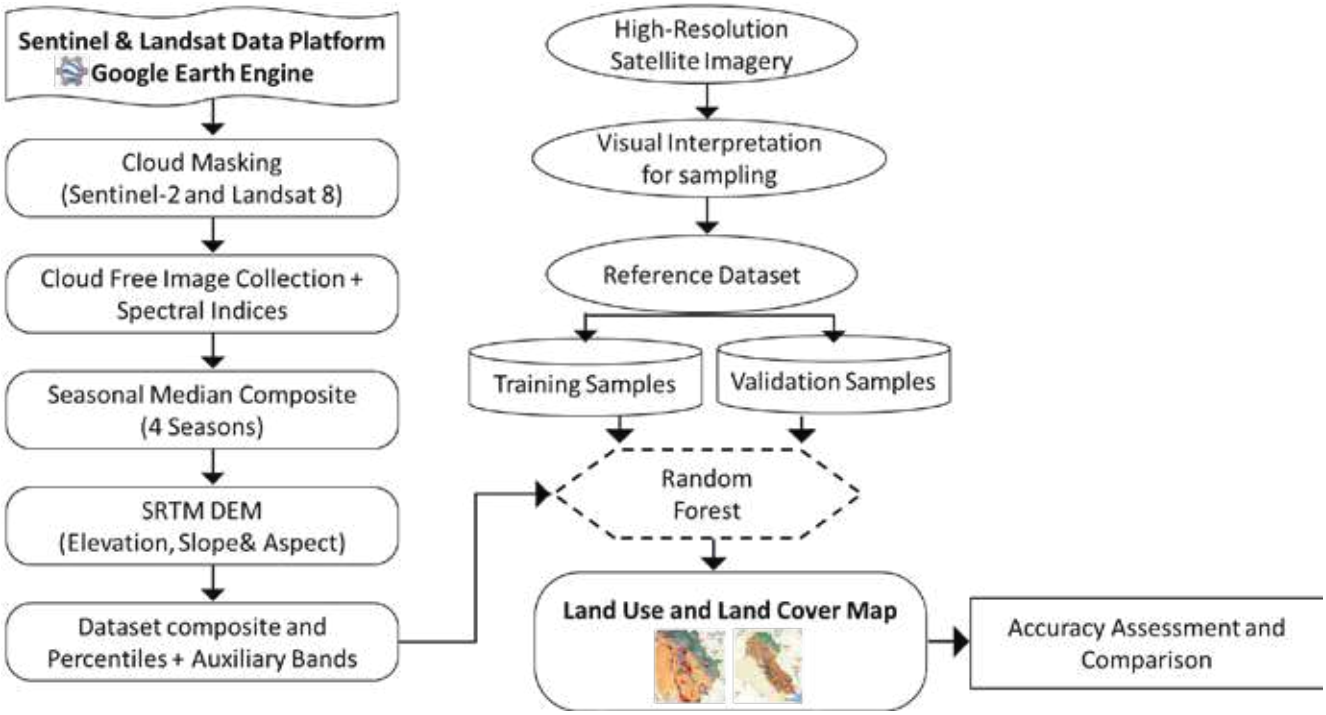

Figure 2 The flow-chart of methodology implemented for land use and land cover (LULC) mapping.

5.5. 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 Hub <https://earthexplorer.usgs.gov/> and <https://scihub.copernicus.eu/dhus/#/home>.

6. Results:

6.1. Land use and land cover distribution in Iraq.

The land use and land cover (LULC) classes of Iraq provide valuable information on the distribution of different types of ecosystems and land uses across the country. The LULC map presents a comprehensive list of the LULC classes in Iraq, along with their corresponding areas in square kilometres (km2) and percentages of the total area with an accuracy of %95.9 (Figure 3, Figure 4, Table 1 and Table 2).

These classes include urban areas, water bodies, wetlands, Dense Forest, Open Forest, palm trees, irrigated land, rainfed land, arable land, grassland, sparse vegetation, marshland vegetation, herbaceous and mangrove, desert land, rocky desert, rock surface, and uncultivated/abandoned farmland. The size and distribution of these LULC classes have important implications for various aspects of life in Iraq, including agriculture, biodiversity, water resources, and urban planning. Understanding the LULC classes of Iraq is crucial for sustainable development and effective natural resource management in the country.

The total area of Iraq is around 437,952.8 km2. The LULC map of Iraq provides the land use and land cover classes along with their corresponding areas of the total area. The largest LULC class in Iraq is desert land, covering 105,493.1 km2, which is %24.09 of the total area. The next largest classes are uncultivated/abandoned farmland (97,277 ,%22.21 km2), Rocky desert (,%17.8 77,969 km2) and arable land (10 years) (33,191 ,%7.58 km2), grassland (,%6.61 28,941 km2), and irrigated land (25,299 ,%5.78 km2). The smallest LULC classes in Iraq are wetlands (1152 ,%0.26 km2), Dense Forest (3217 ,%0.73 km2), and palm trees (1666 ,%0.38 km2).

Agriculture is a crucial sector in Iraq's economy, and the country's land LULC classes reflect the importance of agriculture in the country. Irrigated lands, rainfed, arable lands, grassland, and palm tree lands are some of the most significant agricultural LULC classes in Iraq. Irrigated land is an important agricultural LULC class in Iraq, accounting for %5.78 of the country's total area. This class is critical to produce high-value crops, such as wheat, barley, and rice. Most irrigated lands rely on both surface water and underground water resources, Euphrates and Tigris rivers are the major surface water resource for irrigation throughout the coastal area of these rivers in Iraq. However,

Page

unsustainable irrigation practices can deplete groundwater resources and degrade soil health, leading to reduced productivity and desertification risks in the long term. Arable land covers a combined total of %10.68 of Iraq's total area and is a vital resource for food production in the country where these lands appear to be suitable for cultivation as they are rainfed lands and have been cultivated within the last 10 to 5 years. This LULC class is used for both rain-fed and irrigated agriculture, and it is an essential source of income for rural communities in the provinces of Iraq. Palm trees are widely cultivated in the middle and south of Iraq and are a significant source of income for rural communities. This LULC class accounts for %0.38 of Iraq's total area and is commonly used for date palm cultivation. Palm trees are mostly cultivated across the Euphrates and Tigris rivers in Iraq. Effective management of agricultural LULC classes is critical for ensuring sustainable agriculture and food security in Iraq. Strategies such as sustainable irrigation practices, soil conservation, and improved land use planning can help promote the long-term productivity of agricultural lands meanwhile reducing negative impacts on the environment.

In conclusion, the LULC classes in Iraq reflect the diverse landscapes and ecosystems of the country where classes range from urban areas to desert lands and play a significant role in the country's economy and sustainability planning and decision-making. However, unsustainable land practices, such as overuse of water, and overgrazing can lead to soil degradation, loss of biodiversity, and reduced productivity in local regions and nationally. Therefore, effective management of these LULC classes is crucial for ensuring sustainable land use practices in Iraq, protecting natural resources and improving the livelihoods of communities dependent on these ecosystems.

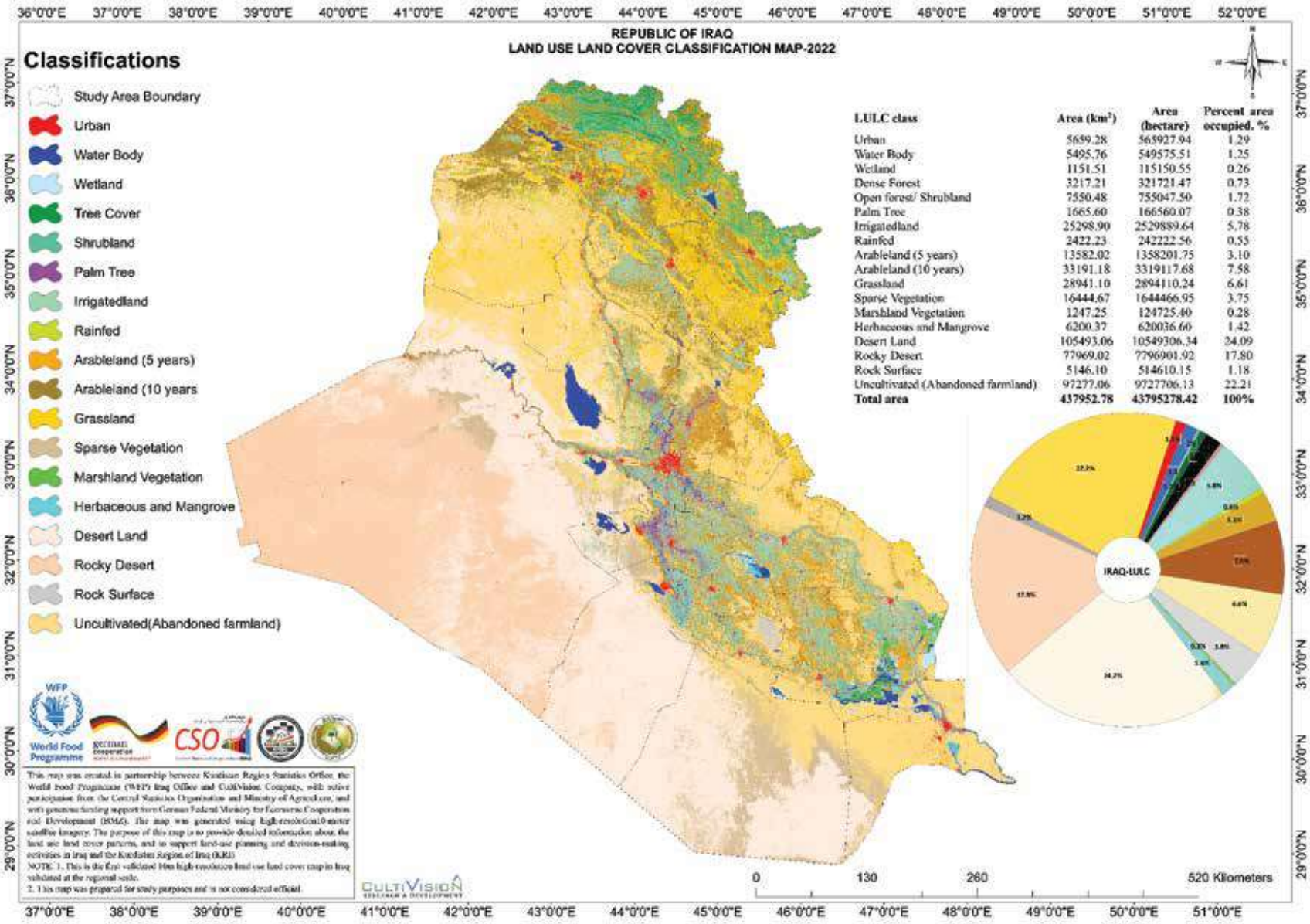

Figure 3: The spatial distribution of land use and land cover of country of Iraq for 2022.

Table 1: Iraq Land use and land cover (LULC) Area produced for Iraq Provinces.

	Urban	Water Body	Wetland	Tree Cover	Shrubland	Palm Tree	Irrigatedland	Rainfed	Arableland (5 years)
Anbar	472.4	1536.7	1.0	1.3	0.7	60.2	1228.0	22.5	297.3
Babylon	265.5	67.3	0.9	0.2	0.0	365.4		0.1	590.7
Baghdad		138.6	2.5	3.6	6.2	259.9	11.3	0.9	449.3
Basrah	431.2	586.0	381.1	0.1	0.0	32.1	369.1	37.5	289.8
Diyala	268.0	67.0	0.8	1.1	0.4	166.0	76.5	69.0	2079.6
Dohuk	181.8	109.8	0.4	1386.6	2720.0	0.0	676.4	264.7	523.2
Erbil	352.1	39.9	2.6	1172.4	2110.6	0.0	858.7	252.0	343.3
Kerbela	142.0	286.3	2.6	0.3	0.0	193.8	480.2	3.0	93.4
Kirkuk	227.21	33.65	26.47	6.11	7.55	0.06		139.00	505.57
Maysan	172.9	230.0	334.9	0.0	0.0	27.6	0.1	27.0	1363.7
Muthana	104.32	11.77	4.87	0.01	0.00	24.43	487.39	4.41	386.40
Nainawa	403.9	204.3	0.5	10.4	44.6	0.0	275.2		521.3
Najaf	147.7	134.4	0.8	0.1	0.0	87.2	521.8	0.6	120.4
Qadisiya	138.1	80.3	64.4	0.2	0.0	114.2	0.7	2.8	1074.3
Salah_alddin	250.4	919.8	16.7	0.5	2.1	172.3		170.2	664.3
Sulaimaniayh	327.1	239.2	1.1	631.7	2657.7	0.0	1189.5	4.2	640.4
Thiqar	220.2	603.4	245.9	2.5	0.0	24.1	1203.7	4.8	1690.6
Wasit	259.3	207.5	63.9	0.1	0.5	138.5		33.8	1948.4

	Arableland (10 years)	Grassland	Sparce Vegetation	Marshland Vegetation	Herbaceous and Mangrove	Desert Land	Rocky Desert	Rock Surface	Uncultivated(Abandoned farmland)
Anbar	513.3	503.6	4140.2	0.0	142.4	44883.7	72146.2	148.5	10282.0
Babylon	667.3	25.5	22.5	0.0	393.6	67.5	1.1	149.3	523.5
Baghdad	588.3	53.0	10.0	0.0	378.6	22.0	1.5	224.9	656.1
Basrah	274.7	298.7	1415.6	64.1	590.7	1383.2	0.2	516.7	12290.2
Diyala	2548.6	1971.7	0.0	0.0	102.9	454.1	0.0	116.5	7002.8
Dohuk	2547.4	1799.2	0.0	0.0	1.6	7.3	0.0	230.6	65.8
Erbil	3360.1	3087.3	0.0	0.0	0.6	15.7	0.0	212.2	288.0
Kerbela	184.7	24.9	977.2	0.0	113.8	1903.7	121.7	84.1	937.5
Kirkuk	2165.35	2540.92	0.00	0.00	8.84	197.06	0.00	156.48	2041.50
Maysan	1339.8	1032.6	0.0	579.1	1197.4	28.7	0.0	576.7	7562.9
Muthana	486.93	145.79	8871.86	0.00	235.02	29926.19	496.03	764.79	9487.86
Nainawa	6312.5	5939.1	0.0	0.0	9.5	2910.2	0.0	152.8	17496.7
Najaf	183.2	18.2	916.5	0.0	266.6	23213.6	2000.3	32.1	912.8
Qadisiya	1308.9	86.0	90.8	0.0	840.2	213.6	1.1	219.7	2466.6
Salah_alddin	2047.1	2261.7	0.0	0.0	172.1	0.0	3201.0	212.9	10833.5
Sulaimaniayh	4642.8	8038.2	0.0	0.0	1.8	161.2	0.0	299.2	1585.0
Thiqar	1817.7	335.9	0.0	604.0	1107.3	7.3	0.0	575.5	5320.7
Wasit	2202.4	778.8	0.0	0.0	637.4	97.9	0.0	473.2	7523.4

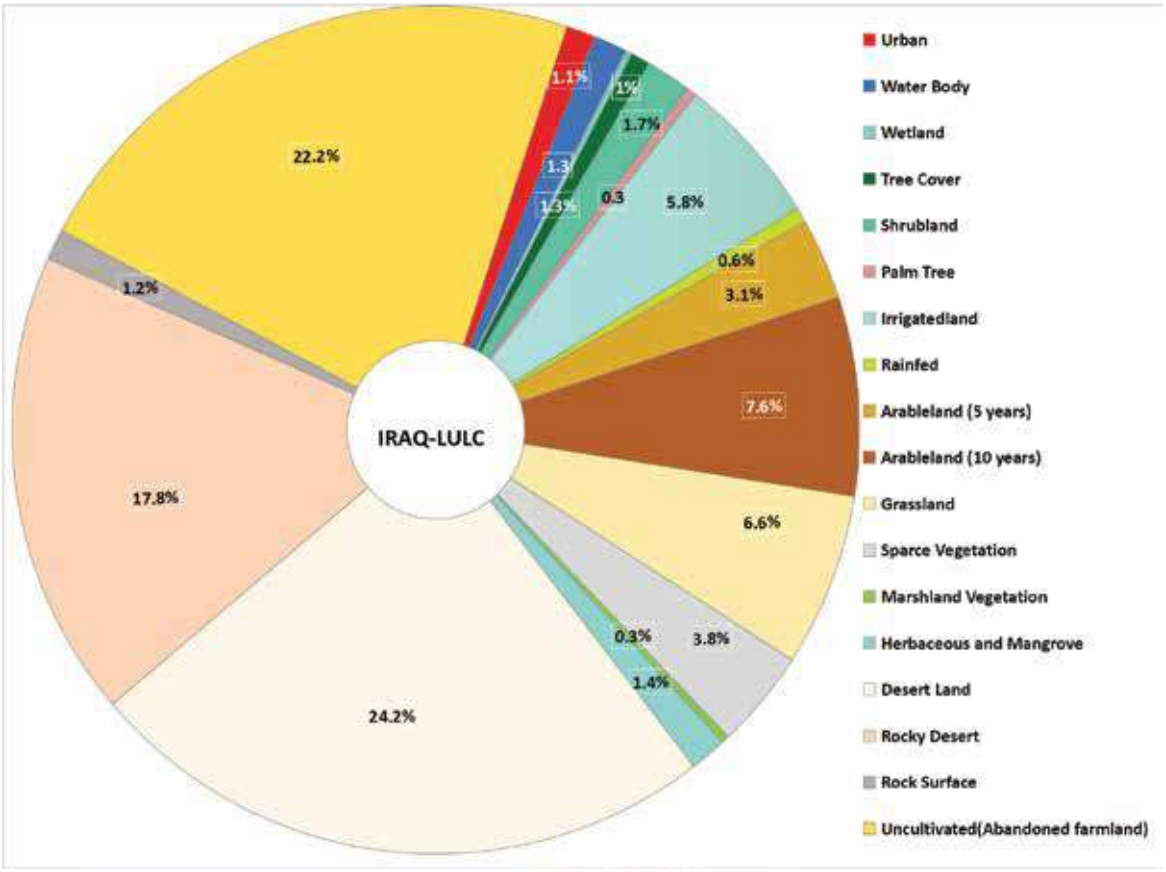

Figure 4 The distribution of land use and land cover of Iraq for 2022.

Table 2 Iraq Land use and land cover (LULC) Classifications Area km2 and Percent.

LULC class	Area (km ^{2})	Area (hectare)	Percent area occupied. %
Urban	5659.28	565927.94	1.29
Water Body	5495.76	549575.51	1.25
Wetland	1151.51	115150.55	0.26
Dense Forest	3217.21	321721.47	0.73
Open forest/ Shrubland	7550.48	755047.50	1.72
Palm Tree	1665.60	166560.07	0.38
Irrigatedland	25298.90	2529889.64	5.78
Rainfed	2422.23	242222.56	0.55
Arableland (5 years)	13582.02	1358201.75	3.10
Arableland (10 years)	33191.18	3319117.68	7.58
Grassland	28941.10	2894110.24	6.61
Sparse Vegetation	16444.67	1644466.95	3.75
Marshland Vegetation	1247.25	124725.40	0.28
Herbaceous and Mangrove	6200.37	620036.60	1.42
Desert Land	105493.06	10549306.34	24.09
Rocky Desert	77969.02	7796901.92	17.80
Rock Surface	5146.10	514610.15	1.18
Uncultivated (Abandoned farmland)	97277.06	9727706.13	22.21
Total area	**437952.78**	**43795278.42**	**100%**

6.2. Baghdad Province

SThe results of LULC classes are the breakdown of the land cover types and their corresponding areas in Baghdad province. The results show the area in square kilometres and the percentage of each land cover type in the given area (Figure 5, Figure 6, and Table 3). Based on the results, it appears that the majority of the land cover in this area is irrigated land, which accounts for %31.29 of the total area of Baghdad. Other prominent land cover types include urban (%14.4), uncultivated (Abandoned lands) (12.74), Arable lands (10 and 5 years) (%11.43 and %8.73) and Herbaceous and Mangrove (%7.35). Figure 6 also shows smaller percentages for palm trees, water bodies, Rock surfaces and grasslands. This information can be useful for understanding the distribution of land cover types in the area, which can have implications for things like biodiversity, water resources, and human land use.

To compare the results of important land cover classes in Baghdad province, we can look at the percentages of the total area that each class represents.

- Urban areas: %14.4
- Water bodies: %2.69
- Agricultural land: 57.5 % (including irrigated land, rainfed land, palm trees, grasslands, and arable lands)

From these percentages, we can see that agricultural land is the largest category of the three, accounting for over half of the total area of Baghdad covered by the three important land cover classes. Urban is the second largest category, covering ~%15 of the total area, while water bodies are the smallest category, representing approximately %2.7 of the total area of Baghdad.

In Baghdad, urban areas represent %14.41 of the land cover in the given area. Urban areas are typically characterised by high human population densities, a concentration of built structures and infrastructure including roads, bridges, etc as well as a high degree of human activity. Urban areas can have both positive and negative impacts on the environment and society. One potential positive impact of urban areas is that they can provide economic and cultural opportunities to residents, including access to jobs, education, and cultural amenities. Urban areas can also be more resource-efficient than rural areas in some cases, due to economies of scale and the ability to implement efficient public transportation systems.

It's worth noting that the categories of urban areas and water bodies are

generally considered to have high ecological value, as they provide important ecosystem services and support a wide range of biodiversity. Agricultural land can have ecological value as well, however, may also have negative impacts on biodiversity depending on the specific farming practices used. Water bodies in the Baghdad region represent only %2.7 of the land cover. Water bodies include rivers, lakes, ponds, and other bodies of water that are an essential component of the natural environment, Tigris River is a major water body in Baghdad and the majority of irrigated farms are located along this river. Water bodies play a crucial role in providing ecosystem services, such as water supply for irrigation for cultivated farms and palm farms in Baghdad, and habitat for aquatic species. They can also have important cultural and recreational value for humans, including fishing, swimming, and boating in the province.

In Baghdad, palm trees represent only %5 of the land cover in the given area. It's important to note that palm trees are not a natural or native plant to many areas and are often cultivated for their fruit, oil, or aesthetic value. In some cases. In terms of potential positive impacts, palm trees can provide economic benefits to local communities through the production of palm oil or other palm-derived products for the region. They can also have aesthetic value in landscaping and urban environments. However, it's important to consider the potential negative environmental impacts associated with the cultivation of palm trees, particularly in regions where they are not native. The presence of palm trees in the given area is just one aspect of the larger picture of land use and land cover in the region of Baghdad, and it's important to consider their impacts in the context of other land cover types and human land use practices.

Overall, the distribution of these three important land cover classes in the given area suggests a significant level of human influence on the landscape, with a relatively low percentage of natural or undisturbed habitats.

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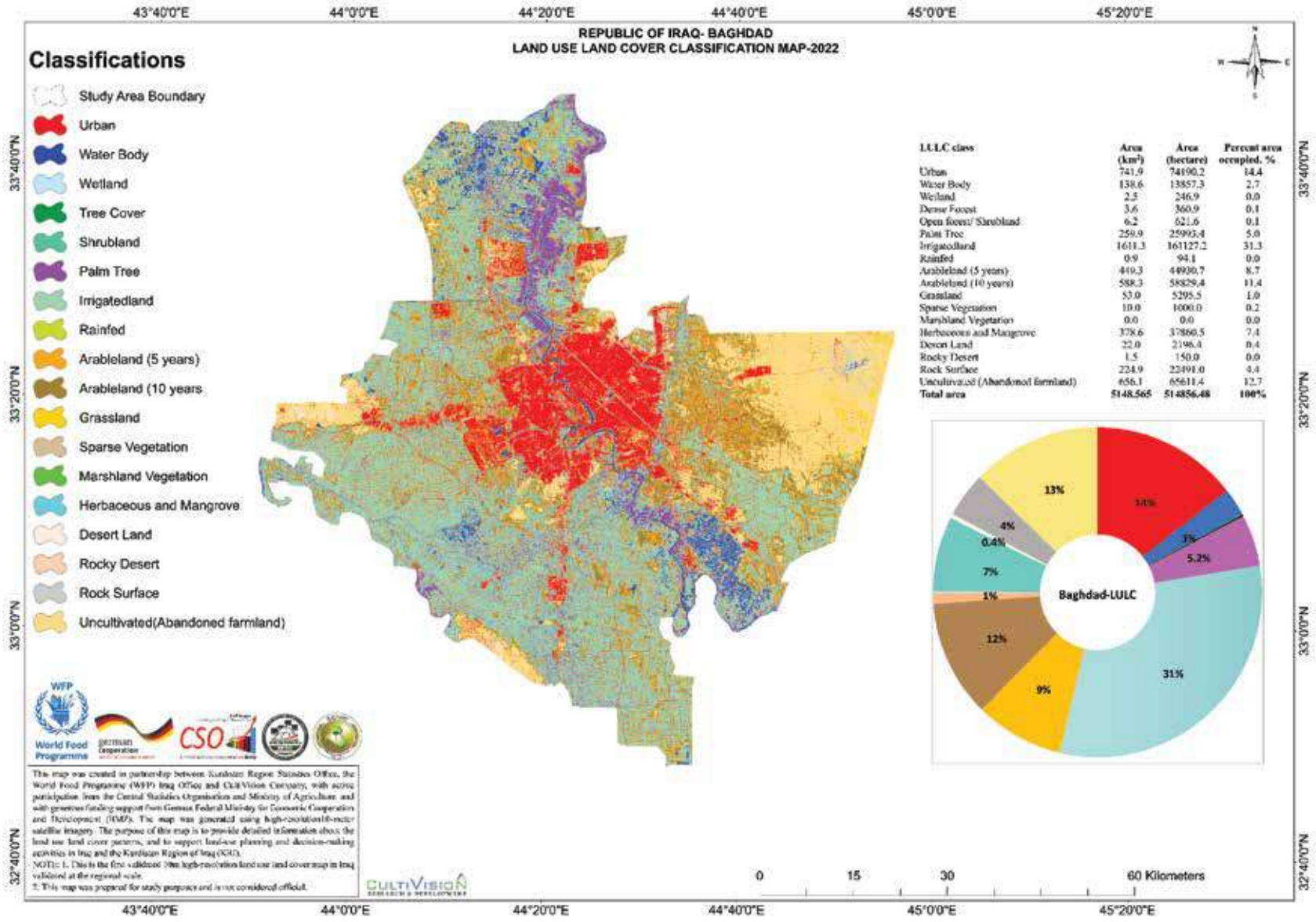


Figure 5 The spatial distribution of land use and land cover of Baghdad province for 2022.

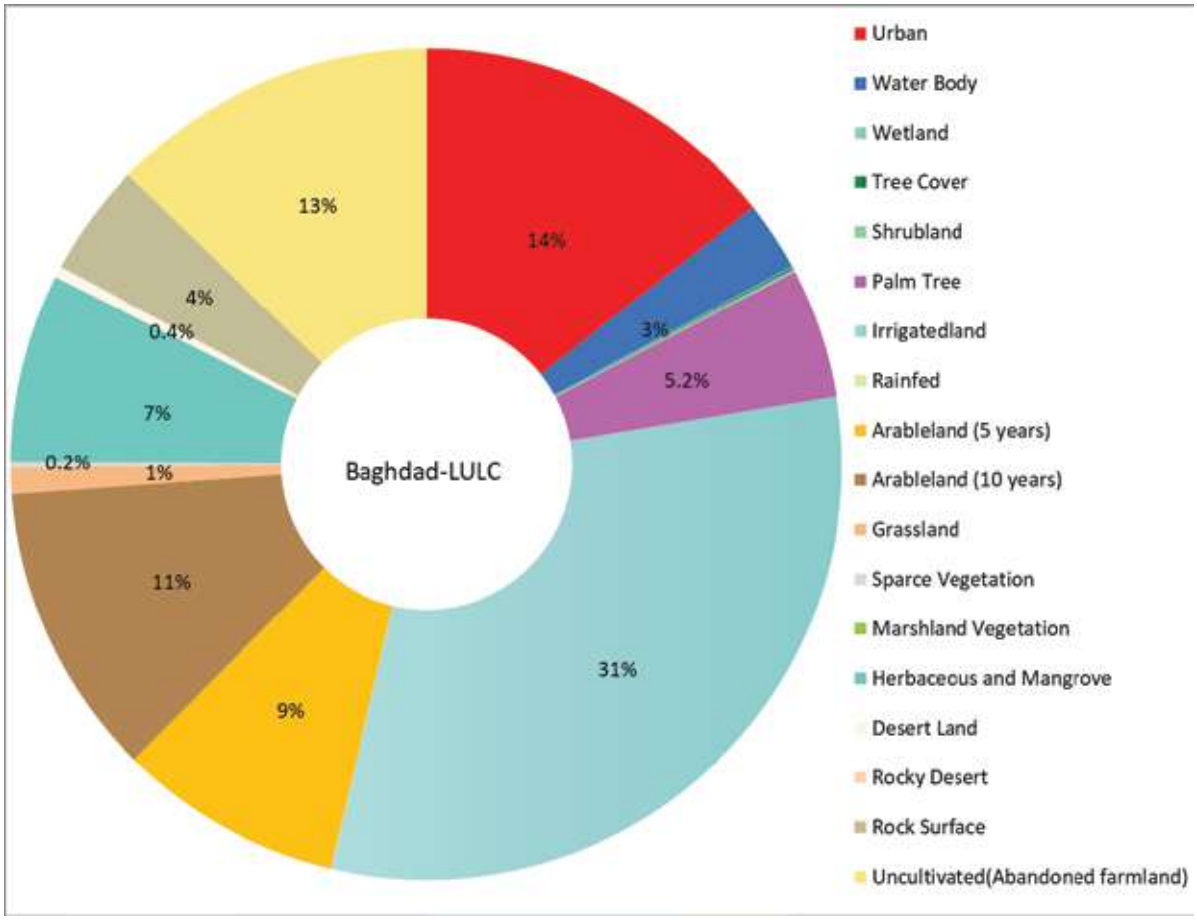


Figure 6 Land use and land cover (LULC) map produced for Baghdad province.

Table 3 Baghdad Land use and land cover (LULC) Classifications Area km2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	741.9	74190.2	14.4
Water Body	138.6	13857.3	2.7
Wetland	2.5	246.9	0.0
Dense Forest	3.6	360.9	0.1
Open forest/ Shrubland	6.2	621.6	0.1
Palm Tree	259.9	25993.4	5.0
Irrigatedland	1611.3	161127.2	31.3
Rainfed	0.9	94.1	0.0
Arableland (5 years)	449.3	44930.7	8.7
Arableland (10 years)	588.3	58829.4	11.4
Grassland	53.0	5295.5	1.0
Sparse Vegetation	10.0	1000.0	0.2
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	378.6	37860.5	7.4
Desert Land	22.0	2196.4	0.4
Rocky Desert	1.5	150.0	0.0
Rock Surface	224.9	22491.0	4.4
Uncultivated (Abandoned farmland)	656.1	65611.4	12.7
Total area	**5148.565**	**514856.48**	**100%**

6.3. Al-Basrah Province

The LULC maps show the different land use and land cover (LULC) classes in Al-Basrah, along with the area in square kilometres and their percentage of the total land area in the Al-Basrah region (Figure 7, Figure7, and Table 4).

Based on the LULC map, it can be observed that the largest LULC class in Al-Basrah is the uncultivated/abandoned farmland, which covers around %63 of the total land area. This is followed by sparse vegetation (%7.3), desert land (%7.1), Urban (%5), Water body and herbaceous and mangrove (%3 each class), Rock surfaces (%2.6) and wetlands (%2). The results also show that urban areas cover only a small portion of the total land area in Al-Basrah, at only %5. However, this could still have a significant impact on the environment and natural resources in the region, as urbanization often leads to changes in the land cover and impacts the natural habitats of plant and animal species.

Urban vs. Uncultivated/Abandoned Farmland: Urban areas cover %2.21 of the total land area in Al-Basrah, while uncultivated/abandoned farmland covers %63. Urban areas are important for economic growth, commerce, and industry, but they also have significant impacts on the environment and natural resources. Uncultivated/abandoned farmland, on the other hand, may provide important habitats for wildlife and have cultural value, but may also indicate a loss of agricultural productivity and rural livelihoods.

Water Body vs. Desert Land: Water bodies cover only %3 of the total land area in Al-Basrah, while desert land covers %7.1. Water bodies provide important ecosystem services, such as habitat for aquatic species, water supply, irrigation in the agriculture sector and recreational opportunities. Desert land usually has lower ecological productivity but may also contain unique ecosystems and provide important cultural and aesthetic value. It may also have the potential for renewable energy production such as solar and wind power, Al-Basrah or Iraqi authorities can potentially plan for sustainable and renewable energy plans in deserts of Al-Basrah province.

Wetland vs. Herbaceous and Mangrove: Wetlands cover %2 of the total land area in Al-Basrah, while herbaceous and mangrove areas cover %3. Wetlands provide a variety of ecosystem services, such as flood control, water filtration, and habitat for migratory birds and other wildlife. They may also support human livelihoods through fishing, agriculture, and tourism activities. Herbaceous and mangrove areas,

on the other hand, may provide important habitats for aquatic and terrestrial species, stabilize coastal areas, and have the potential for carbon sequestration. However, they may also be impacted by pollution, overexploitation, and climate change.

The marshland vegetation class represents areas of land in Al-Basrah that are characterized by wetland ecosystems with diverse plant communities. These areas may include marshes, swamps, and other types of wetlands that are dominated by herbaceous plants, including grasses, sedges, and rushes. The marshland vegetation class covers %0.3 of the total land area in Al-Basrah, which may seem small compared to other classes, but these areas play an important role in the ecological health of the region. Marshland vegetation provides a variety of ecosystem services that are crucial to the local environment and human communities throughout civilisations in the region. These areas have been used by local communities for centuries for fishing, hunting, and other traditional practices. These areas help to regulate water flow and reduce the impacts of flooding, as they can absorb and store large amounts of water. They also serve as important habitats for many species of birds, fish, and other wildlife, and support the biodiversity of the region

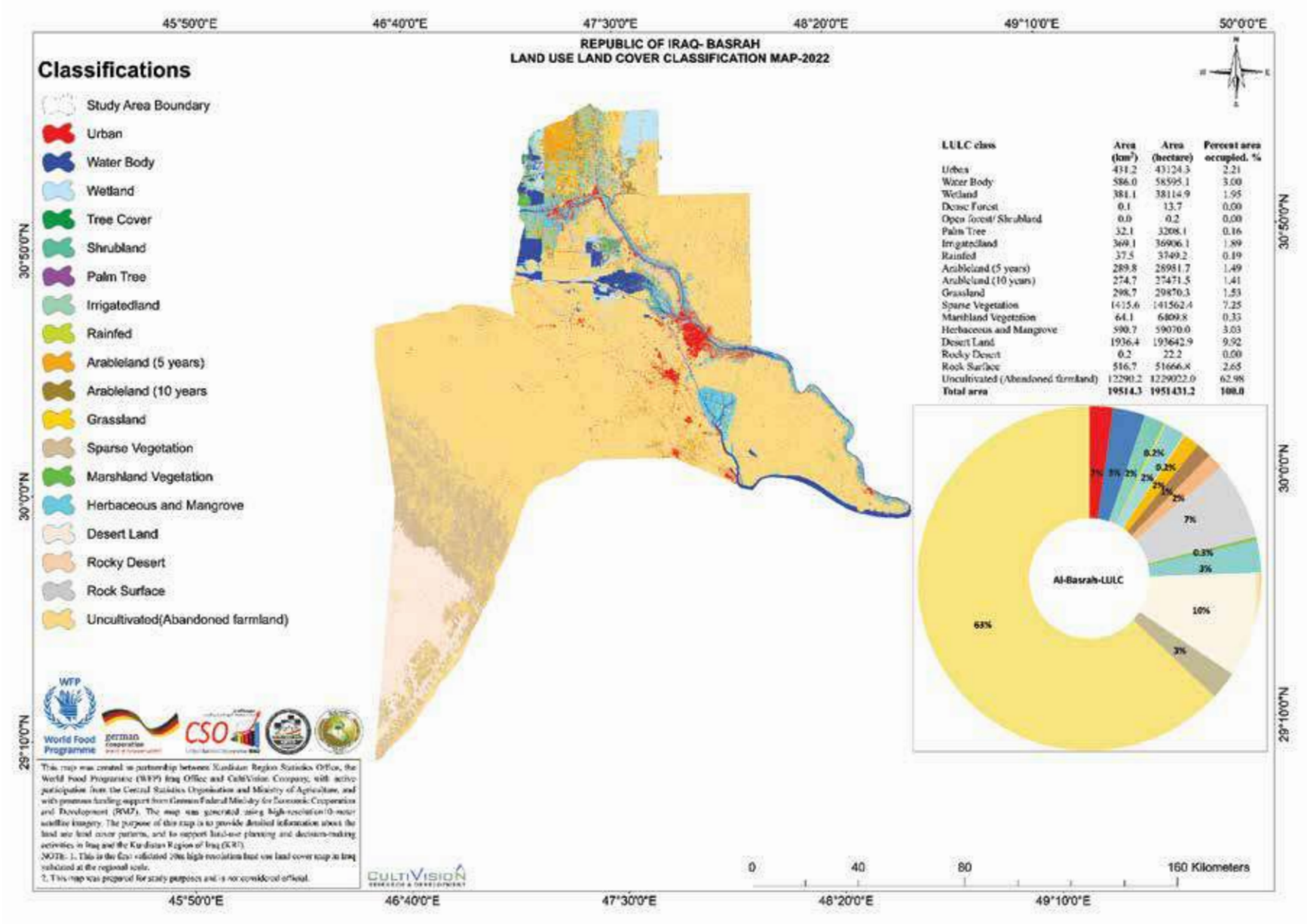


Figure 7 The spatial distribution of land use and land cover of Al-Basrah province for 2022.

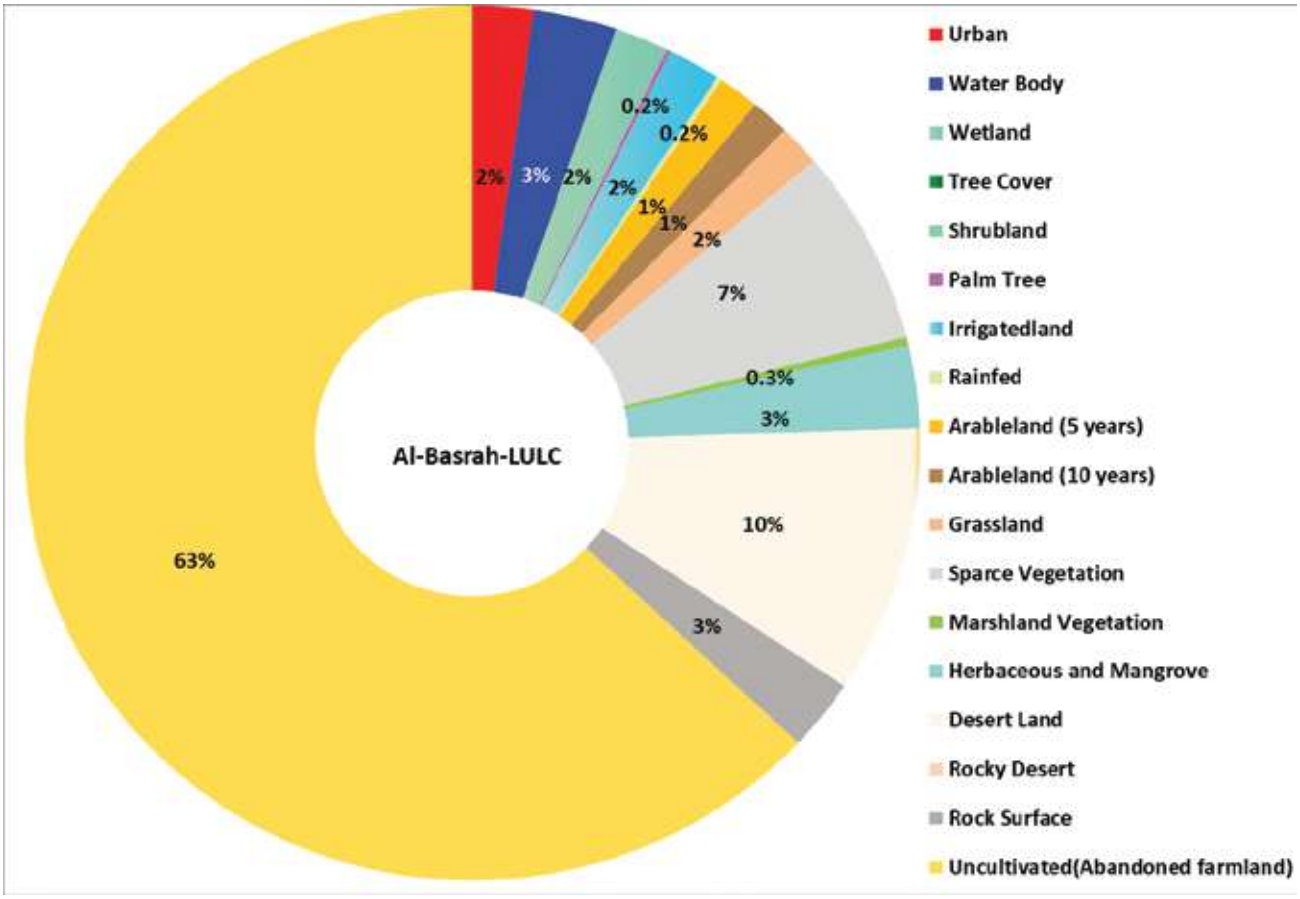


Figure 8 Land use and land cover (LULC) map produced for Al-Basrah province.

Table 4 Al-Basrah Land use and land cover (LULC) Classifications Area km2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	431.2	43124.3	2.21
Water Body	586.0	58595.1	3.00
Wetland	381.1	38114.9	1.95
Dense Forest	0.1	13.7	0.00
Open forest/ Shrubland	0.0	0.2	0.00
Palm Tree	32.1	3208.1	0.16
Irrigatedland	369.1	36906.1	1.89
Rainfed	37.5	3749.2	0.19
Arableland (5 years)	289.8	28981.7	1.49
Arableland (10 years)	274.7	27471.5	1.41
Grassland	298.7	29870.3	1.53
Sparse Vegetation	1415.6	141562.4	7.25
Marshland Vegetation	64.1	6409.8	0.33
Herbaceous and Mangrove	590.7	59070.0	3.03
Desert Land	1936.4	193642.9	9.92
Rocky Desert	0.2	22.2	0.00
Rock Surface	516.7	51666.8	2.65
Uncultivated (Abandoned farmland)	12290.2	1229022.0	62.98
Total area	**19514.3**	**1951431.2**	**100.0**

6.4. Nineva Province

The LULC map produced for Ninewa province shows the land use classes of Ninewa province in Iraq, along with their respective area and percentage of the total area of the province (Figure 9 Figure 10 and Table 5). The most extensive LULC class in Ninewa province is Uncultivated (Abandoned farmland) with an area of 17,496.7 km2 or %48.31 of the province's total area. The second largest class is Grassland with an area of 5,939.1 km2 or %16.4 of the total area, followed by Arable Land (10 years) with an area of 6,312.5 km2 or %17.43 of the total area. These classes cover more than three-quarters of the province's total area (~29,748 ,%82 km2). The Urban class only covers %1.12 of the total area of Ninewa province, and Water Body Wetland cover %0.6 and %0.0, respectively. The smallest LULC classes are Palm Tree, Sparse Vegetation, Marshland Vegetation, Rocky Desert, and Wetland classes each with an area of < 0.5 km2.

The importance of land cover and land use class in Ninewa province depends on various factors, such as ecological, social, economic, and cultural aspects. However, based on the available LULC map, here are some of the most important LULC classes in the Ninewa province of Iraq:

Uncultivated (Abandoned farmland): This class covers the largest area in Ninewa province, accounting for almost half of the total land area of Ninewa. While the reasons for abandoned farmland could be complex, it indicates a significant change in the local agriculture and land use practices, which could have socio-economic local and tribal conflicts and environmental consequences.

Arable land (10 years): This class covers over %17 of the total area in Ninewa province and is an essential resource for local agriculture, food production, and rural livelihoods. The productivity and sustainability of this land class depend on various factors, such as soil quality, irrigation, land tenure, and climate change. This indicates %17 of the agricultural lands of Ninewa have been used for agricultural purposes at least once within the last 10 years. Appropriate and strategic plans are required to utilise these lands for agricultural purposes by Ninewa and/or Iraqi authorities.

Grassland: This class covers over %16 (5939 km2) of the total area in Ninewa province and provides various ecological and socio-economic services. Grasslands are essential habitats for many plant and animal

species, including livestock grazing, and wild animal food supply which is crucial for the local biodiversity, economy and culture. Grasslands can also help mitigate climate change by sequestering carbon in the soil and reducing soil erosion in Ninewa province.

Irrigated land: This class covers around %3.52 (1275 km2) of the total area in Ninewa province and is critical for food production, especially in areas with limited rainfall. Irrigation can increase agricultural productivity, but it can also cause environmental problems such as soil salinization and water depletion where poor irrigation techniques are applied.

Desert land: This class covers around %8 of the total area in Ninewa province and is an important natural landscape with unique ecological features. Desert lands can provide various ecosystem services, such as water infiltration, and wildlife habitats. However, desertification, which is the process of land degradation in drylands, is a growing concern in many parts of Iraq, including Ninewa province. Suitable land management strategies are essential to eliminate desertification risks in the remaining lands in Ninewa province.

The Water Body class in Ninewa province covers an area of 204.3 km2, which represents only %0.56 of the total land area. The water bodies in the province include rivers, lakes, and man-made reservoirs, such as the Mosul Dam, which are essential sources of water for irrigation, hydroelectric power generation, and drinking water supply. Tigris River is a main surface water resource in Ninewa province which is relied on by the majority of the growers for agricultural activities in Ninewa province. Water resources in Ninewa province face several challenges due to natural and human-induced factors. One of the primary natural factors is the limited rainfall in the region, which results in low water availability, especially during the dry season. Climate change is expected to exacerbate this problem by increasing the frequency and intensity of droughts and floods in the region.

Overall, the land cover and land use patterns in Ninewa province of Iraq are undergoing rapid changes due to various natural and anthropogenic factors, such as climate change, conflict, and displacement. Therefore, understanding the dynamics and impacts of these LULC classes is essential for sustainable land use planning, ecosystem conservation, and livelihood improvement in the region.

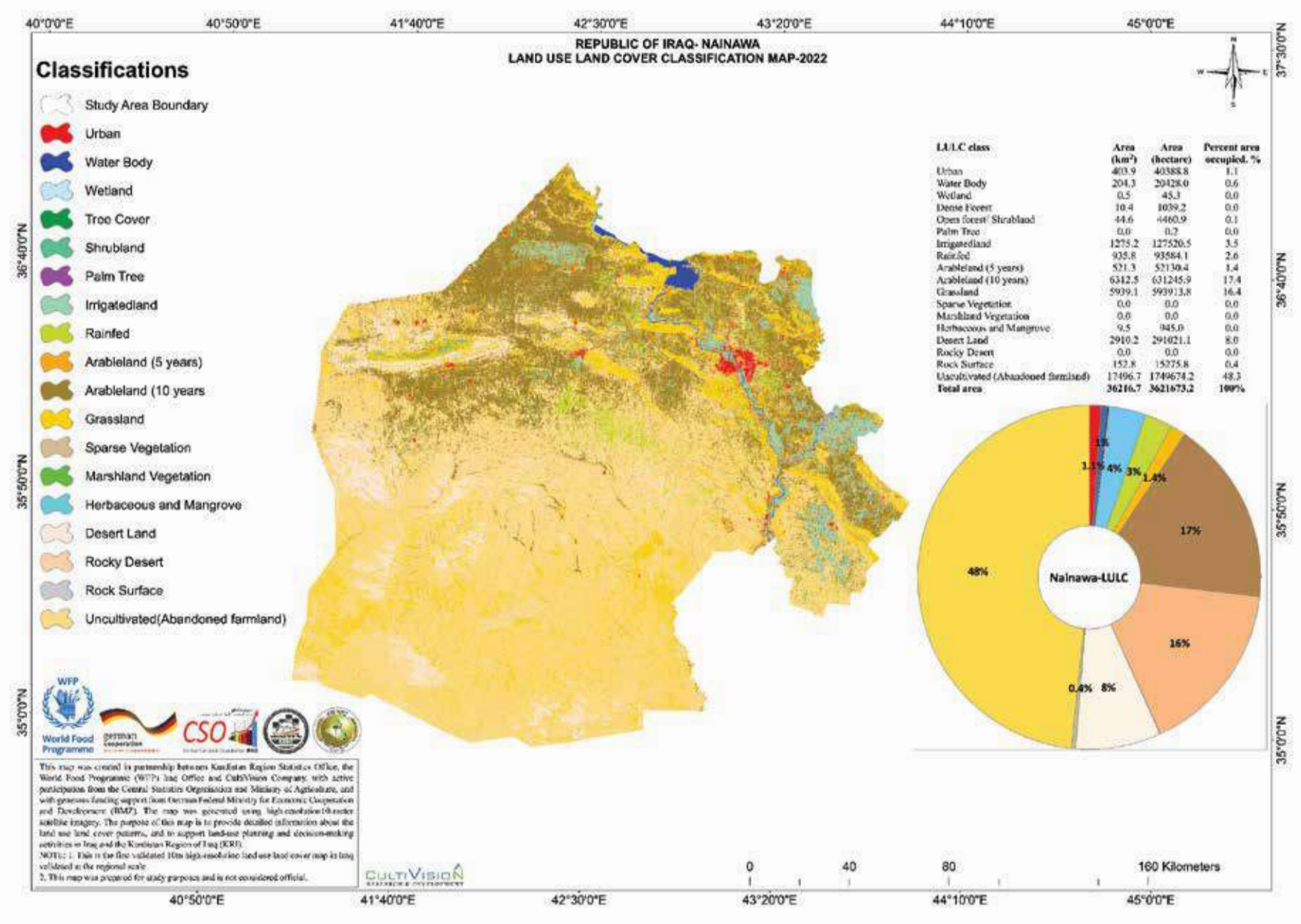


Figure 9 The spatial distribution of land use and land cover of Ninewa province for 2022.

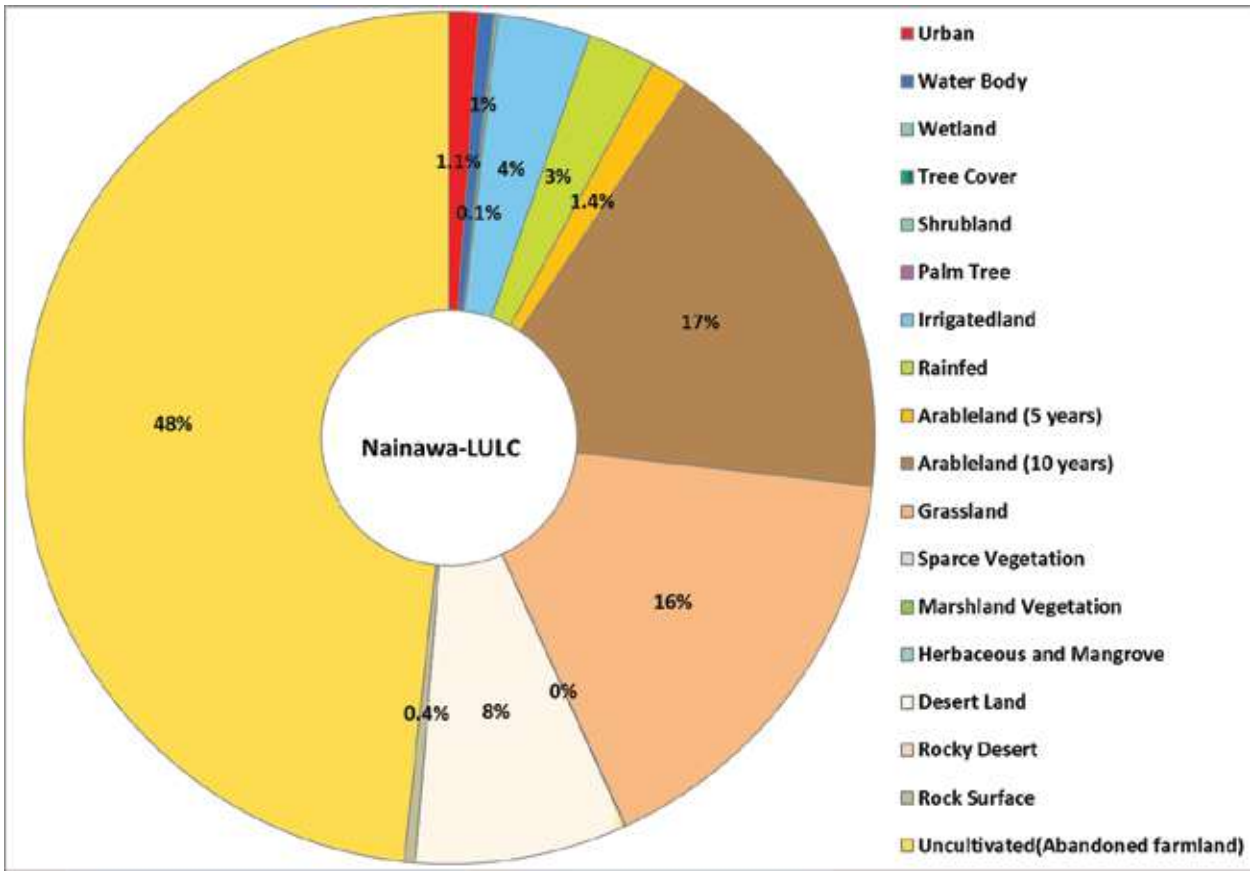


Figure 10 Land use and land cover (LULC) map produced for Ninewa province.

Table 5 Ninewa Land use and land cover (LULC) Classifications Area km and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	403.9	40388.8	1.1
Water Body	204.3	20428.0	0.6
Wetland	0.5	45.3	0.0
Dense Forest	10.4	1039.2	0.0
Open forest/ Shrubland	44.6	4460.9	0.1
Palm Tree	0.0	0.2	0.0
Irrigatedland	1275.2	127520.5	3.5
Rainfed	935.8	93584.1	2.6
Arableland (5 years)	521.3	52130.4	1.4
Arableland (10 years)	6312.5	631245.9	17.4
Grassland	5939.1	593913.8	16.4
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	9.5	945.0	0.0
Desert Land	2910.2	291021.1	8.0
Rocky Desert	0.0	0.0	0.0
Rock Surface	152.8	15275.8	0.4
Uncultivated (Abandoned farmland)	17496.7	1749674.2	48.3
Total area	**36216.7**	**3621673.2**	**100%**

6.5. Al-Anbar Province

The LULC map produced for Al-Anbar province provides information about land use and land cover for Al-Anbar in Iraq, along with their respective area and percentage of the total area of the province (Figure 11Figure 12 and Table 6). The most dominant LULC class in Al-Anbar province is the rocky desert, covering %52.9 of the province's area, followed by desert lands (%32.9), uncultivated land (%7.54) and water bodies (%1.13). Urban areas cover a very small percentage of the province's area (%0.35). There is also an absence or the minor classes of vegetation classes, such as Dense Forest, Open Forest, palm trees (farms) and marshland vegetation with around %0, whereas grassland, sparse vegetation, and herbaceous and mangrove cover %3.04 ,%0.37, and %0.1, respectively. There are also some areas of irrigated land (%0.9), rainfed land (%0.02), and arable land (%0.6). The province has some wetland areas (1 km2), it is interesting to note that there are no marshland vegetation areas in Al-Anbar province. The most important LULC classes in Al-Anbar province depend on the specific context and objectives of the analysis. However, some LULC classes can be considered important for various reasons:

Rocky Desert: This is the dominant LULC class in Al-Anbar province, covering over %50 of the area. Rocky desert is important for understanding the natural environment of the province, and its ecological and geological features. It also plays a role in the socio-economic activities of the local communities, such as livestock grazing and mining such as Akashat Mine, Akashat, and Ar-Rutba District.

Uncultivated (Abandoned Farmland): This LULC class covers a significant portion of Al-Anbar province, representing over %7.5 of the area (10,282 km2). Understanding the extent and characteristics of uncultivated land is important for assessing the potential for land degradation, salinisation, dispersivity, soil erosion, and desertification. It can also provide insights into the historical and current patterns of land use and land management in the province.

Water Body: Water bodies are important for many reasons, including their ecological value, cultural significance, and economic benefits. In Al-Anbar province, water bodies cover only %1.13 of the area, and they include rivers, lakes, and reservoirs such as the Euphrates River, Hadithah dam lake, Therthar lake, Habbaniyah lake and Razazza lake. Understanding the spatial distribution and characteristics of water bodies can help in assessing the availability

and quality of water resources, as well as their vulnerability to climate change and human activities.

Sparse Vegetation: Sparse vegetation covers %3.04 of Al-Anbar province, and it includes various types of grasses, shrubs, and bushes in the region. This LULC class is important for understanding the biodiversity and ecosystem services of the province, as well as its potential for rangeland management and restoration.

Urban: Although urban areas cover a small percentage of Al-Anbar province (%0.35), they are important for assessing the spatial patterns of population growth, urbanisation, and development. Understanding the characteristics and dynamics of urban areas can provide insights into the social, economic, and environmental impacts of urbanisation, as well as the opportunities and challenges for sustainable urban development in the province.

To conclude, the most important LULC classes in Al-Anbar province generally include rocky desert, uncultivated land, water bodies, sparse vegetation, and urban areas, which reflects the arid and semi-arid climate of the region. These LULC classes provide valuable insights into the natural environment, land use patterns, and socio-economic activities of the province, and they can support informed decision-making for sustainable development and environmental conservation by Al-Anbar and/or Iraqi authorities.

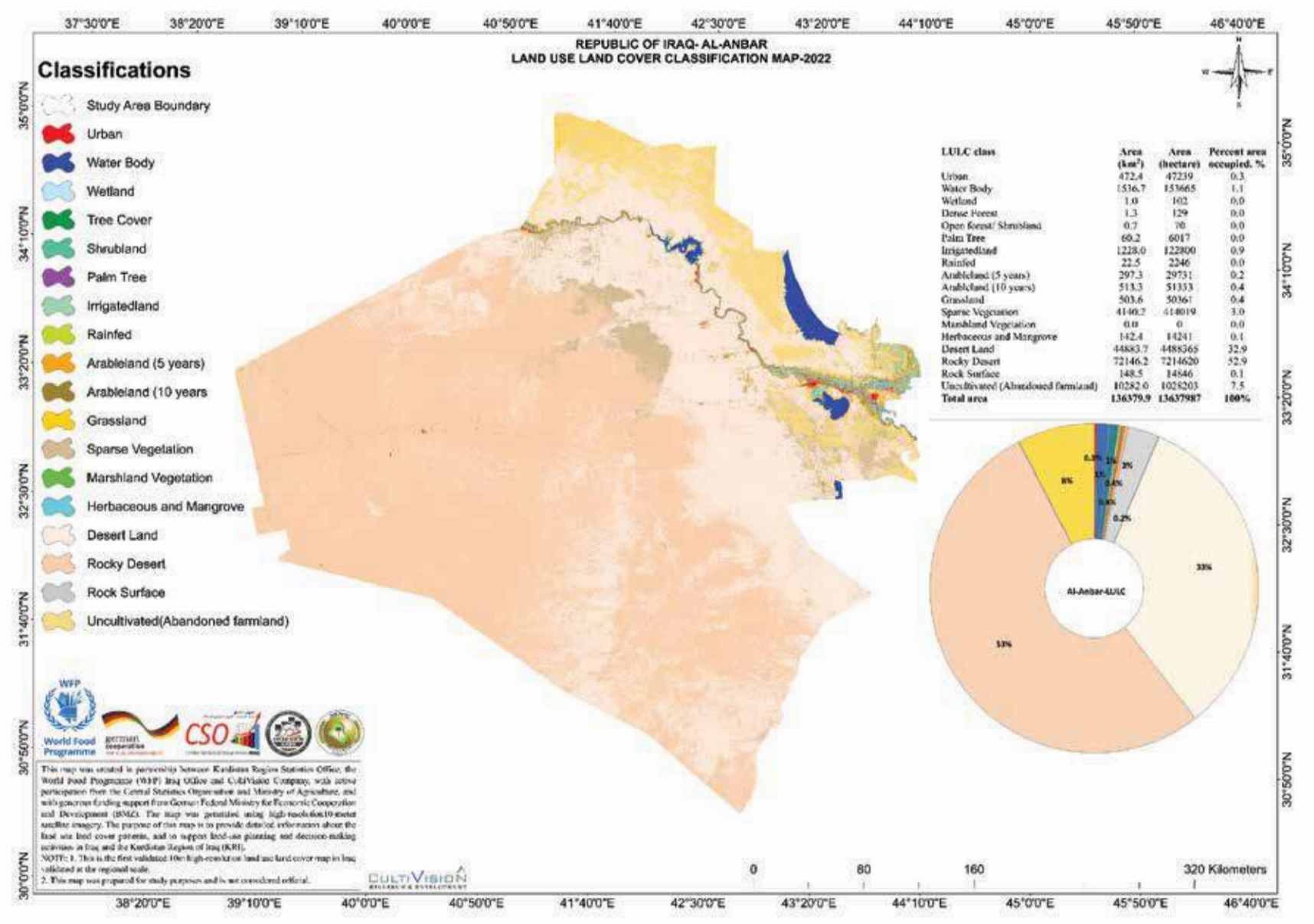


Figure 11 The spatial distribution of land use and land cover of Al-Anbar province for 2022.

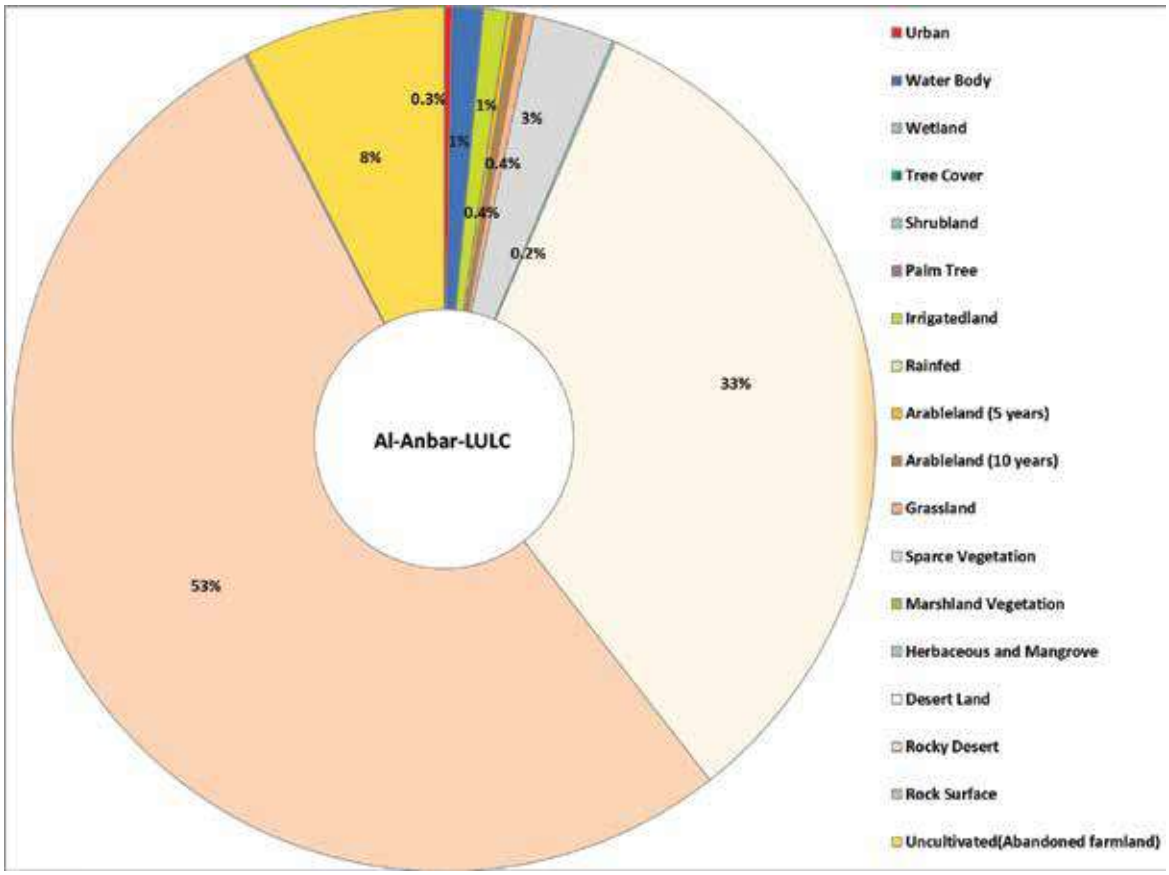


Figure 12 Land use and land cover (LULC) map produced for Al-Anbar province.

Table 6 Al-Anbar Land use and land cover (LULC) Classifications Area km^2 and Percent.

LULC class	**Area (km^2)**	**Area (hectare)**	**Percent area occupied. %**
Urban	472.4	47239	0.3
Water Body	1536.7	153665	1.1
Wetland	1.0	102	0.0
Dense Forest	1.3	129	0.0
Open forest/ Shrubland	0.7	70	0.0
Palm Tree	60.2	6017	0.0
Irrigatedland	1228.0	122800	0.9
Rainfed	22.5	2246	0.0
Arableland (5 years)	297.3	29731	0.2
Arableland (10 years)	513.3	51333	0.4
Grassland	503.6	50361	0.4
Sparse Vegetation	4140.2	414019	3.0
Marshland Vegetation	0.0	0	0.0
Herbaceous and Mangrove	142.4	14241	0.1
Desert Land	44883.7	4488365	32.9
Rocky Desert	72146.2	7214620	52.9
Rock Surface	148.5	14846	0.1
Uncultivated (Abandoned farmland)	10282.0	1028203	7.5
Total area	**136379.9**	**13637987**	**100%**

6.6. Babil Province

The LULC map for Babil shows different classes along with their corresponding areas in square kilometres and percentages (Figure 13, Figure 14 and Table 7). The common LULC classes include Urban, Water Body, Palm Tree, Irrigated land, Rainfed, Arable land (5 years), Arable land (10 years), Grassland, Sparse Vegetation, Herbaceous and Mangrove, Desert Land, Rock Surface, and Uncultivated (Abandoned farmland).

According to the LULC map, the dominant LULC class in Babil is Irrigated land, which covers %40.7 (2155 km2) of the area, followed by Arable land (5 years) and Arable land (10 years) which covers %11.2 and %12.6, respectively. The Urban area covers only %5 (265.5 km2) of the land area while Water Body covers %1.3 and almost an absence of Wetland cover (0.9 ,%0 km2). The other LULC classes cover relatively smaller areas.

The palm tree class in LULC dataset refers to areas covered with palm trees in the Babil region. Palm trees are cultivated for their fruit. The palm tree class covers %6.9 (365.4 km2) of the area in Babil, making it one of the significant LULC classes in the region. Palm tree class represents an important economic and environmental factor in the region. Its cultivation has significant economic benefits, and it is an important part of the region's culture and heritage. However, it is essential to balance the benefits of palm cultivation with its potential environmental impacts and ensure sustainable practices are followed.

The important land use and land cover (LULC) classes in Babil are:

Irrigated Land: This is the largest LULC class in Babil, covering %40.7 (2155 km2) of the total area. This suggests that agriculture is a significant economic activity in the region, and irrigation is an essential component of it.

Urban: This class covers %5 of the area, indicating that there is a significant population and urbanisation in the region.

This can be an essential factor for environmental planning and management in the area.

Palm Tree: This class covers %6.9 of the area, suggesting that the region may have palm groves or plantations, which could be a significant economic activity.

Arable Land (5 and 10 years): These classes together cover %23.8 (1258 km2) of the area, indicating that agriculture is a crucial economic activity in the region. The fact that there are two classes may suggest that there are different types of crops grown in the region within the last 10 and 5 years.

Water Body: This class covers %1.3 (67.3 km2) of the area, suggesting that there are water resources in the region that could be essential for environmental planning, agriculture sector and management.

It is important to note that the significance of these LULC classes can vary depending on the purpose of the analysis and the context of the region and potential planning by Babil authorities and/or the Iraqi government to further develop the region.

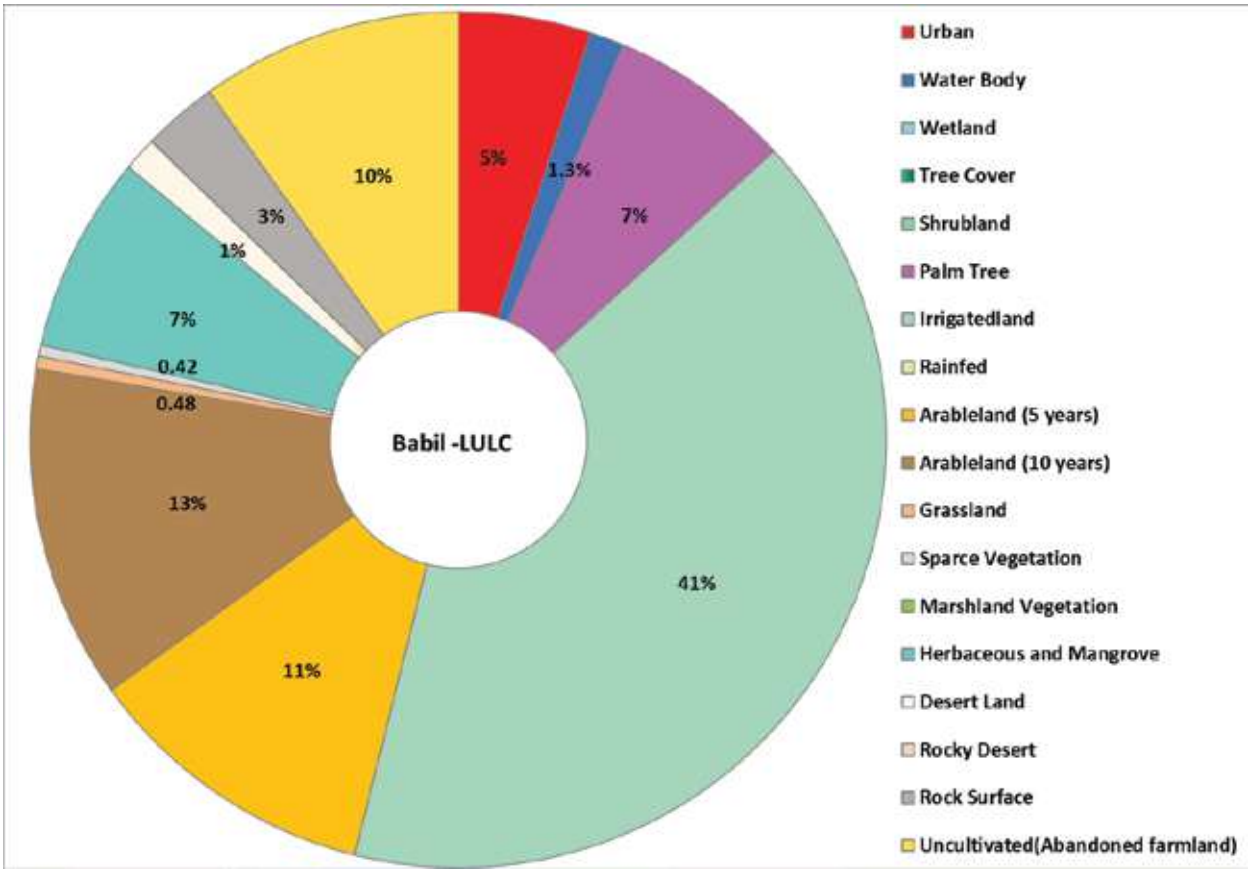


Figure 13 Land use and land cover (LULC) map produced for Babil province.

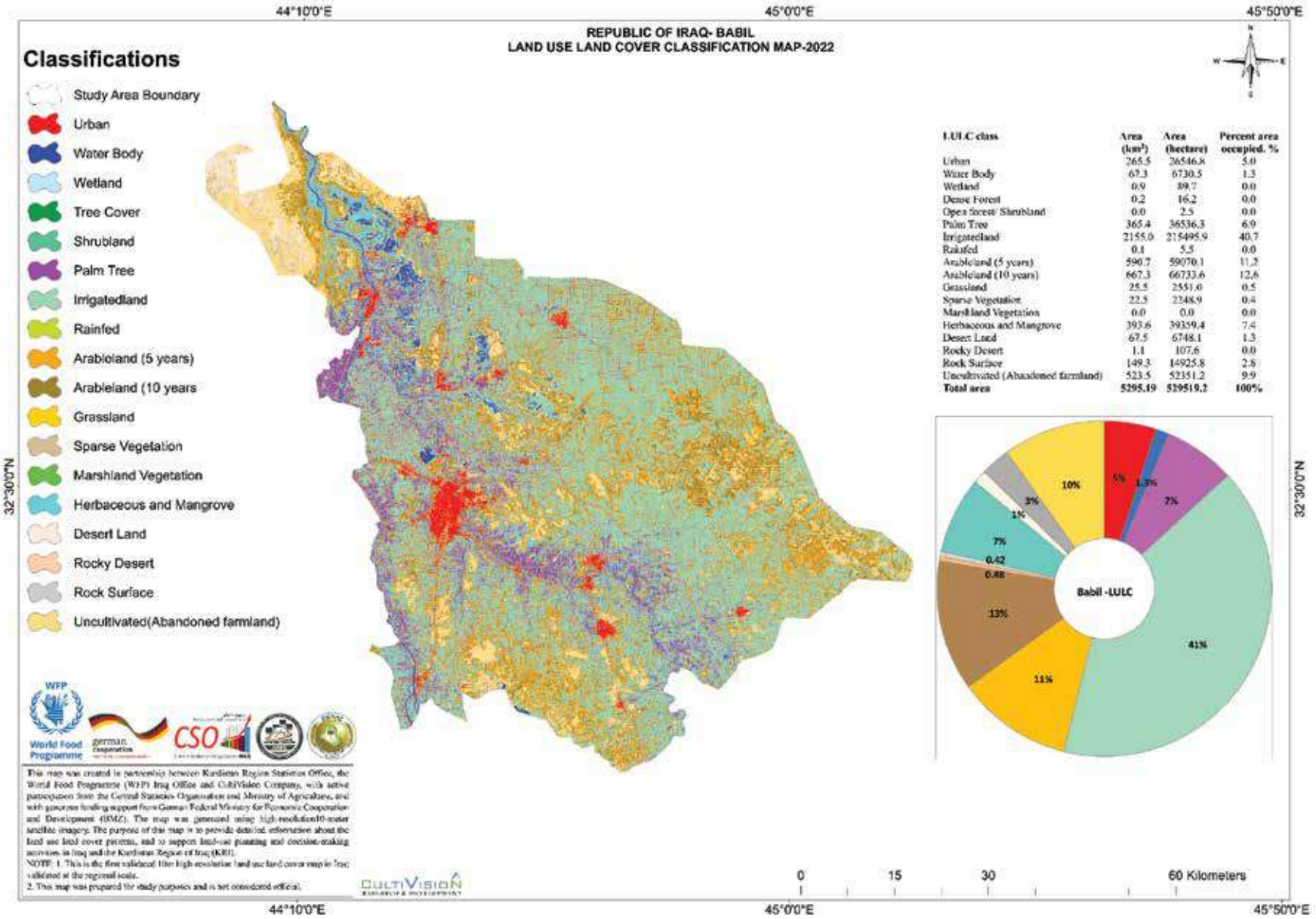


Figure 13 Land use and land cover (LULC) map produced for Babil province.

Table 7 Babil Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percen t area occupied. %
Urban	265.5	26546.8	5.0
Water Body	67.3	6730.5	1.3
Wetland	0.9	89.7	0.0
Dense Forest	0.2	16.2	0.0
Open forest/ Shrubland	0.0	2.5	0.0
Palm Tree	365.4	36536.3	6.9
Irrigatedland	2155.0	215495.9	40.7
Rainfed	0.1	5.5	0.0
Arableland (5 years)	590.7	59070.1	11.2
Arableland (10 years)	667.3	66733.6	12.6
Grassland	25.5	2551.0	0.5
Sparse Vegetation	22.5	2248.9	0.4
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	393.6	39359.4	7.4
Desert Land	67.5	6748.1	1.3
Rocky Desert	1.1	107.6	0.0
Rock Surface	149.3	14925.8	2.8
Uncultivated (Abandoned farmland)	523.5	52351.2	9.9
Total area	**5295.19**	**529519.2**	**100%**

6.7. Thi-Qar Province

The LULC map for Thi-Qar or Dhi-Qar shows different classes long with their corresponding areas in square kilometres and percentages (Figure 15, Figure 16 and Table 8). The LULC classes include Urban, Water Body, Wetland, Palm Tree, Irrigated land, Arableland (5 years), Arableland (10 years), Marshland Vegetation, Herbaceous and Mangrove, Desert Land, Rock Surface, and Uncultivated (Abandoned farmland). The LULC classes for Thi-Qar province in Iraq can be compared based on their respective areas (km2) and percentages (%) as follows:

The largest LULC class in Thi-Qar province is **"Uncultivated (Abandoned farmland)"** with an area of around 5321 km2, which accounts for %38.7 of the total land cover.

The second-largest class is **"Arable land (10 years)"** with an area of 1818 km2, accounting for %13.2 of the total land cover.

The third-largest class is **"Arable land (5 years)"** with an area of 1691 km2, accounting for %12.3 of the total land cover.

The fourth-largest class is "Herbaceous and Mangrove" with an area of 1107 km2, accounting for %8 of the total land cover.

The fifth-largest class is "Irrigated land" with an area of 1203.7 km2,

accounting for %8.7 of the total land cover.
The other minor LULC classes such as **"Water Body", "Marshland Vegetation", "Rock Surface", "Grassland", "Urban", "Wetland", "Palm Tree", "Desert Land", "Dense Forest",** and **"Open Forest"** occupy relatively smaller areas of land cover. It can be noted that there was an absence of some important classes in Thi-Qar province such as Dense Forest, Open Forest, rainfed farms, sparse vegetation, and rocky deserts.

According to the LULC map, the Thi-Qar province has a total area of approximately 13,763.8 square kilometres. Out of this, only %1.6 of the area is classified as urban, with a total area of 220.2 km2. This indicates that Thi-Qar is a predominantly rural province with a relatively low level of urbanization.

The palm tree class covers a total area of 24.1 km2 or %0.2 of the Thi-Qar province's total area. Palm trees are a characteristic feature of the Middle East, where they have been cultivated for centuries for their fruit, oil, and other products. In Thi-Qar province, palm trees are likely cultivated for their dates, which are a popular food and an important export product for Iraq. The small area covered by the palm tree class suggests that date cultivation may not be a major economic activity in Thi-Qar compared to other regions in Iraq.

One of the most important land cover classes in Thi-Qar province is the arable land class, which covers a total area of 3508.3 km2 or %25.5 of the province's total area. This indicates that agriculture is a significant economic activity in Thi-Qar and that the province has a relatively large area of land suitable for agriculture. Arable land includes land that is currently under cultivation as well as land that has been cultivated within the last 10 or 5 years.

Irrigated land class is another important land cover class in Thi-Qar province, covering an area of 1203.7 km2 or %8.7 of the province's total area. This class indicates that irrigation is an important aspect of agriculture in Thi-Qar, as water is a scarce resource in this region. Irrigated land also plays a crucial role in maintaining the province's wetlands and marshes, which are important for biodiversity and act as natural water filters. The wetland and marshland vegetation classes are also important in Thi-Qar, covering a combined area of 850 km2 or %6.2 of the province's total area. These classes support a diverse range of plant and animal species, provide important ecosystem services

such as water purification and flood control, and are also important for cultural and recreational purposes.

Finally, the abandoned or uncultivated land class, covering the largest area in Thi-Qar at %38.7 (5321 km2) of the province's total area, also has significant ecological and economic implications. While some of this land may have low ecological value, it also provides important habitats for wildlife and can be used for activities such as grazing and tourism or other sustainable government activities.

Overall, the land cover classification for Thi-Qar province shows a mix of natural and human-modified landscapes, with a low level of urbanisation and a significant portion of land dedicated to agriculture and wetlands.

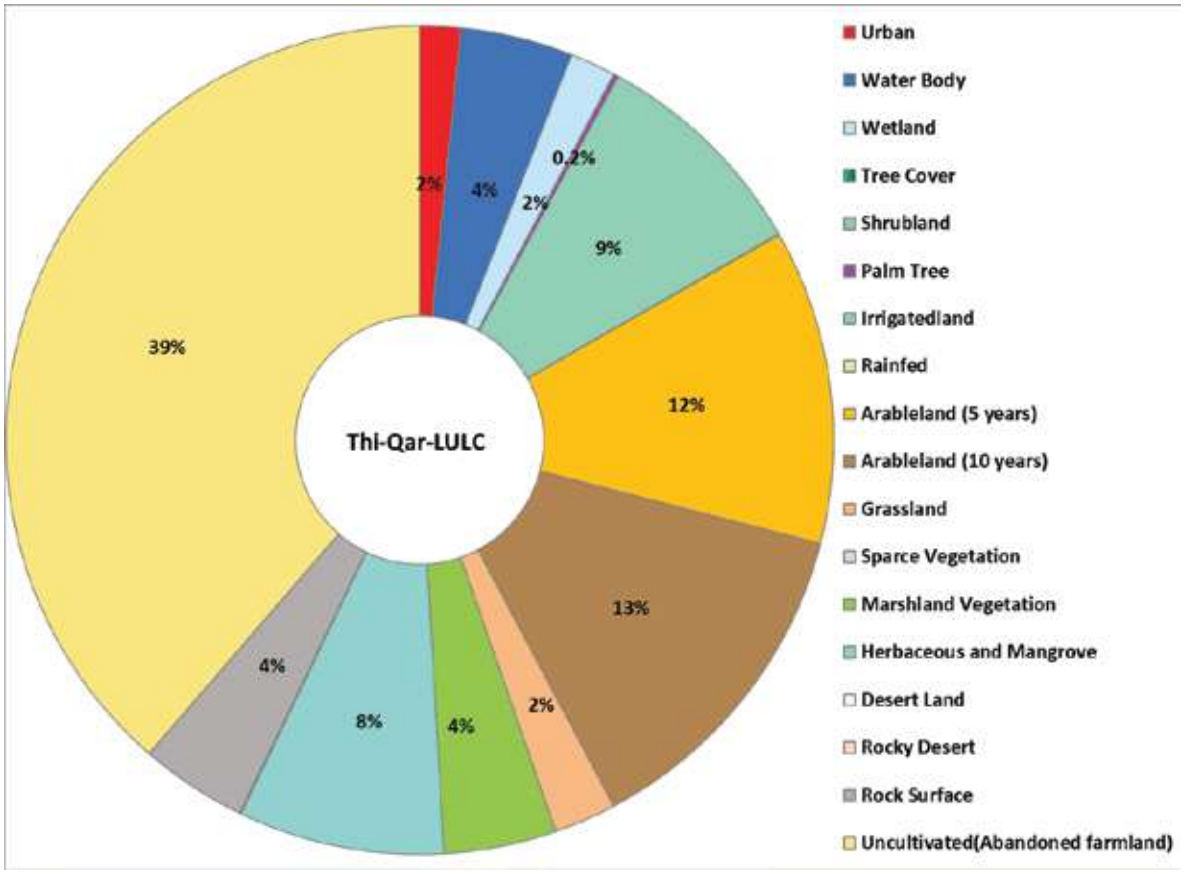


Figure 15 Land use and land cover (LULC) map produced for Thi -Qar province.

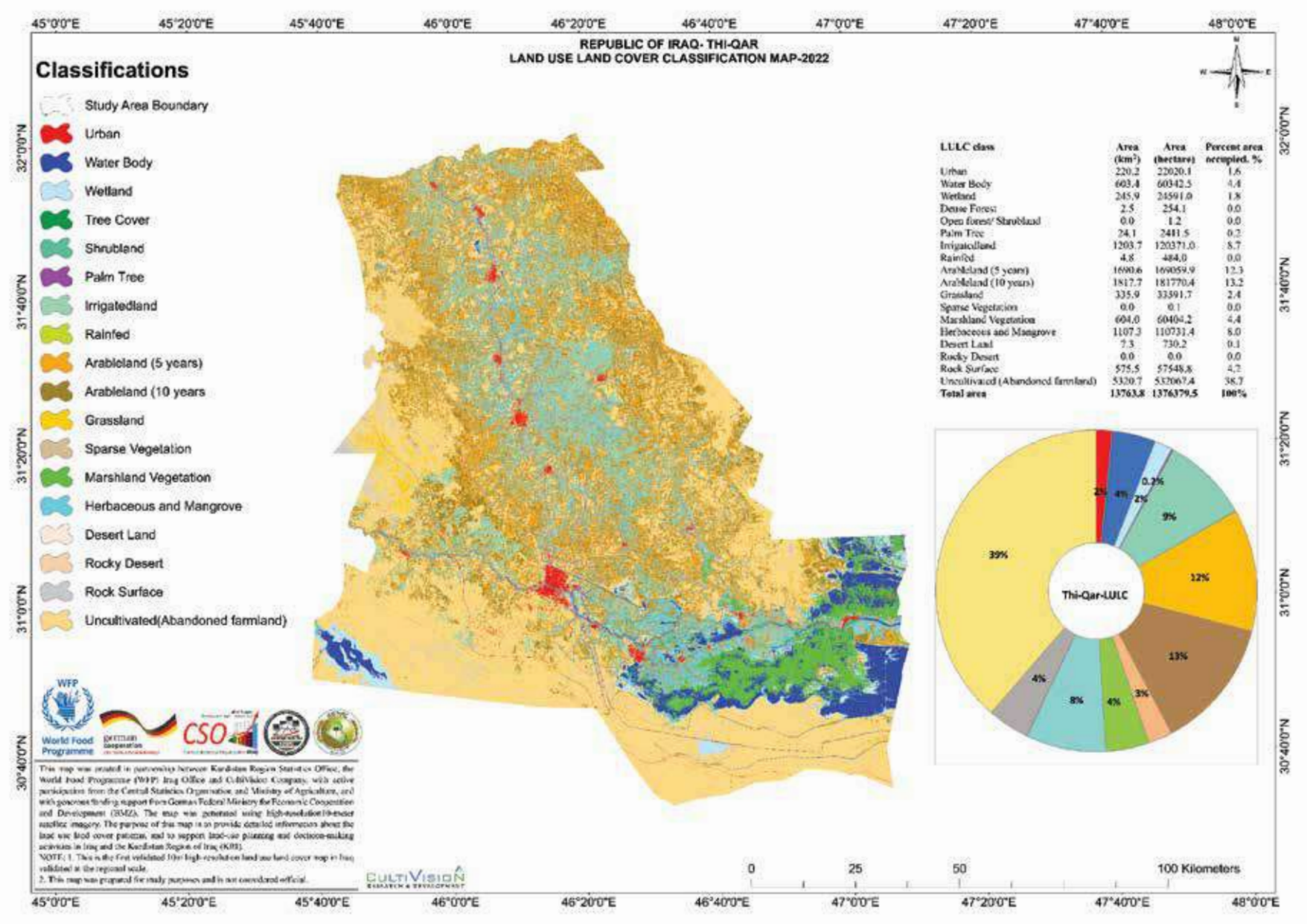


Figure 16 The spatial distribution of land use and land cover of Thi-Qar province for 2022.

Table 7 Babil Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	220.2	22020.1	1.6
Water Body	603.4	60342.5	4.4
Wetland	245.9	24591.0	1.8
Dense Forest	2.5	254.1	0.0
Open forest/ Shrubland	0.0	1.2	0.0
Palm Tree	24.1	2411.5	0.2
Irrigatedland	1203.7	120371.0	8.7
Rainfed	4.8	484.0	0.0
Arableland (5 years)	1690.6	169059.9	12.3
Arableland (10 years)	1817.7	181770.4	13.2
Grassland	335.9	33591.7	2.4
Sparse Vegetation	0.0	0.1	0.0
Marshland Vegetation	604.0	60404.2	4.4
Herbaceous and Mangrove	1107.3	110731.4	8.0
Desert Land	7.3	730.2	0.1
Rocky Desert	0.0	0.0	0.0
Rock Surface	575.5	57548.8	4.2
Uncultivated (Abandoned farmland)	5320.7	532067.4	38.7
Total area	**13763.8**	**1376379.5**	**100%**

6.8. Al-Qadissiya Province

The land use and land cover (LULC) map class distribution for Al-Qadissiya province (8137 km2). The LULC results show the area in square kilometres and the percentage for each LULC type within the region (Figure 17, Figure 18 and Table 9). From the table, we can see that the dominant LULC class is "Uncultivated (Abandoned farmland)" with an area of 2467 km2, which accounts for %28.9 of the total area. This indicates that a significant portion of the region is no longer being used for agricultural purposes.

Other notable LULC types include "Irrigated land" with an area of 1830 km2, accounting for %21.4 of the total area, and "Arable land (10 years)" with an area of 1309 km2, accounting for %15.3 of the total area. These results suggest that agriculture)irrigated farming(is still an important land use within the region, The sustainability of these land use practices and their impacts on the environment and local communities should be carefully monitored and managed.

In the LULC map produced for Al-Qadissiya province, several agricultural classes are important for the region. These include irrigated land, arable land (5 and 10 years), palm trees, and herbaceous and mangroves. Irrigated land is the largest agricultural class in the area, covering %21.4 of the total area. Irrigated land refers to land that is artificially watered to support crop growth. In an arid region such as Al-Qadissiya province, irrigation is essential for crop production. The data suggests that the region has a relatively high level of investment in irrigation infrastructure to support agriculture.

In contrast, the LULC types "Open Forest" have very small area, indicating that they are not significant land uses within the Al-Qadissiya region. Additionally, the absence of any area classified as "Marshland Vegetation" suggests that the region may not have significant wetlands or coastal ecosystems to encourage the presence of marshes.

The Water Body class represents the area of the region that is covered by surface water, such as rivers, lakes, and reservoirs in Al-Qadissiya province. The water body class accounts for around %1 (80.3 km2) of the total area, which is relatively small compared to other LULC classes. Despite its relatively small size, the water body class is an important LULC class to consider in the context of sustainable land use and management. Water bodies provide critical ecosystem services, such as water supply, flood control, and biodiversity conservation. They also support a wide range of human activities, such as fishing, boating, and recreation. However, water bodies can also be sensitive to human activities and land use practices. For example, pollution from agricultural runoff, urban development, and industrial activities can negatively impact water quality and threaten aquatic ecosystems. Climate change and variability can also affect water availability and quality, which can have significant social and economic implications for local communities.

In Al-Qadissiya province "Urban" class represents the area of the region that is covered by urban development, such as buildings, roads, and other infrastructure. In the provided results, the "Urban" class accounts for %1.6 of the total area, which is relatively small (only 138.1 km2) compared to other LULC classes. However, even a small percentage of urban development can have significant impacts on the environment and society. Urbanisation can lead to changes in land use, loss of biodiversity, increased air, and water pollution, and altered hydrological processes. It can also affect human health

and social well-being, by changing access to services, opportunities, and social networks. The spatial distribution and characteristics of urban development within the region are also important to consider. For example, urban areas that are located near natural resources, sensitive ecosystems, or vulnerable communities may have greater environmental and social impacts than those located in less critical areas.

Overall, these results provide valuable information about the distribution of different land use types within the region, which can be useful for land management, conservation, and planning efforts.

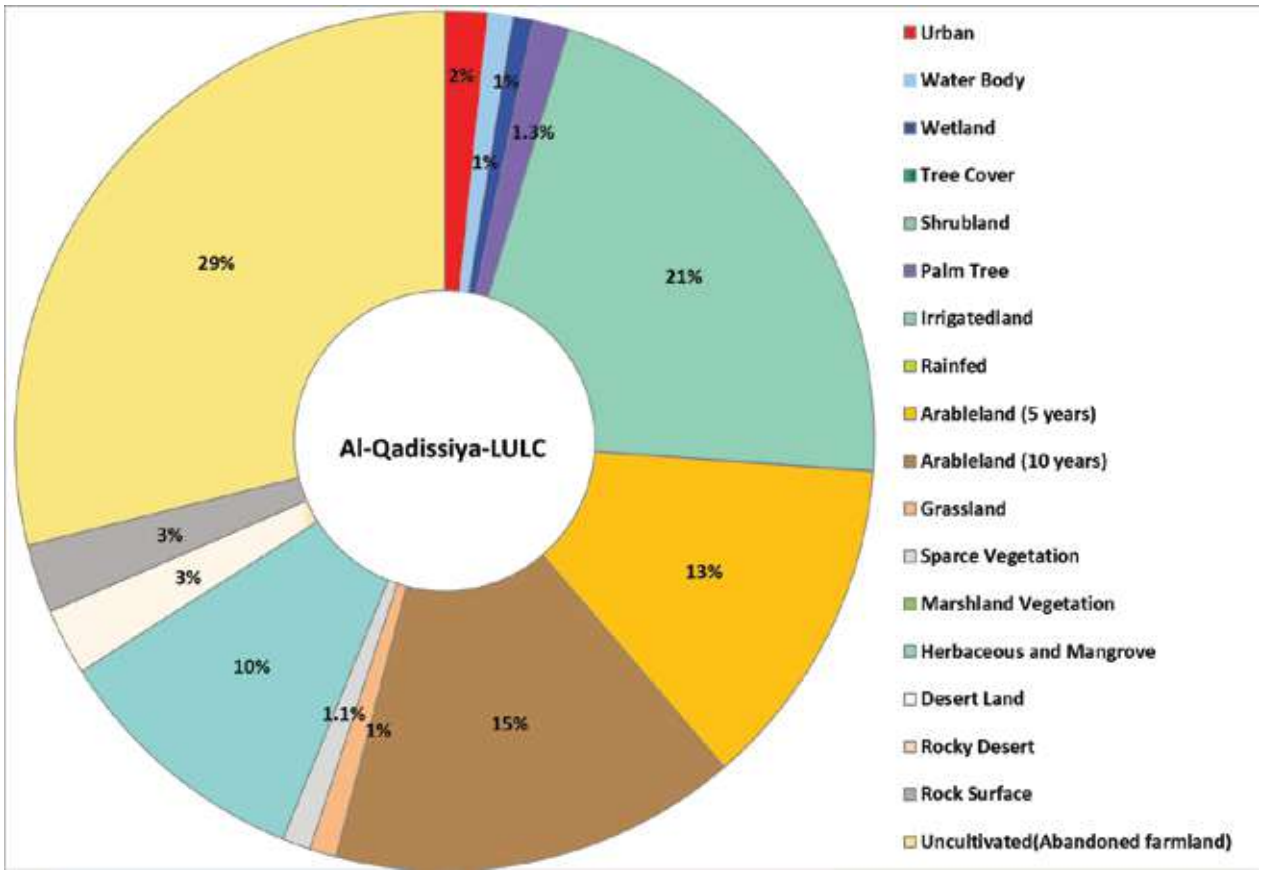


Figure 17 Land use and land cover (LULC) map produced for Al-Qadissiya province.

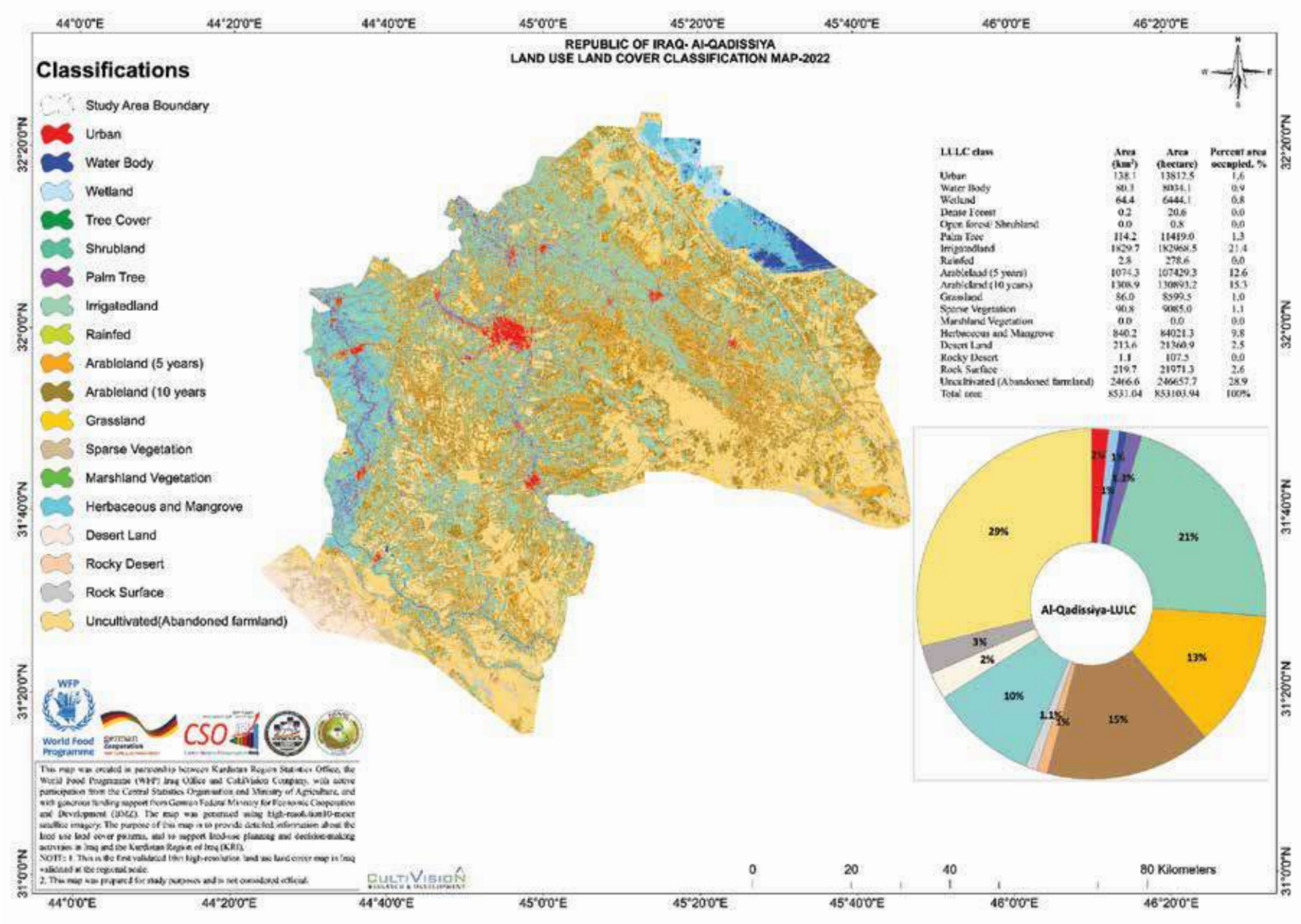


Figure 18 The spatial distribution of land use and land cover of Al-Qadissiya province for 2022.

Table 9 Al-Qadissiya Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	138.1	13812.5	1.6
Water Body	80.3	8034.1	0.9
Wetland	64.4	6444.1	0.8
Dense Forest	0.2	20.6	0.0
Open forest/ Shrubland	0.0	0.8	0.0
Palm Tree	114.2	11419.0	1.3
Irrigatedland	1829.7	182968.5	21.4
Rainfed	2.8	278.6	0.0
Arableland (5 years)	1074.3	107429.3	12.6
Arableland (10 years)	1308.9	130893.2	15.3
Grassland	86.0	8599.5	1.0
Sparse Vegetation	90.8	9085.0	1.1
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	840.2	84021.3	9.8
Desert Land	213.6	21360.9	2.5
Rocky Desert	1.1	107.5	0.0
Rock Surface	219.7	21971.3	2.6
Uncultivated (Abandoned farmland)	2466.6	246657.7	28.9
Total area	8531.04	853103.94	100%

6.9. Diyala Province

LULC classes for Diyala or Diyala province in Iraq can vary based on different classification systems and interpretations. The LULC maps show the different land use and land cover (LULC) classes in Diyala, along with the area (in km2) and their percentage of the total land area of Diyala (Figure 19, Figure 20 and Table 10). Here is a more detailed description and discussion of some of these classes:

Arable Land (5 years) and Arable Land (10 years): These two classes represent the largest areas of land use in Diyala province, covering a total of 4628 km^2 or %28.4 of the province. These lands are used for agriculture within the last 10 or 5 years, providing food and income for growers and local communities. This class includes irrigated and rainfed lands that are used for crops, such as wheat, barley, corn, and vegetables etc. Agriculture is a major economic activity in the region, providing food and income for local communities.

Uncultivated (Abandoned Farmland): This class covers a significant portion of Diyala province, accounting for %42.9 or 7003 km^2 of the total area, including areas where farmland has been abandoned due to various reasons,

such as soil degradation, water scarcity, and local conflict. These lands can potentially be restored and used for sustainable agriculture, afforestation, or conservation purposes, providing multiple environmental and social benefits.

Urban and Palm Tree: These two classes represent the most intensive human activities in Diyala province, covering a total of 434 km^2 or %2.7 of the province. Urban: The urban class in Diyala province covers 268 km^2, which is about %1.6 of the province. Urbanisation in this region is mainly concentrated in the cities of Baqubah, Muqdadiyah, and Khanaqin, as well as smaller towns and villages. Palm groves provide shade, food, and income for local communities, as well as supporting biodiversity.

Grassland and Herbaceous & Mangrove: These two classes represent important ecosystems in Diyala province, covering a total of ~2075 km^2 or %12.7 together of the province. Grasslands provide important ecosystem services, such as carbon sequestration, soil conservation, and biodiversity preservation. Herbaceous and Mangroves are important for regulating water flow, filtering pollutants, and supporting biodiversity. Both of these ecosystems can be impacted by climate change, habitat loss, and overgrazing, leading to negative consequences for the environment and local communities.

Water Body: The water body class in Diyala province covers only 67 km^2, which is %0.42 of the province. The Tigris River is the main source of water in the region, and it also supports a number of smaller tributaries and wetlands. Sirwan river also has a significant impact on agricultural activities in the Diyala region. Water bodies are important resources for the ecosystem and human activities, such as irrigation, fishing, and recreation for the region.

Desert Land: The desert land class in Diyala province covers 454 km^2, which is about %2.8 of the province. This class includes areas with low vegetation cover, typically associated with arid and semi-arid regions. Desert lands have limited productivity but can support some wildlife and plant species adapted to harsh conditions in Diyala.

Understanding the distribution and dynamics of LULC classes in Diyala province is crucial for sustainable land management and conservation efforts. Maintaining a balance between human activities and environmental protection can lead to long-term benefits for both as well as restoration of the ecosystem in the region for present and future generations.

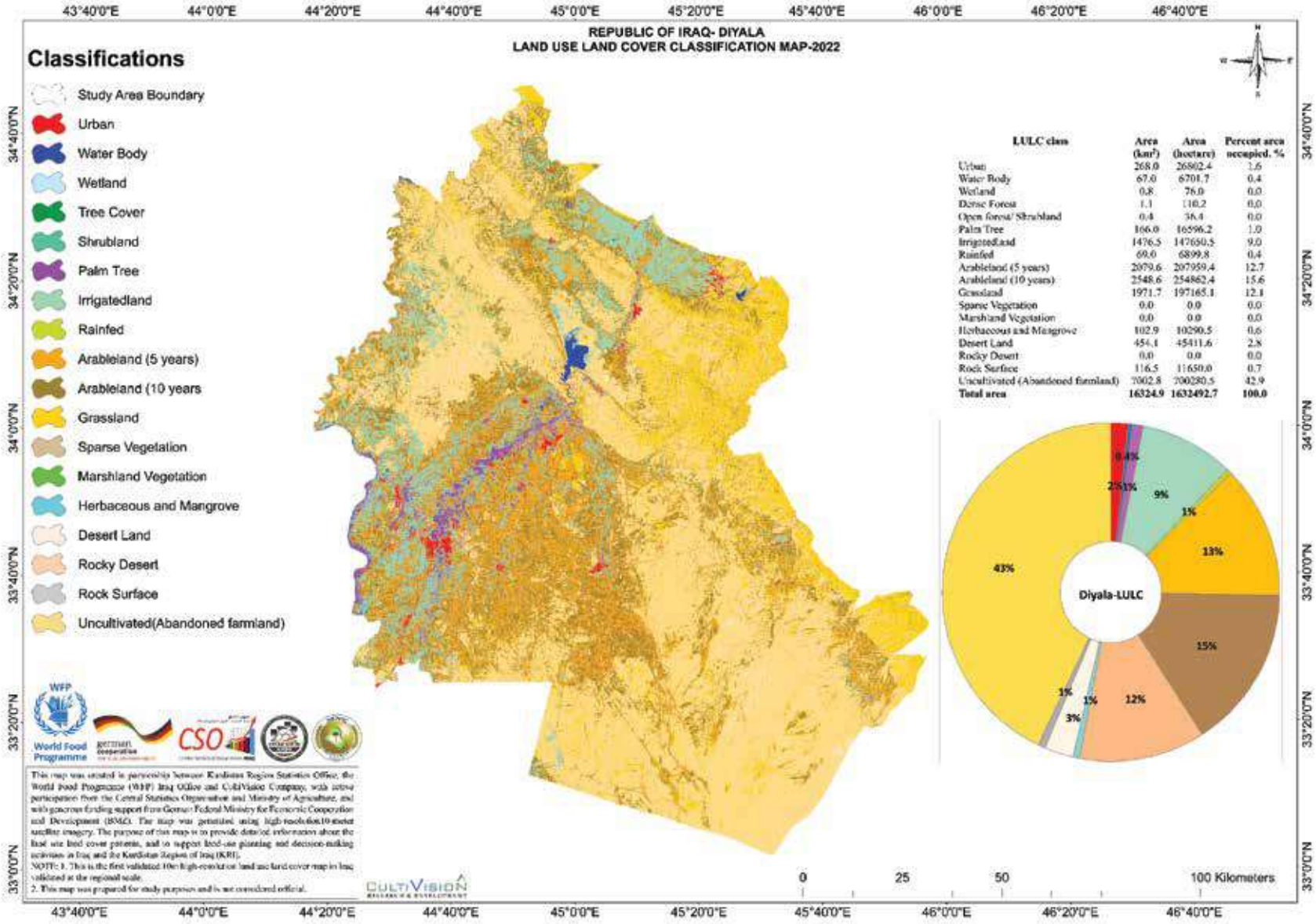


Figure 19 The spatial distribution of land use and land cover of Diyala province for 2022.

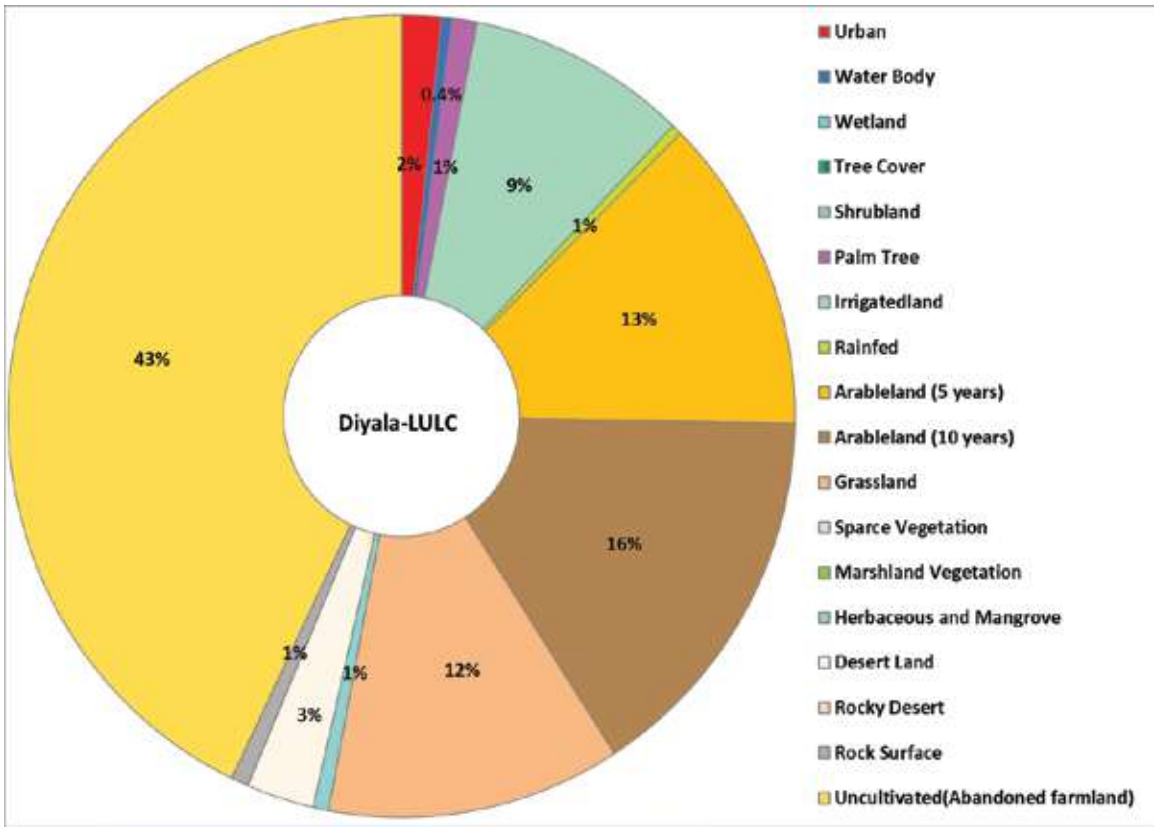


Figure 20 Land use and land cover (LULC) map produced for Diyala province.

Table 10 Diyala Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	268.0	26802.4	1.6
Water Body	67.0	6701.7	0.4
Wetland	0.8	76.0	0.0
Dense Forest	1.1	110.2	0.0
Open forest/ Shrubland	0.4	36.4	0.0
Palm Tree	166.0	16596.2	1.0
Irrigatedland	1476.5	147650.5	9.0
Rainfed	69.0	6899.8	0.4
Arableland (5 years)	2079.6	207959.4	12.7
Arableland (10 years)	2548.6	254862.4	15.6
Grassland	1971.7	197165.1	12.1
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	102.9	10290.5	0.6
Desert Land	454.1	45411.6	2.8
Rocky Desert	0.0	0.0	0.0
Rock Surface	116.5	11650.0	0.7
Uncultivated (Abandoned farmland)	7002.8	700280.5	42.9
Total area	**16324.9**	**1632492.7**	**100.0**

6.10. Kerbala Province

The LULC map for Kerbala province shows different classes long with their corresponding areas in square kilometres and percentages (Figure 21, Figure 22 and Table 11). The major LULC classes include Urban, Water Body, Palm Tree, Irrigated land, Arable lands (5 and10 years), Sparse Vegetation, Herbaceous and Mangrove, Desert Land, Rocky Desert, Rock Surface, and Uncultivated (Abandoned farmland). The three largest LULC classes in terms of area are Desert Land, Sparse Vegetation and Uncultivated (Abandoned farmland) which together account for more than two-thirds of the total area of Kerbala province (3818 ,%69 km2).

Desert Lands of Kerbala cover the largest area with %34.3 (~1904 km2) of the total area, followed by Sparse Vegetation with %17.6 (977 km2) and Uncultivated (Abandoned farmland) with %16.9 (938 km2). These three classes are major land uses and important because they represent the natural and semi-natural vegetation cover of the region and are affected by human activities such as land use change, overgrazing, and water extraction. Urban areas of Kerbala, on the other hand, cover a relatively small area with only %2.6 (142 km2), indicating that the province has a relatively low level of urbanisation. However, the expansion of urban areas may associate with the presence of natural resources or other socio-economic factors and could have impacts on the natural environment and the availability of resources, such as water and land for agriculture.

Water Body and Palm tree forest classes are also important classes in Kerbala province as they represent natural resources and cultural heritage, respectively. The Palm tree forest class has a relatively large area of %3.5 (194 km2), which indicates the importance of this crop in the region where the presence of water bodies (286 km%5.2 ,2) has a significant impact on the Palm tree forest in the province.

In Kerbala province, two agricultural land use and land cover (LULC) classes are present, including irrigated land, and arable land. Irrigated land is the largest agricultural LULC class in the province, covering 480 km2, or %8.7 of the total land area. This type of land requires irrigation to support crop production and is a critical aspect of agriculture in Kerbala due to the dry climate (very limited precipitation) and arid soils. Arable lands for 5 and 10 years, covering 278 km2, or %5 of the total land area, and they seem to be suitable for growing crops where they have been cultivated in the past years.

Page

In summary, irrigated land is the most significant agricultural LULC class in Kerbala, followed by arable land, and the agricultural sector is an essential part of the province's economy and food security for local people and exporting to neighbouring provinces and/or countries.

In summary, the most important LULC classes in Kerbala Province are Desert Land, Uncultivated (Abandoned farmland), and Sparse Vegetation. However, Water Body and Palm tree forest classes are also significant in terms of natural resources and cultural heritage. Urban areas, while covering a relatively small area, are also important due to their potential impacts on the natural environment and the availability of resources.

Table 11 Kerbala Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	**Area (km^2)**	**Area (hectare)**	**Percent area occupied. %**
Urban	142.0	14203.0	2.6
Water Body	286.3	28629.8	5.2
Wetland	2.6	258.7	0.0
Dense Forest	0.3	27.0	0.0
Open forest/ Shrubland	0.0	0.7	0.0
Palm Tree	193.8	19376.3	3.5
Irrigatedland	480.2	48020.9	8.7
Rainfed	3.0	298.3	0.1
Arableland (5 years)	93.4	9341.6	1.7
Arableland (10 years)	184.7	18471.9	3.3
Grassland	24.9	2491.5	0.4
Sparse Vegetation	977.2	97718.7	17.6
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	113.8	11381.9	2.1
Desert Land	1903.7	190373.1	34.3
Rocky Desert	121.7	12171.4	2.2
Rock Surface	84.1	8411.1	1.5
Uncultivated (Abandoned farmland)	937.5	93753.4	16.9
Total area	**5549.3**	**554929.3**	**100%**

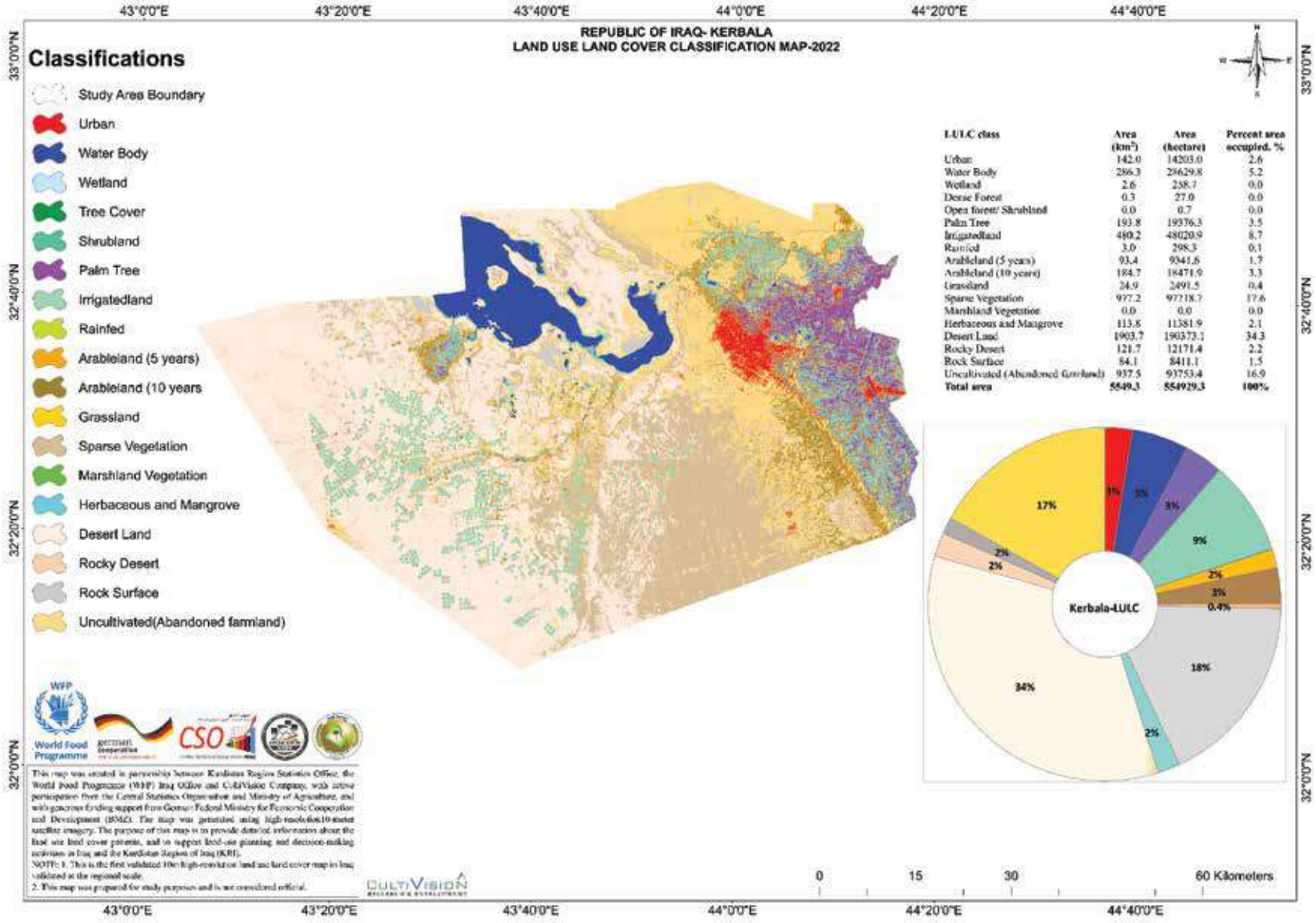


Figure 21 The spatial distribution of land use and land cover of Kerbala province for 2022.

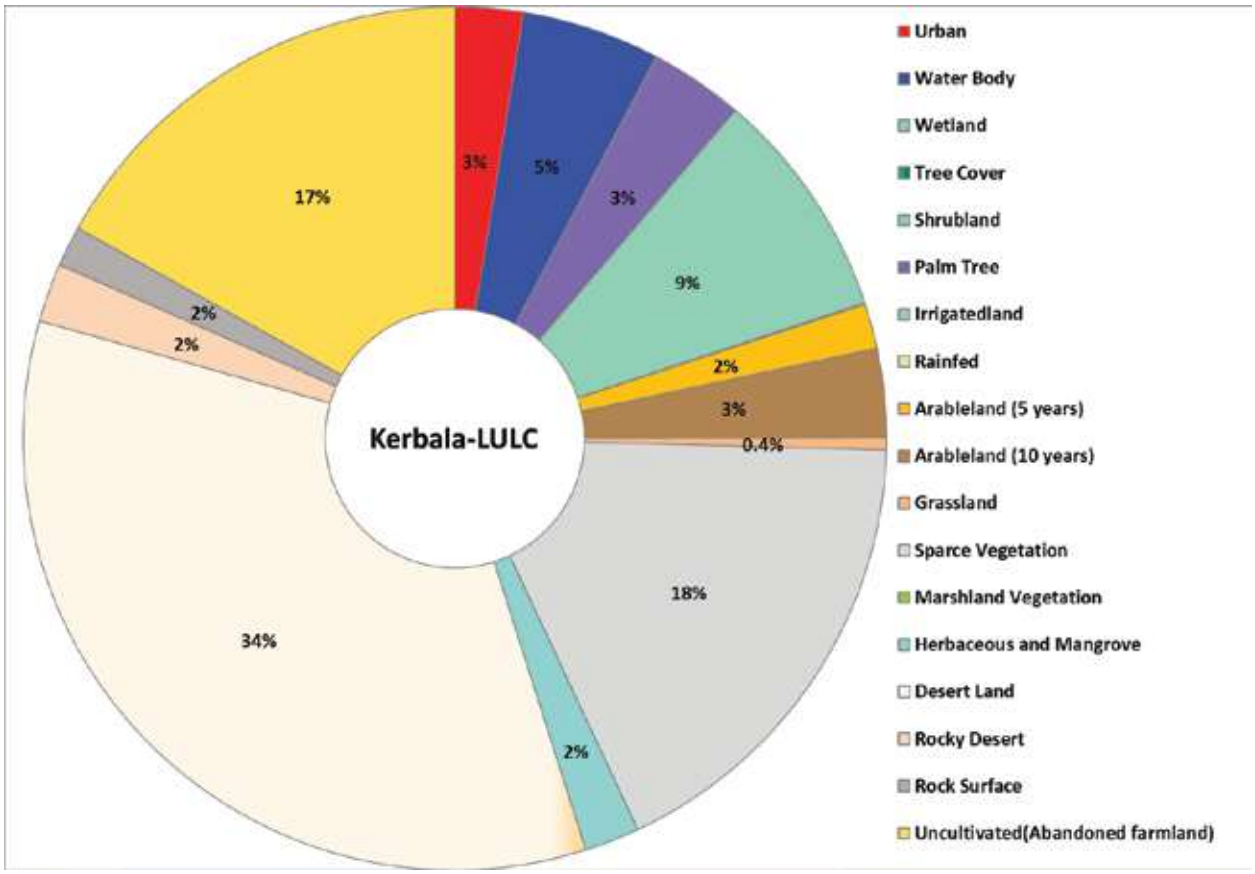


Figure 22 Land use and land cover (LULC) map produced for Kerbala province.

6.11. Maysan Province

The LULC map present the land cover class distribution for Maysan province (16243 km2). The LULC results exhibit the area in square kilometres and the percentage for each LULC type within the Maysan region (Figure 23, Figure 24 and Table 12). The most dominant LULC classes in Maysan province in Iraq are likely to be those that cover the largest areas.

Uncultivated (Abandoned farmland): %46.6 (7563 km2)
Irrigated Land: %10.9 (1770 km2)
Arable Land (5 years): 8.4 % (1364 km2)
Arable Land (10 years): %8.2 (1339 km2)
Herbaceous and Mangrove: %7.4 (1197 km2)

Uncultivated (Abandoned Farmland): This is the largest LULC class in Maysan province, covering %46.6 of the total area. This class indicates that a significant proportion of agricultural land has been abandoned or left fallow, which could be due to factors such as soil degradation, low productivity, or socio-economic factors. This land may have the potential for restoration or conversion to other land uses.

Irrigated Land: This LULC class covers %10.9 of the total area and is an important class for agriculture in Maysan province. This class indicates that irrigation is necessary to support agricultural production in the region. Irrigation may be through surface water (from the Tigris River), groundwater, or a combination of both.

Arable Land (5 years) and Arable Land (10 years): These LULC classes represent cultivated land that is used for growing crops with in the last 10 or 5 years. The presence of arable land indicates that agriculture is an important sector in Maysan province. However, the relatively small areas of arable land (%8.8 (1363.7 km2) and %8.6 (1339.2 km2) for 5-year and 10-year arable land, respectively) suggest that there may be limitations to agricultural productivity in the region, such as soil quality, water availability, or infrastructure.

Grassland: This LULC class covers %6.4 (1032.6 km2) of the total area and is important for grazing livestock. Grasslands are also important ecosystems that provide habitat for wildlife and may have cultural and economic significance.

Herbaceous and Mangrove: This LULC class covers %7.4 (1197.4 km2) of the total area and may include salt-tolerant vegetation that grows in coastal areas of the Tigris River. This class indicates that there may be important biodiversity and ecosystem services in Maysan province, particularly in coastal areas.

Marshland Vegetation: This LULC class only covers %3.6 (579 km2) of the total area and represents wetland vegetation that grows in marshes or swamps. Marshes are important ecosystems that provide a range of services, such as water purification, flood control, and habitat for wildlife in Maysan province.

Water Body: This LULC class covers %1.4 (230 km2) of the total area and includes rivers, lakes, and other bodies of water. These water bodies are important for local communities, wildlife, and agriculture in Maysan province. The urban class in Maysan province covers only 173 km2 (%1.1 of the total area), indicating that urbanisation is not a major land use in the province. However, this small urban area can still have significant social and economic importance for the local population.

Overall, the vital LULC classes in Maysan province reflect the province's agricultural, ecological, and socio-economic characteristics. The large areas of uncultivated land suggest that there may be potential for restoration or

conversion to other land uses in particular agricultural production, while the presence of wetlands, grasslands, and mangroves indicates that there may be important biodiversity, recreation and ecosystem services in the region. The small areas of arable land and urban development suggest that there may be limitations to productivity and economic development in the province.

Table 12 Maysan Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	**Area (km^2)**	**Area (hectare)**	**Percent area occupied. %**
Urban	172.9	17292.9	1.1
Water Body	230.0	22995.3	1.4
Wetland	334.9	33490.4	2.1
Dense Forest	0.0	1.9	0.0
Open forest/ Shrubland	0.0	1.3	0.0
Palm Tree	27.6	2756.0	0.2
Irrigatedland	1770.1	177005.9	10.9
Rainfed	27.0	2703.5	0.2
Arableland (5 years)	1363.7	136366.1	8.4
Arableland (10 years)	1339.8	133977.1	8.2
Grassland	1032.6	103256.6	6.4
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	579.1	57911.4	3.6
Herbaceous and Mangrove	1197.4	119736.6	7.4
Desert Land	28.7	2870.4	0.2
Rocky Desert	0.0	0.0	0.0
Rock Surface	576.7	57666.9	3.6
Uncultivated (Abandoned farmland)	7562.9	756289.7	46.6
Total area	**16243.2**	**1624322.0**	**100%**

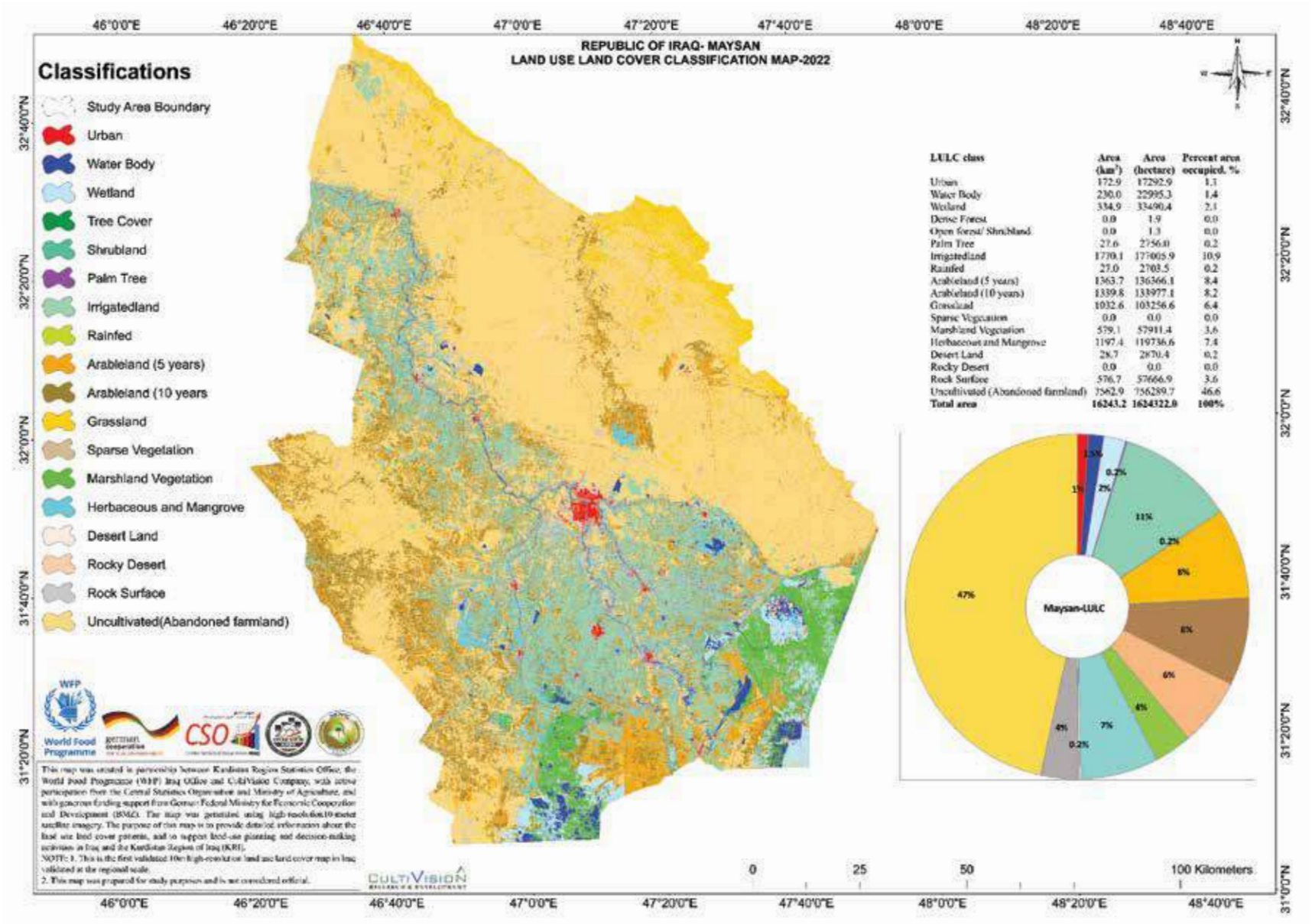


Figure 23 The spatial distribution of land use and land cover of Maysan province for 2022.

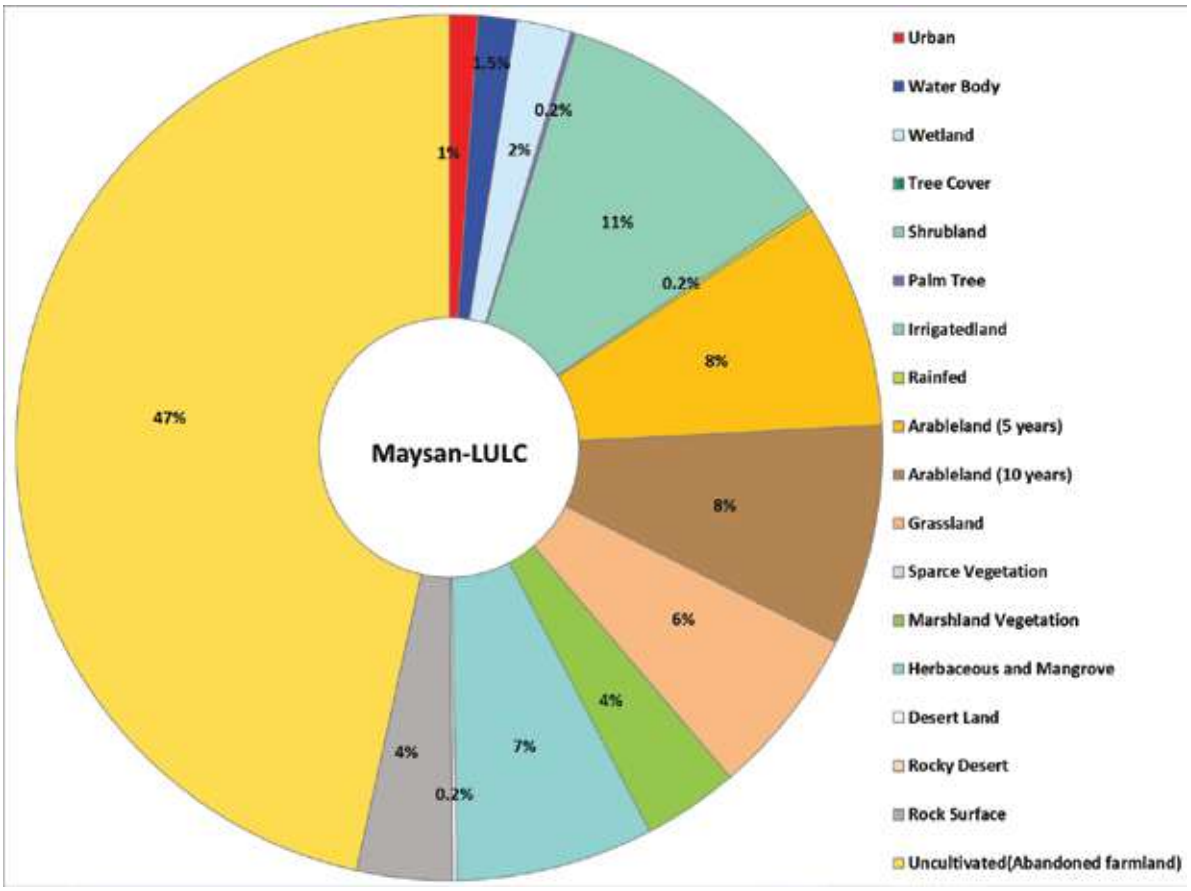


Figure 24 Land use and land cover (LULC) map produced for Maysan province.

6.12. Al-Muthanna Province

The LULC map shows the distribution of land cover classes Al-Muthanna province in square kilometres and the percentage for each LULC class within the province (Figure 25, Figure 26 and Table 13). The dominant LULC classes in Al-Muthanna province are the desert land (29926 ,%58.2 km2) and the uncultivated (abandoned farmland) class (9488 ,%18.5 km2). These two classes alone make up more than %75 of the total area of Al-Muthanna province. The desert land class is characterised by arid and bare landscapes, dominated by sand dunes. The lack of vegetation and the extreme climate in this region make it unsuitable for most types of human activities.

The uncultivated (abandoned farmland) class, on the other hand, covers 9488 km2 or %18.5 of the total area of the province, which is an indication of the decline in agriculture or unsuitability in the region. This class includes areas that were once used and/or might be suitable for agriculture but have since been abandoned and left to natural vegetation. This class reflects the

challenges that farmers in the region face, including a lack of water resources and poor soil quality.

The water body class in the Al-Muthanna province covers an area of only 11.8 km2 (%0.02 of the total area), which is a relatively small portion of the total area. In this region, the Euphrates River is the main water source, which plays an important role in supporting agricultural activities and urbanisation across the river.

The other LULC classes in Al-Muthanna, such as irrigated land, arable land, and grassland, occupy a much smaller percentage of the total area. These classes are mostly confined to areas where water resources are available, such as the Euphrates River, and are dependent on irrigation to support agricultural activities which is very limited in this province. The agricultural classes in the Al-Muthanna province include irrigated land, arable land (5 and 10 years), and palm trees. These classes cover a total area of 1390 km2, which is around %2.7 of the total area of the province. These classes cover a relatively small portion of the total area of the province, indicating that agriculture is not a significant economic activity in the region.

The urban class in the Al-Muthanna province covers an area of 104.3 km2, which is a relatively small portion of the total area of the province (%0.2). This class includes areas that are densely populated and have a high degree of built-up structures such as residential and commercial buildings, roads, and other infrastructure. The urban areas in Al-Muthanna province are mainly concentrated in the provincial capital, Samawah, and other small towns and villages. Samawah is the largest city in the province and is the centre of administration, commerce, and services in the region.

Overall, the dominant LULC classes in Al-Muthanna province reflect the harsh and arid nature of the region, with limited opportunities for human activities and economic development.

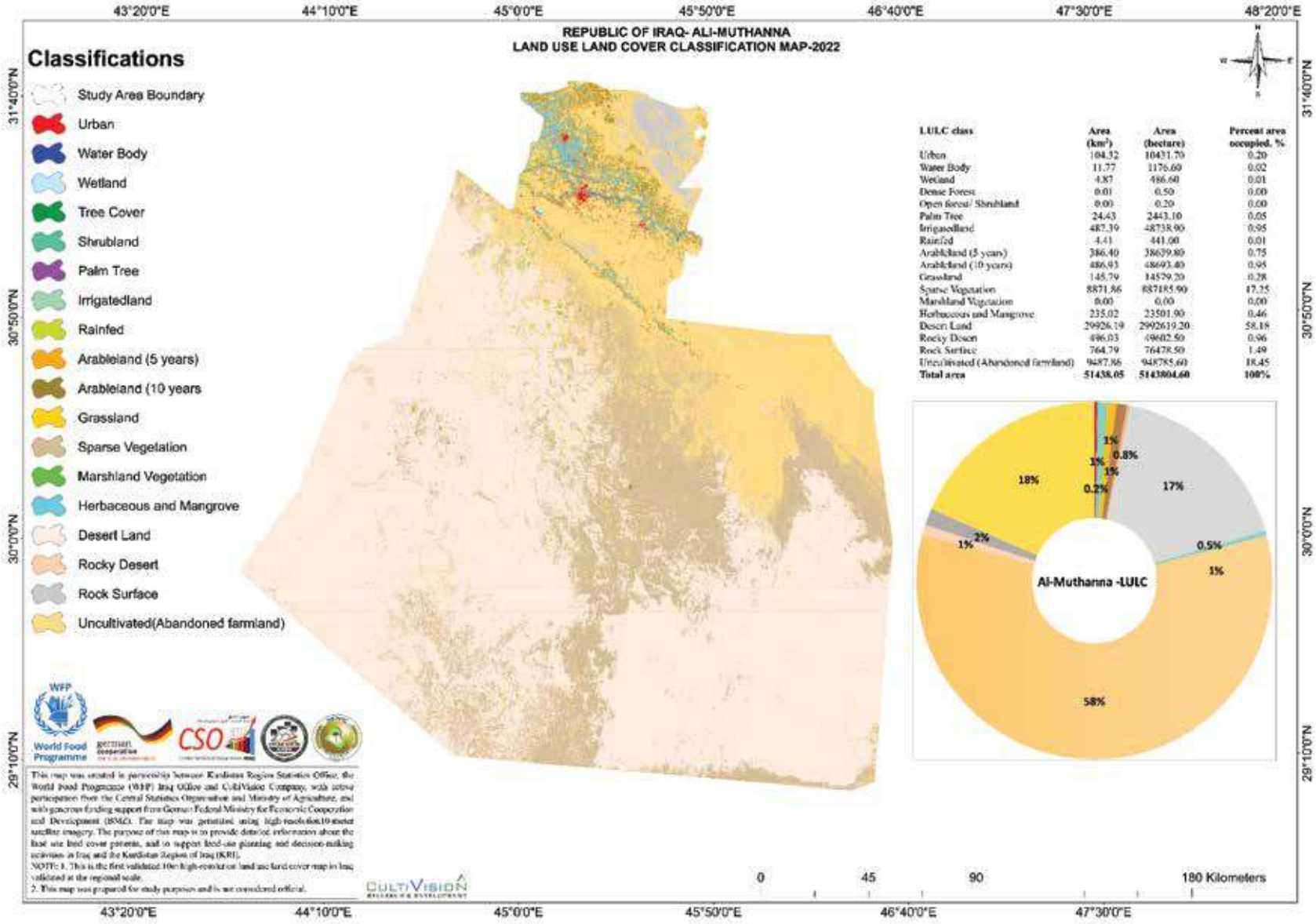


Figure 25 The spatial distribution of land use and land cover of Al-Muthanna province for 2022.

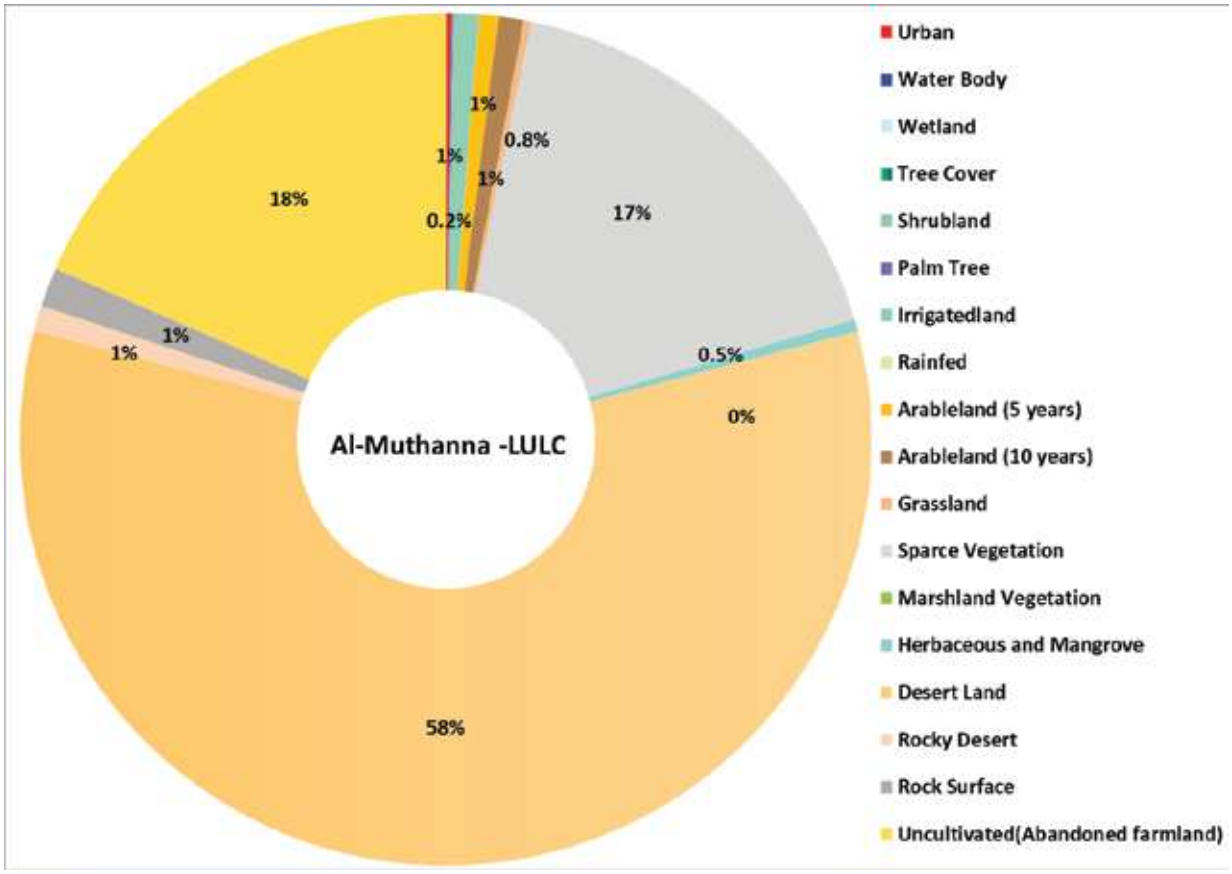


Figure 26 Land use and land cover (LULC) map produced for Al-Muthanna province.

Table 13 Al-Muthanna Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	**Area (km ^{2})**	**Area (hectare)**	**Percent area occupied. %**
Urban	104.32	10431.70	0.20
Water Body	11.77	1176.60	0.02
Wetland	4.87	486.60	0.01
Dense Forest	0.01	0.50	0.00
Open forest/ Shrubland	0.00	0.20	0.00
Palm Tree	24.43	2443.10	0.05
Irrigatedland	487.39	48738.90	0.95
Rainfed	4.41	441.00	0.01
Arableland (5 years)	386.40	38639.80	0.75
Arableland (10 years)	486.93	48693.40	0.95
Grassland	145.79	14579.20	0.28
Sparse Vegetation	8871.86	887185.90	17.25
Marshland Vegetation	0.00	0.00	0.00
Herbaceous and Mangrove	235.02	23501.90	0.46
Desert Land	29926.19	2992619.20	58.18
Rocky Desert	496.03	49602.50	0.96
Rock Surface	764.79	76478.50	1.49
Uncultivated (Abandoned farmland)	9487.86	948785.60	18.45
Total area	**51438.05**	**5143804.60**	**100%**

6.13.Al-Najaf Province

The LULC map produced for Al-Najaf province provides information about land use and land cover classes in Al-Najaf province of Iraq, including the area covered by each class and the percentage of the province that it represents (Figure 27, Figure 28 and Table 14). The dominant land use and land cover class in the province is desert land, which covers %81.3 of the total area (23213.7 km2). The next most common class is rocky desert, which covers %7 of the total area (2000 km2). Urban areas cover only %0.52 of the total area (147.7 km2), while water bodies (%0.47), irrigated land (%1.83), arable land (%0.42 and %0.64 for 5-year and 10-year cycles, respectively), and grassland (%0.06) are also present, albeit in smaller amounts. The remaining LULC classes, such as wetlands, Dense Forest, palm trees, rainfed land, herbaceous and mangrove, rocky surface, sparse vegetation, and uncultivated (abandoned farmland), cover less than %1 of the total area each.

The first and foremost LULC class is desert land, which covers more than %80 of Al-Najaf province. The desert ecosystem is unique and has adapted to the extreme climatic conditions of the region. The desert also contains valuable mineral resources, including oil and gas and oil refineries (such as Najaf Refinery and Golden Oil Refinery). However, desertification and land degradation due to human activities, such as overgrazing of livestock and deforestation and climate change, can have severe consequences on the environment and the local population.

The second important LULC class is irrigated land, which covers more than %1.8 of the province. Irrigated agriculture is vital for the economy and food security of the region, as it provides the necessary water and nutrients to grow crops. However, improper irrigation practices can lead to soil salinization and waterlogging, which can negatively impact land productivity and the environment.

The third important LULC class is urban, which covers %0.52 (148 km2) of the province. Urbanisation has been rapidly increasing in Al-Najaf province in recent years, leading to the conversion of agricultural land and natural habitats into built-up areas. Finally, the herbaceous and mangrove LULC class, which covers %0.93 (267 km2) of the province, is also important as it includes important habitats for many plant and animal species. The herbaceous and mangrove vegetation helps to prevent soil erosion and provides ecological services, such as carbon sequestration and water filtration.

Overall, the most important LULC classes in Al-Najaf province are those that have the greatest impacts on the environment, economy, and society of the region, and therefore require careful management and monitoring by local communities, Al-Najaf and/or Iraqi authorities.

Table 14 Al-Najaf Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	**Area (km^2)**	**Area (hectare)**	**Percent area occupied. %**
Urban	147.7	14770.9	0.52
Water Body	134.4	13441.3	0.47
Wetland	0.8	84.2	0.00
Dense Forest	0.1	5.9	0.00
Open forest/ Shrubland	0.0	0.4	0.00
Palm Tree	87.2	8719.0	0.31
Irrigatedland	521.8	52183.5	1.83
Rainfed	0.6	63.1	0.00
Arableland (5 years)	120.4	12036.8	0.42
Arableland (10 years)	183.2	18320.4	0.64
Grassland	18.2	1820.7	0.06
Sparse Vegetation	916.5	91647.0	3.21
Marshland Vegetation	0.0	0.0	0.00
Herbaceous and Mangrove	266.6	26658.6	0.93
Desert Land	23213.6	2321364.8	81.29
Rocky Desert	2000.3	200025.0	7.00
Rock Surface	32.1	3213.8	0.11
Uncultivated (Abandoned farmland)	912.8	91282.1	3.20
Total area	**28556.4**	**2855637.5**	**100%**

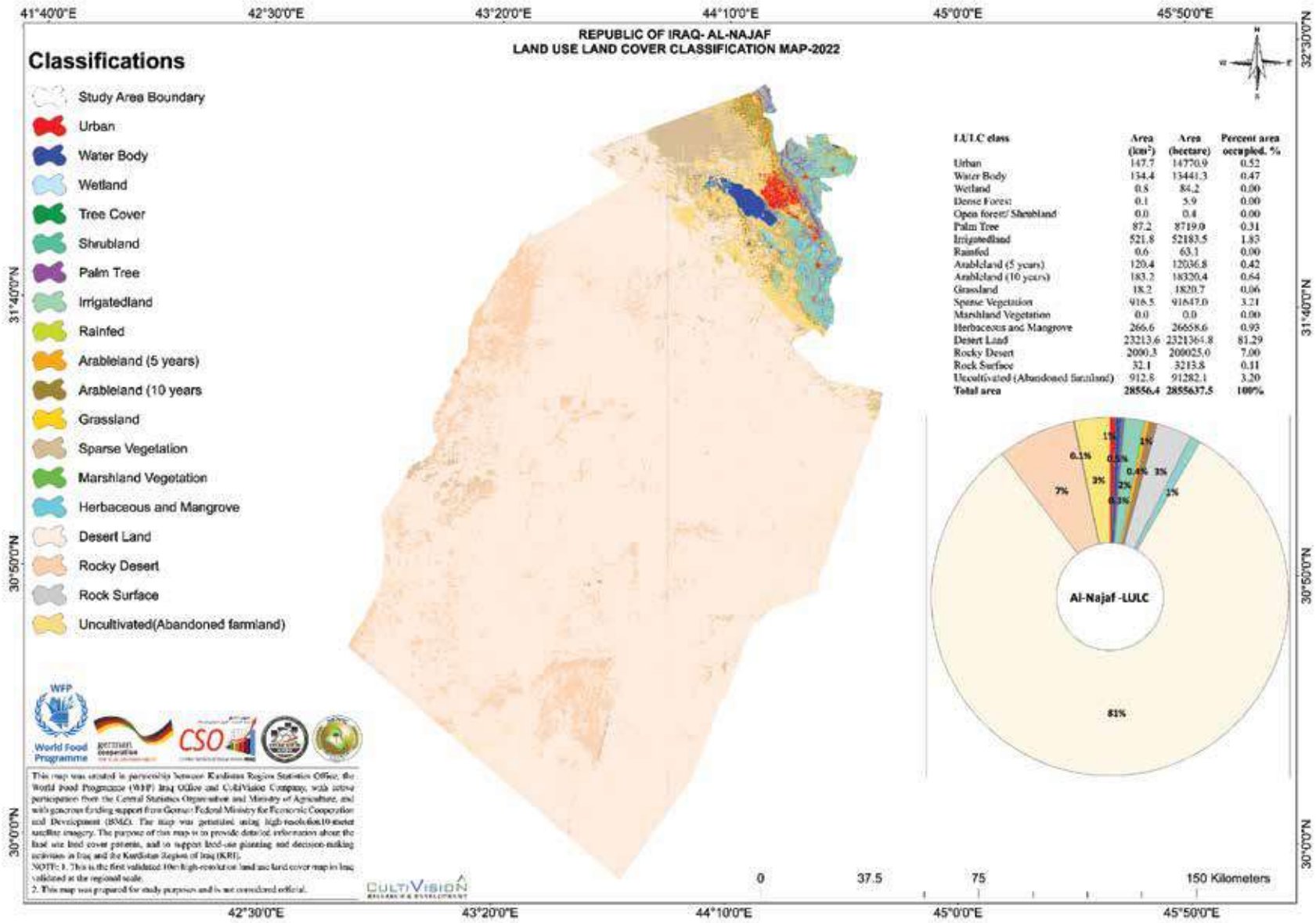


Figure 27 The spatial distribution of land use and land cover of Al-Najaf province for 2022.

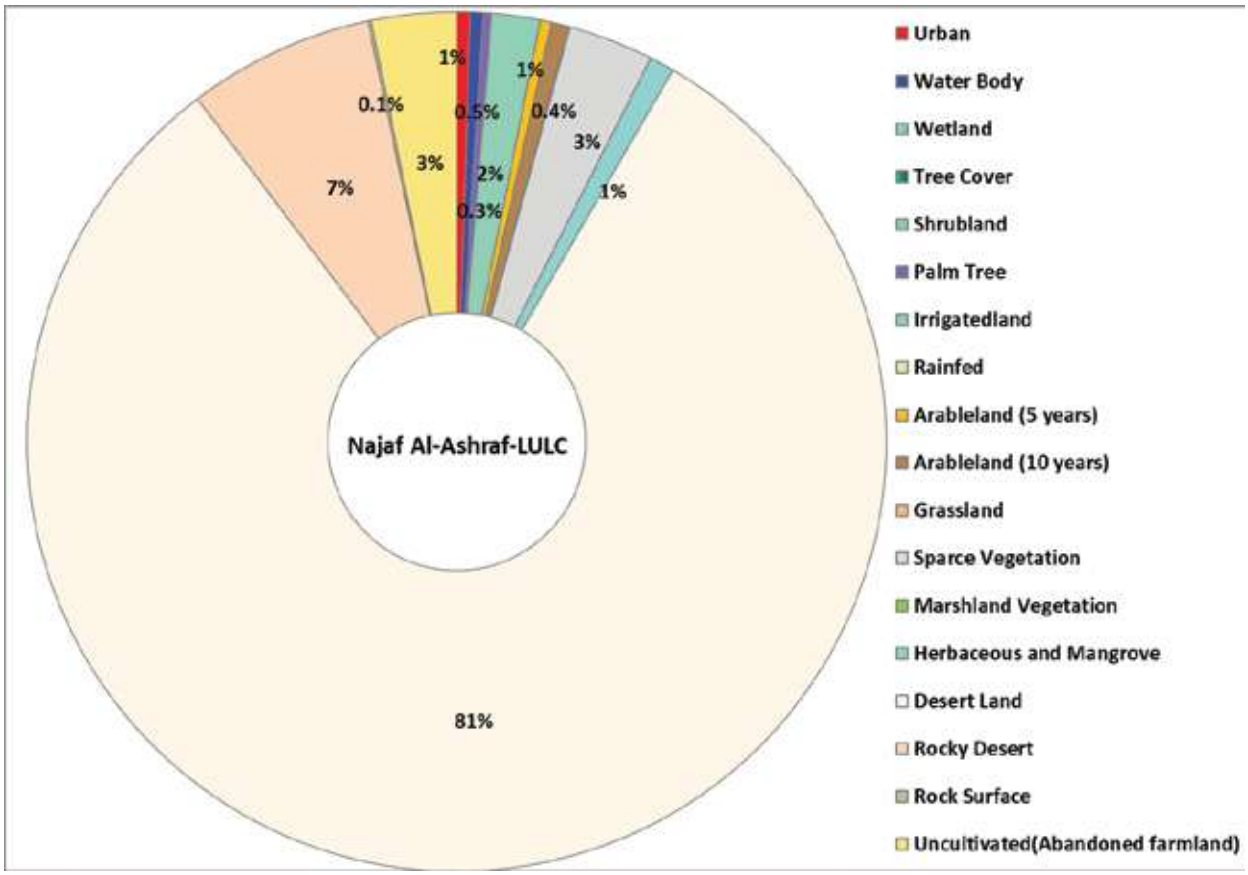


Figure 28 Land use and land cover (LULC) map produced for Al-Najaf province.

6.14. Salah Al-Din Province

The LULC map for Salah Al-Din shows different classes along with their corresponding areas and percentages (Figure 29, Figure 30 and Table 15). The common LULC classes include Urban, Water Body, Palm Tree, Irrigated land, Arable land (5 years), Arable land (10 years), Grassland, Desert Land, and Uncultivated (Abandoned farmland). Salah Al-Din province in Iraq has several significant LULC classes that are important for understanding the region's ecology, economy, and society. Here are some of the major LULC classes in Salah Al-Din:

Uncultivated (Abandoned farmland): This is the most extensive LULC class in the region, covering %46.3 (10833 km2) of the total area. It includes land that has been left uncultivated due to various reasons, such as land abandonment, soil degradation, or local and tribal conflicts. This class reflects the current socio-economic and political conditions in the region and is crucial for understanding the dynamics of land use change and its impact on ecosystems and communities.

Rocky Desert: This LULC class covers %13.7 (3201 km2) of the total

area and includes areas with rocky and barren terrain, limited vegetation, and harsh climatic conditions. This class is an essential feature of the region's landscape and provides a habitat for unique and specialized flora and fauna, such as reptiles, rodents, and birds of prey in Salah Al-Din province.

Irrigated Land: This LULC class covers %10.5 (2467 km2) of the total area and includes areas that are cultivated using irrigation systems. The region's economy heavily relies on agriculture, and this class reflects the region's productive and fertile land. The majority of Irrigated lands rely on the Tigris River and are located along with Tigris River, Tharthar Canal, and Al Uzym River. It is essential for food security and livelihoods and provides a source of income for many families in the region and/or exporting to neighbouring provinces.

Arable Land (10 years): This LULC class covers %8.8 of the total area and includes areas that are cultivated within the last ten years. This class reflects the region's long-term agricultural land use practices and provides insights into the region's traditional farming systems, crop choices, and crop rotations.

Grassland: This LULC class covers %9.7 of the total area and includes areas dominated by grasses and herbaceous plants. This class is important for grazing livestock, as the region has a long history of pastoralism. It also provides ecosystem services such as carbon sequestration, soil conservation, and habitat for wildlife.

Water Body: This LULC class covers %3.93 (920 km2) of the total area and includes various water bodies such as lakes, rivers, and wetlands (Tigris River, Tharthar canal and Al Uzym River). This class is important for the region's biodiversity, water resources, Irrigation, and recreational activities such as fishing and boating. It also provides a habitat for migratory birds and other aquatic species in the region.

In summary, the major LULC classes in Salah Al-Din province are shaped by the region's natural, socio-economic, and political conditions. Understanding these classes' spatial distribution, temporal changes, and ecological functions is crucial for developing sustainable land use practices and policies that support the region's socio-economic development and ecological conservation.

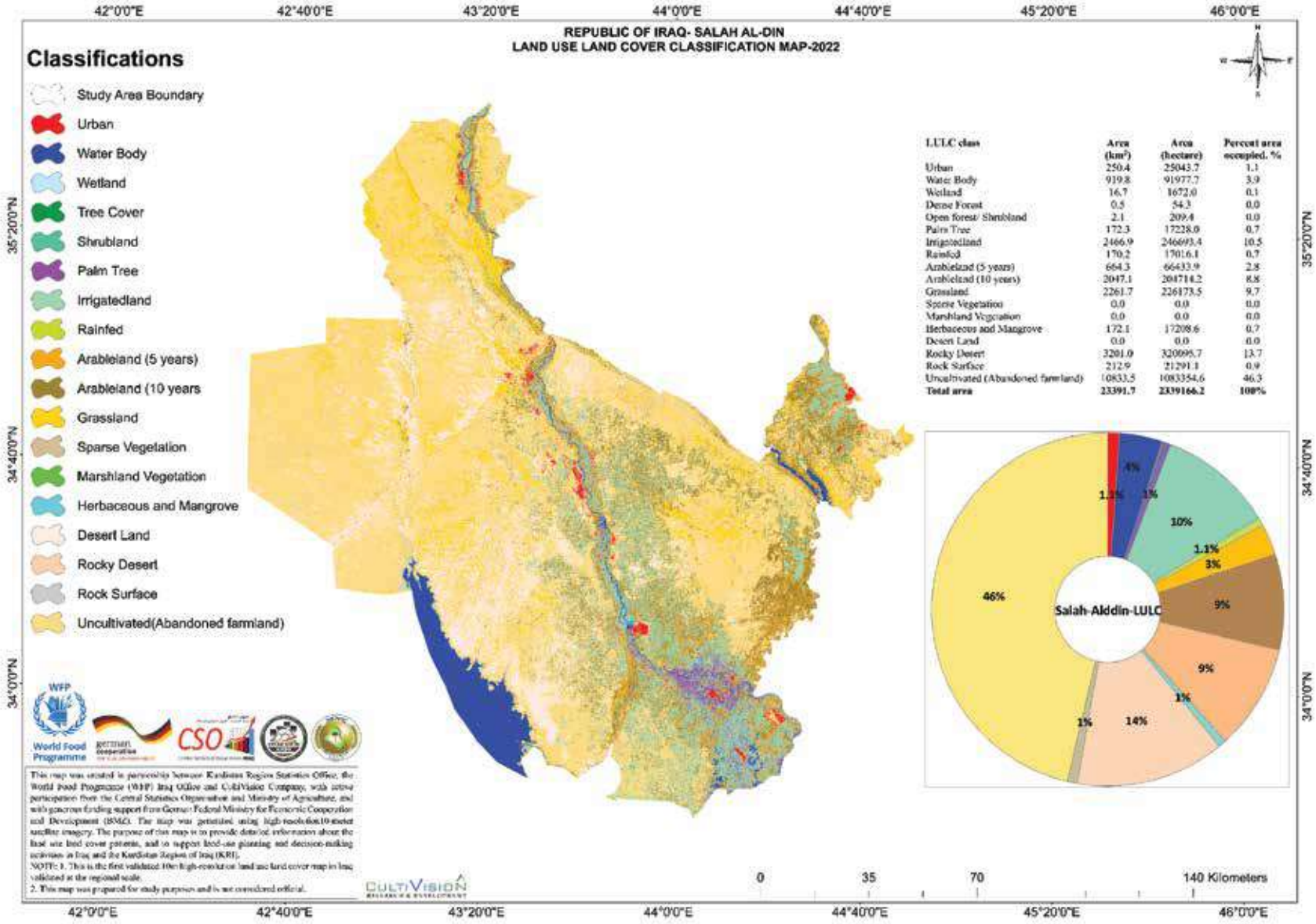


Figure 29 The spatial distribution of land use and land cover of Salah Al-Din province for 2022.

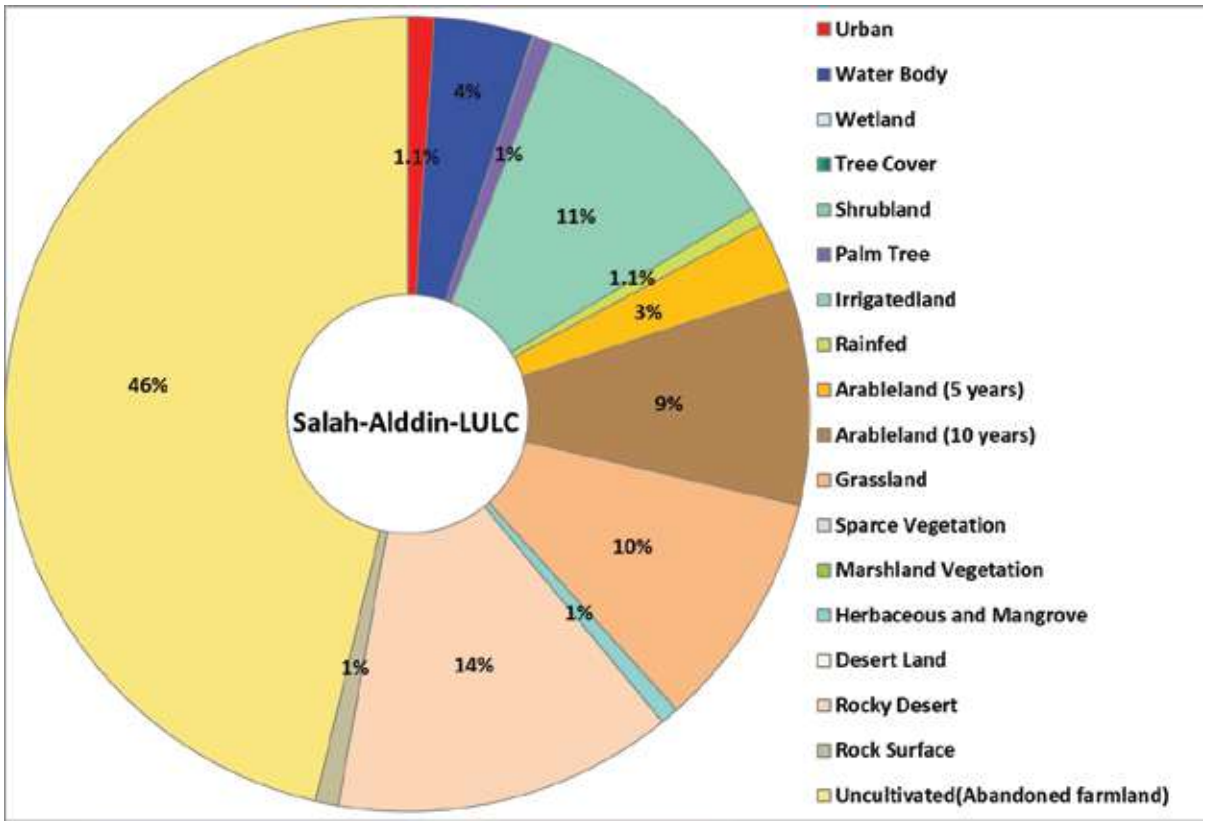


Figure 30 Land use and land cover (LULC) map produced for Salah Al-Din province.

Table 15 Salah Al-Din Land use and land cover (LULC) Classifications Area Km2 and percent.

LULC class	**Area (km ^{2})**	**Area (hectare)**	**Percent area occupied. %**
Urban	250.4	25043.7	1.1
Water Body	919.8	91977.7	3.9
Wetland	16.7	1672.0	0.1
Dense Forest	0.5	54.3	0.0
Open forest/ Shrubland	2.1	209.4	0.0
Palm Tree	172.3	17228.0	0.7
Irrigatedland	2466.9	246693.4	10.5
Rainfed	170.2	17016.1	0.7
Arableland (5 years)	664.3	66433.9	2.8
Arableland (10 years)	2047.1	204714.2	8.8
Grassland	2261.7	226173.5	9.7
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	172.1	17208.6	0.7
Desert Land	0.0	0.0	0.0
Rocky Desert	3201.0	320095.7	13.7
Rock Surface	212.9	21291.1	0.9
Uncultivated (Abandoned farmland)	10833.5	1083354.6	46.3
Total area	**23391.7**	**2339166.2**	**100%**

6.15.WASSIT Province

The LULC map produced for Wassit province shows the different LULC classes in Wassit cities, towns, and villages, along with the area (in km2) and their percentage of the total land area (Figure 31, Figure 32 and Table 16). Based on the LULC map, it can be observed that the largest LULC class in Wassit is the uncultivated/abandoned farmland, which covers around %42.3 of the total land area. This is followed by irrigated lands (%19.2) and Arable land for 10 and 5 years with %12.4 and %11, respectively. Grasslands (%4.4) and herbaceous and mangroves (%3.6) are also present in Wassit province. The LULC map also shows that urban areas cover only a small portion of the total land area in Wassit, at only %1.5 of the total area of Wassit.

Based on LULC maps of Wassit, some of the important LULC classes in this province are:

Uncultivated (Abandoned farmland): This class covers the largest area in the province, accounting for %42.3 (7523 km2) of the total area. This suggests that many agricultural lands in the province have been abandoned due to various reasons such as drought, water scarcity, and local conflicts.

Irrigated land: This class covers %19.2 (3423 km2) of the total area in Wassit province, indicating the importance of irrigation in agriculture in the region. Irrigated lands are usually highly productive and support a wide range of crops and receive water from the Tigris River where the majority of irrigated lands are distributed along with the flow of the Tigris River.

Arable land (5 and 10 years): These classes cover %11 (1948 km2) and %12.4 (2202 km2) of the total area, respectively, suggesting that a significant portion of the province's land is suitable for agriculture and has been cultivated at least a season within the last 10 or 5 years. However, the productivity of these lands may be affected by various factors such as water availability, soil quality, and climate conditions.

Water body and wetland classes cover %1.2 and %0.4 of the total area of Wassit, respectively. These areas are important for the conservation of biodiversity and ecosystem services such as irrigation, fishing, recreation, water purification and flood control in the province. The water body class in Wassit province covers an area of 207.5 km2, which is approximately %1.2 of

the total area. This class includes different types of water bodies such as rivers (Tigris River), lakes, and ponds. In Wassit province, the primary water body is the Tigris River, which is the major source of water for irrigation and other uses. In Wassit urban class covers a relatively small area (259.3 km%1.5 ,2), but it is still an important class as it represents the urbanisation and development of the province.

Overall, understanding the distribution and dynamics of LULC classes in Wassit province is essential for sustainable land use planning and natural resource management. However, the LULC map needs to be updated with the development of the province and changing land use practices in the province.

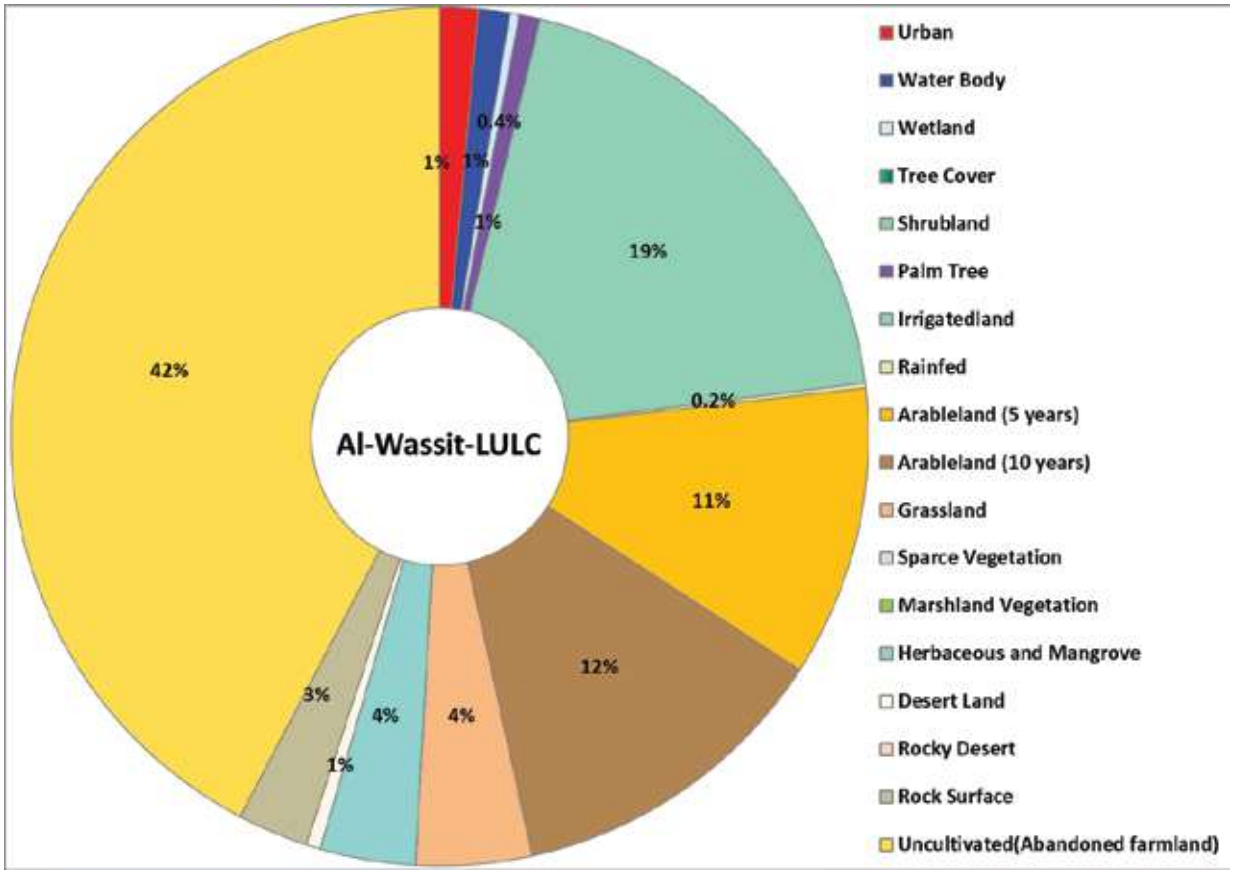


Figure 31 Land use and land cover (LULC) map produced for Al-Wassit province.

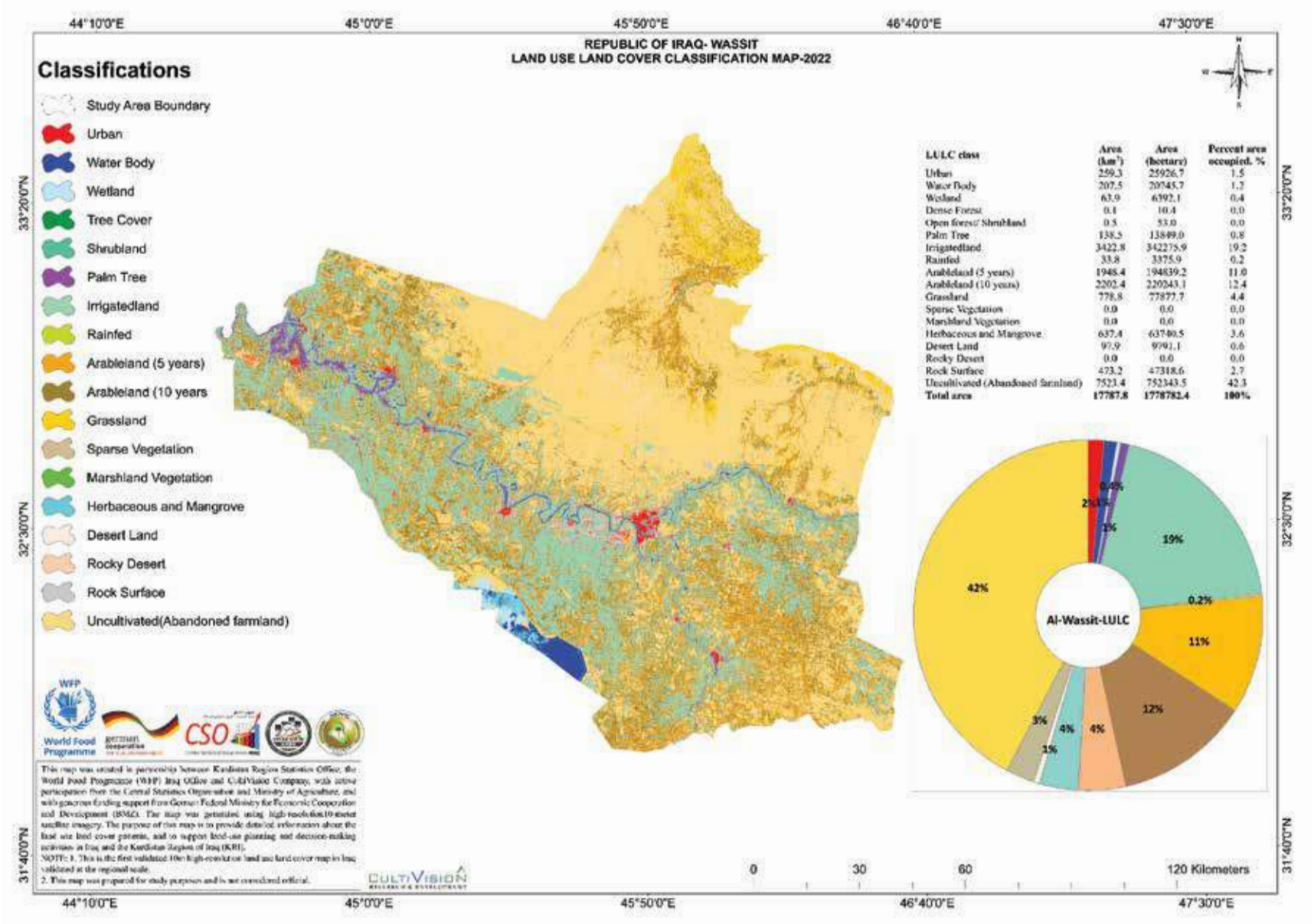


Figure 32 The spatial distribution of land use and land cover of Wassit province for 2022.

Table 16 Wassit Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	259.3	25926.7	1.5
Water Body	207.5	20745.7	1.2
Wetland	63.9	6392.1	0.4
Dense Forest	0.1	10.4	0.0
Open forest/ Shrubland	0.5	53.0	0.0
Palm Tree	138.5	13849.0	0.8
Irrigatedland	3422.8	342275.9	19.2
Rainfed	33.8	3375.9	0.2
Arableland (5 years)	1948.4	194839.2	11.0
Arableland (10 years)	2202.4	220243.1	12.4
Grassland	778.8	77877.7	4.4
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	637.4	63740.5	3.6
Desert Land	97.9	9791.1	0.6
Rocky Desert	0.0	0.0	0.0
Rock Surface	473.2	47318.6	2.7
Uncultivated (Abandoned farmland)	7523.4	752343.5	42.3
Total area	**17787.8**	**1778782.4**	**100%**

6.16. Erbil Province

The LULC map for Erbil province shows different classes along with their corresponding areas and percentages (Figure 33, Figure 34 and Table 17). The common LULC classes include Arable land (10 years), Grassland, Open Forests, Dense Forest, Irrigated lands, and Urban classes. 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:

Urban: The urban class is an important LULC class in Erbil province because it includes the city and its infrastructure, it covers 352 km2 (%2.9). Erbil is the capital of the Kurdistan Region of Iraq and is one of the fastest-growing cities in Iraq. The urban class is essential for providing housing, services, and employment opportunities to the residents of Erbil.

Dense Forest: The Dense Forest occupies %9.7 (1172.4 km2) of the total area of the Erbil province class and 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.

Open forest Shrubland: The Open Forest 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. Open forests cover %17.4 (2111 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 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 %40 (4814 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. An 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.

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 39.86 km2, which represents %0.33 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.

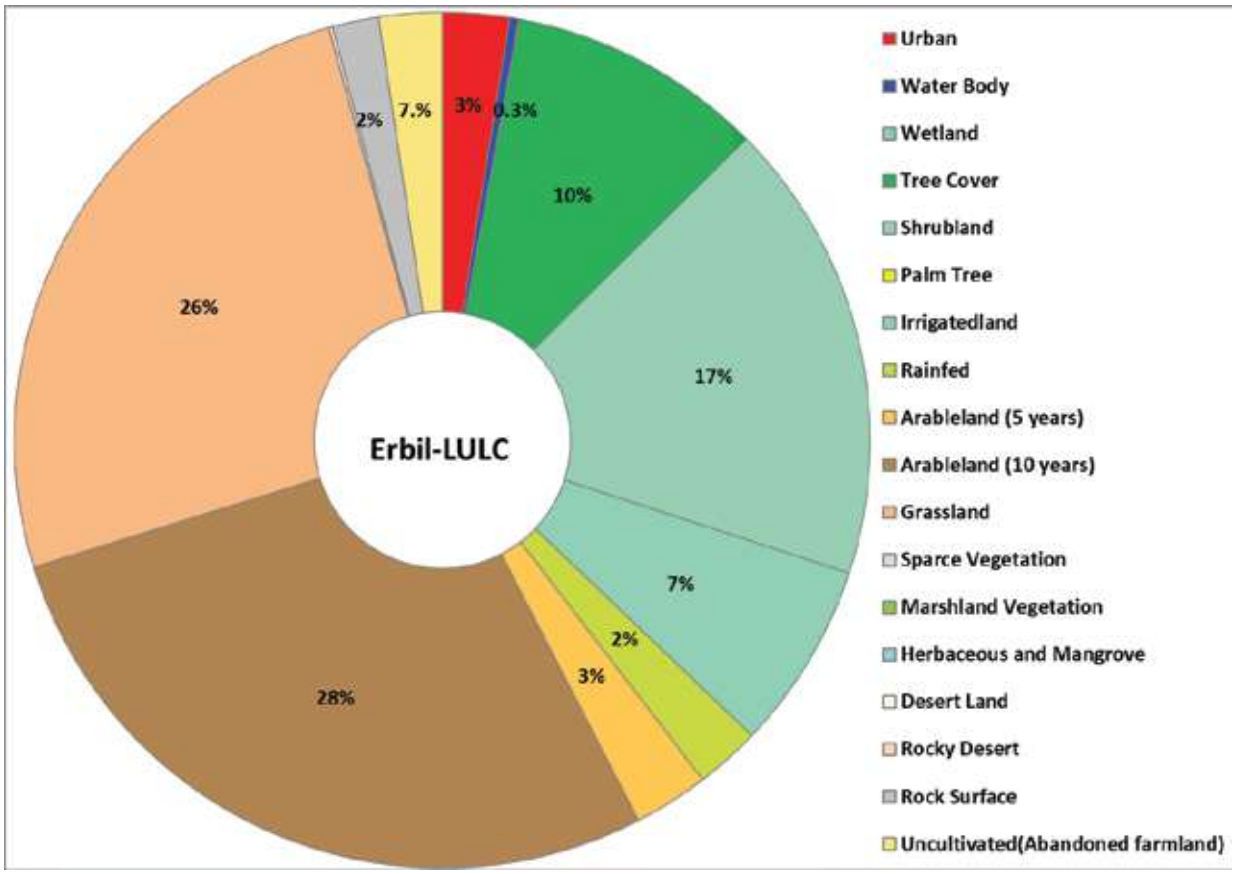


Figure 33 Land use and land cover (LULC) map produced for Erbil province.

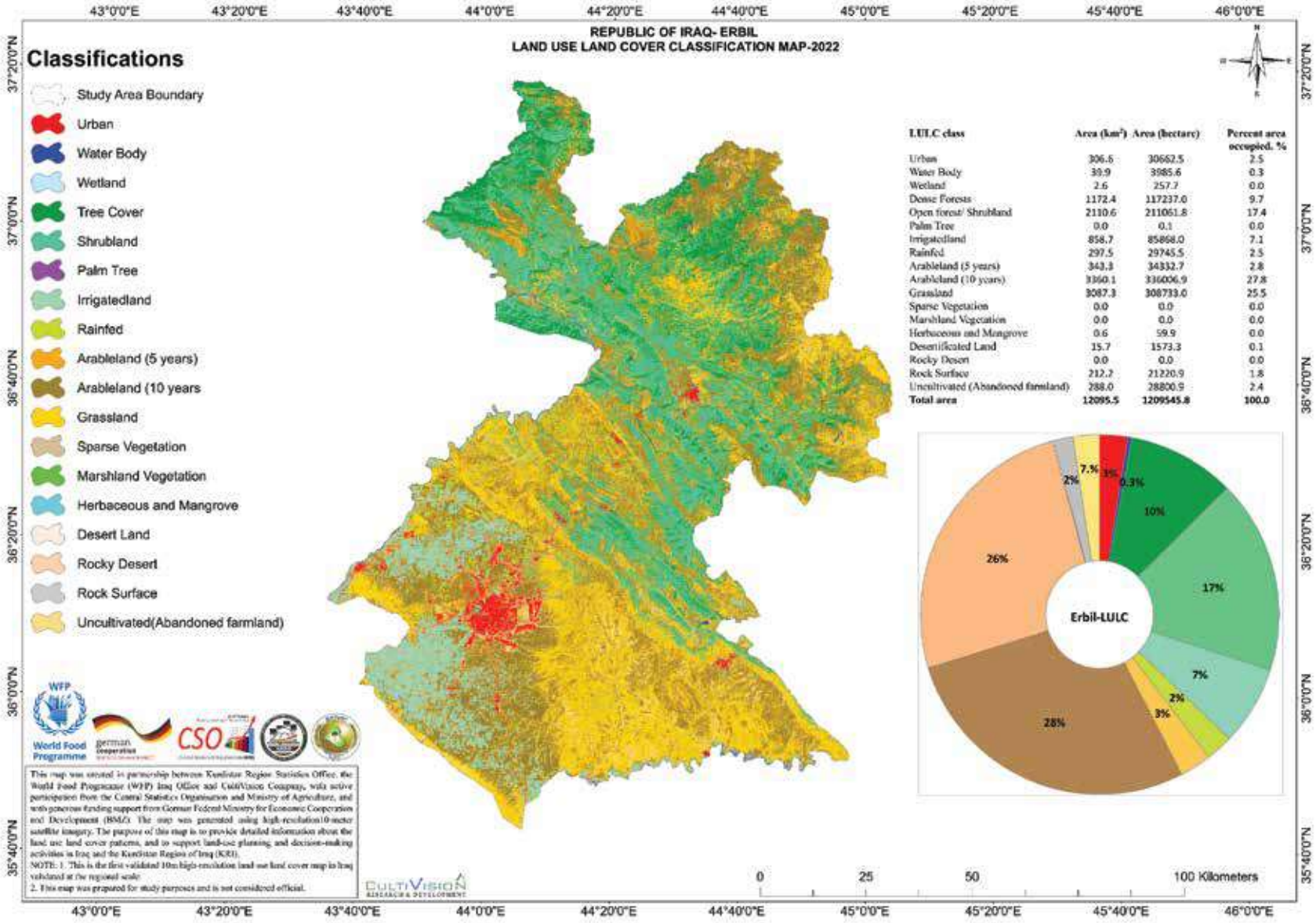


Figure 34 The spatial distribution of land use and land cover of Erbil province for 2022.

Table 17 Erbil Land use and land cover (LULC) Classifications Area Km^2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	306.6	30662.5	2.5
Water Body	39.9	3985.6	0.3
Wetland	2.6	257.7	0.0
Dense Forests	1172.4	117237.0	9.7
Open forest/ Shrubland	2110.6	211061.8	17.4
Palm Tree	0.0	0.1	0.0
Irrigatedland	858.7	85868.0	7.1
Rainfed	297.5	29745.5	2.5
Arableland (5 years)	343.3	34332.7	2.8
Arableland (10 years)	3360.1	336006.9	27.8
Grassland	3087.3	308733.0	25.5
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	0.6	59.9	0.0
Desertificated Land	15.7	1573.3	0.1
Rocky Desert	0.0	0.0	0.0
Rock Surface	212.2	21220.9	1.8
Uncultivated (Abandoned farmland)	288.0	28800.9	2.4
Total area	**12095.5**	**1209545.8**	**100.0**

6.17. Al-Sulaymaniyah Province

The LULC map for Al-Sulaymaniyah province shows different classes along with their corresponding areas and percentages (Figure 35, Figure 36 and Table 18). The common LULC classes include Grassland, Arable land (10 years), Open Forests, Uncultivated (Abandoned farmland), Irrigated lands, Dense Forest, and Urban classes. The importance of each LULC class in Al-Sulaymaniyah province depends on various factors, such as the economic and environmental significance of the class. The most dominant land use classes in Al-Sulaymaniyah province are grassland, followed by arable land (10 years) and Open Forest. The urban areas, water bodies, and wetlands cover a small percentage of the total area. The most important land use and land cover (LULC) classes in Al-Sulaymaniyah province are:

Grassland: With an area of 8038.2 km(%38.5) 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 4642.8 km(%22.2) 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.

Open forest: With an area of 2657.7 km(%12.7) 2, Open Forest 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 1585 km2 (%7.6), 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 327.1 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 239.2 km2, which is %1.15 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 an area of about 270 square kilometres.

Al-Sulaymaniyah province in Iraq has several agricultural classes, including irrigated land, rain-fed land, arable land (5 and 10 years), and Grasslands which together approximately cover %72 (14,965 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 %5.7 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 %2.2 of the total area and is mainly found in areas where there is sufficient rainfall for crop production. Arable Lands (10 and 5 years) makeup %22.2 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 (8,038 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, Open Forest, urban, Dense Forest, and irrigated land classes are all important for various reasons, ranging from ecological significance to economic and social importance for the province.

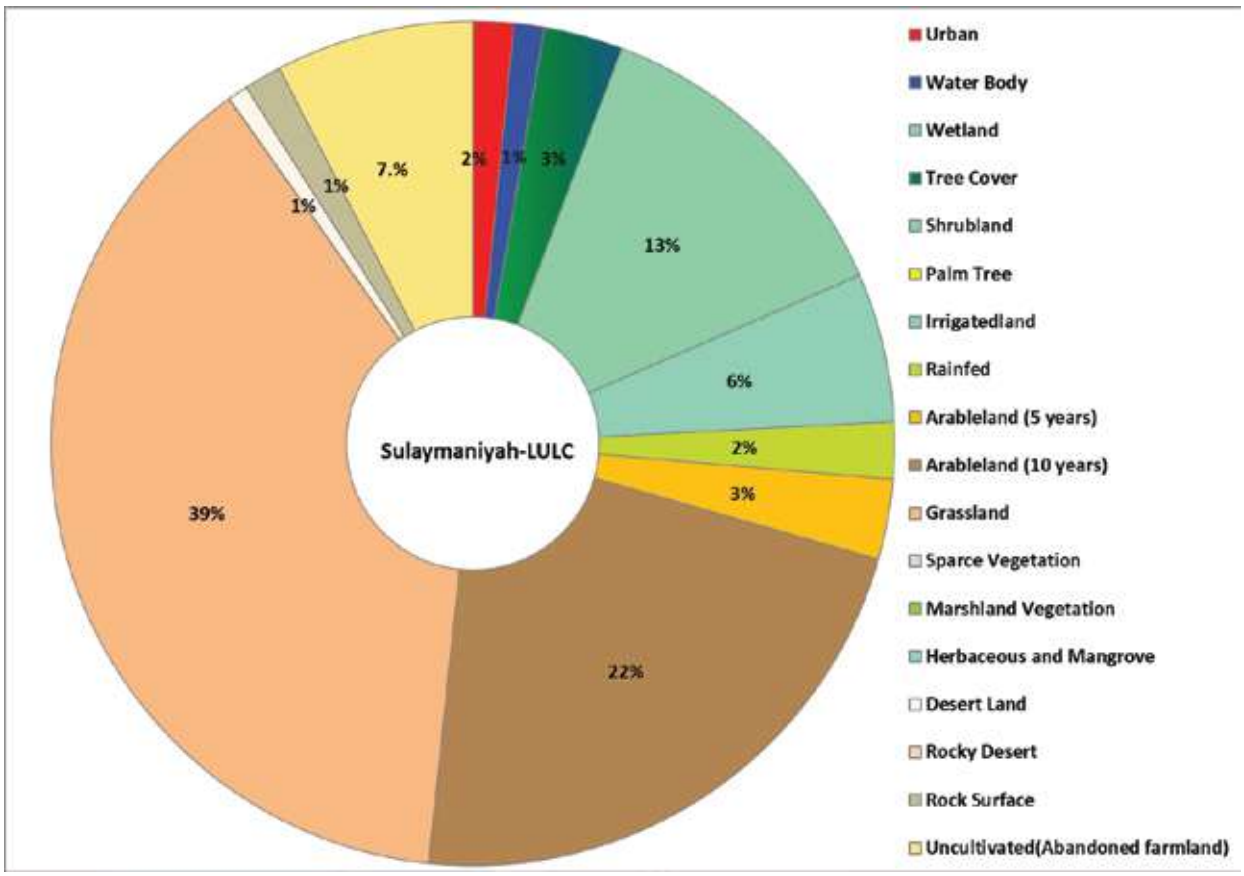


Figure 35 Land use and land cover (LULC) map produced for Al-Sulaymaniyah province.

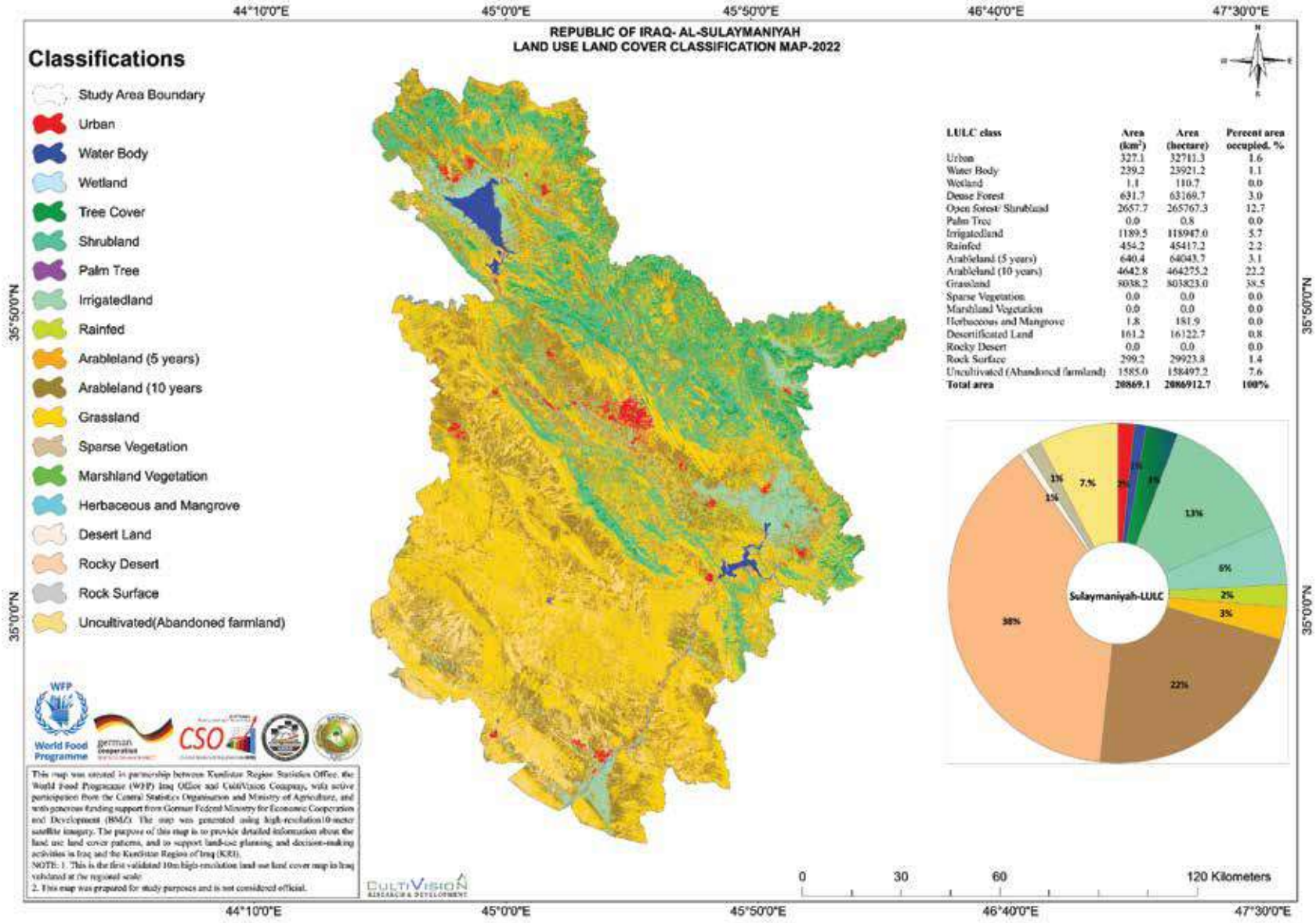


Figure 36 The spatial distribution of land use and land cover of Al-Sulaymaniyah province for 2022.

Table 18 Al-Sulaymaniyah Land use and land cover (LULC) Classifications Area Km^2 and Percent.

LULC class	Area (km^2)	Area (hectare)	Percent ar ea occupied. %
Urban	327.1	32711.3	1.6
Water Body	239.2	23921.2	1.1
Wetland	1.1	110.7	0.0
Dense Forest	631.7	63169.7	3.0
Open forest/ Shrubland	2657.7	265767.3	12.7
Palm Tree	0.0	0.8	0.0
Irrigatedland	1189.5	118947.0	5.7
Rainfed	454.2	45417.2	2.2
Arableland (5 years)	640.4	64043.7	3.1
Arableland (10 years)	4642.8	464275.2	22.2
Grassland	8038.2	803823.0	38.5
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	1.8	181.9	0.0
Desertificated Land	161.2	16122.7	0.8
Rocky Desert	0.0	0.0	0.0
Rock Surface	299.2	29923.8	1.4
Uncultivated (Abandoned farmland)	1585.0	158497.2	7.6
Total area	**20869.1**	**2086912.7**	**100%**

6.18. Kirkuk Province

The produced LULC map for Kirkuk province shows different classes long with their corresponding areas in square kilometres and percentages of the total land in Kirkuk province (Figure 37, Figure 38 and Table 19). The LULC classes include Urban, Water Body, Wetland, Dense Forest, Shrub land, Irrigated land, Rainfed lands, Arable lands (5 and 10 years), Grasslands, Desert Land, Rock Surface, and Uncultivated (Abandoned farmland). The three largest LULC classes in terms of area are Grasslands, Irrigated lands and Arable lands (10 years), which together account for more than two-thirds of the total area of Kirkuk province. Based on the provided table, the important results of LULC in Kirkuk province are:

Dominance of grassland: Grassland covers the largest area in Kirkuk province with %24.6 (2541 km2), which indicates the significance of pasturelands and natural grazing areas in the region. This is a particularly important natural resource to graze livestock and sustain agricultural meat and dairy production in the region.

Large area of irrigated land: Irrigated land covers a significant area in the province with %22 (2276.8 km2), indicating the importance of

agriculture and irrigation in the region.

High percentage of uncultivated land: Uncultivated land covers almost %19.8 (2041.5 km2) of the province, indicating a potential for reclamation and cultivation of abandoned farmlands, considering environmental, ecological, and socio-economic factors to expand the agricultural lands and agricultural production.

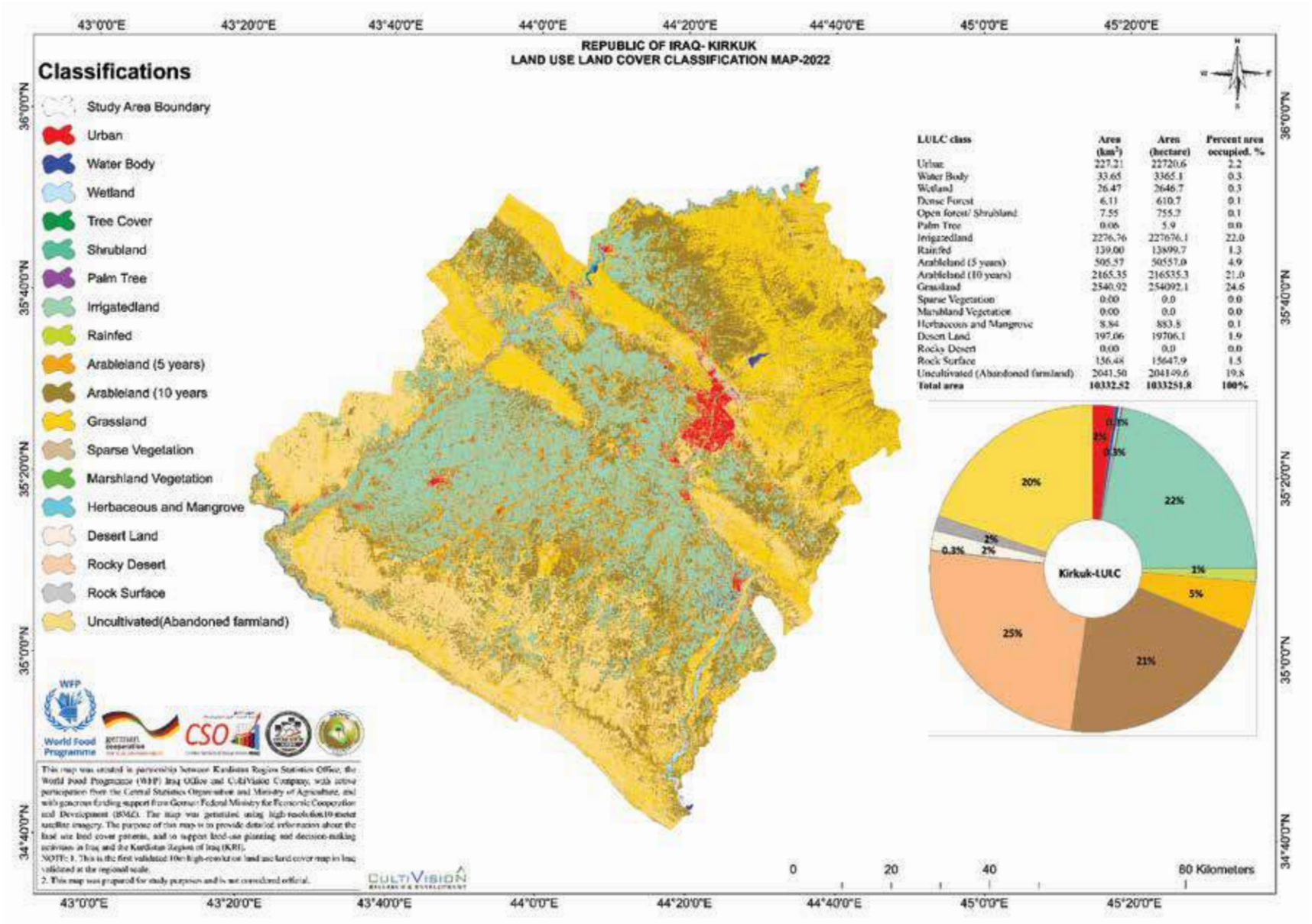
Limited forest and Dense Forest: Forest and Dense Forest including Open forests constitute a small percentage of the province's land area with only %0.2 (13.7 km2), which highlights the need for reforestation and afforestation initiatives in order to improve carbon stock and sequestration in the region. The expansion of forests and vegetation in the province is a critical strategy that directly assists in global warming combat through reducing green house gases emitted in the region.

Low percentage of urban areas: Urban areas constitute only %2.2 of the province's land area (~227 km2), indicating a predominantly rural landscape in the region.

Presence of wetlands: The province has a small area of wetlands with %0.3 (26.5 km2), indicating the importance of these ecosystems for biodiversity conservation and water management.

The Kirkuk province has agricultural land use classes including irrigated land, rainfed, and arable lands (5 years and 10 years). Irrigated land covers an area of %22 of the total area and is important for crop production throughout the year, with wheat, barley, and vegetables being the main crops. Rainfed land covers %1.3 of the total area and is used for growing crops such as wheat, barley, and legumes, limited precipitation in the Kirkuk province resulted in having a relatively small land used for Rainfed compared to Irrigated lands. Arable land (5 years) covers %4.9 of the total area, while arable land (10 years) covers %21 of the total area. These classes are important for crop rotation, which helps improve soil health, improve soil hydrological functions, and prevent soil erosion.

Overall, the LULC data for Kirkuk province provides important insights into the distribution and patterns of land use and land cover in the region, which can be useful for land management, conservation, and planning purposes .



LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	227.21	22720.6	2.2
Water Body	33.65	3365.1	0.3
Wetland	26.47	2646.7	0.3
Dense Forest	6.11	610.7	0.1
Open forest/ Shrubland	7.55	755.2	0.1
Palm Tree	0.06	5.9	0.0
Irrigatedland	2276.76	227676.1	22.0
Rainfed	139.00	13899.7	1.3
Arableland (5 years)	505.57	50557.0	4.9
Arableland (10 years)	2165.35	216535.3	21.0
Grassland	2540.92	254092.1	24.6
Sparse Vegetation	0.00	0.0	0.0
Marshland Vegetation	0.00	0.0	0.0
Herbaceous and Mangrove	8.84	883.8	0.1
Desert Land	197.06	19706.1	1.9
Rocky Desert	0.00	0.0	0.0
Rock Surface	156.48	15647.9	1.5
Uncultivated (Abandoned farmland)	2041.50	204149.6	19.8
Total area	**10332.52**	**1033251.8**	**100%**

Figure 37 The spatial distribution of land use and land cover of Kirkuk province for 2022

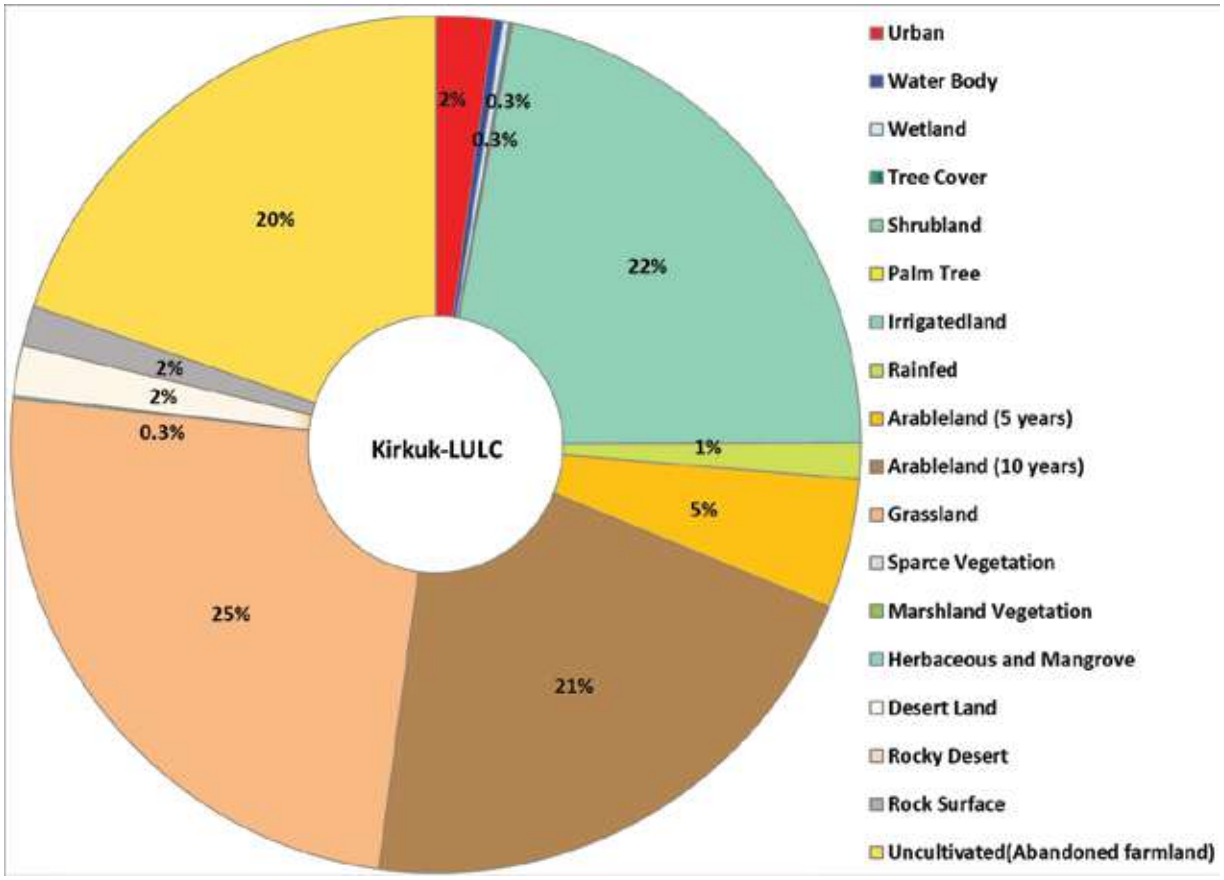


Figure 38 Land use and land cover (LULC) map produced for Kirkuk province.

Table 19 Kirkuk Land use and land cover (LULC) Classifications Area Km2 and Percent.

LULC class	Area (km ^{2})	Area (hectare)	Percent area occupied. %
Urban	227.21	2272 0.6	2.2
Water Body	33.65	3365.1	0.3
Wetland	26.47	2646.7	0.3
Dense Forest	6.11	610.7	0.1
Open forest/ Shrubland	7.55	755.2	0.1
Palm Tree	0.06	5.9	0.0
Irrigatedland	2276.76	227676.1	22.0
Rainfed	139.00	13899.7	1.3
Arableland (5 years)	505.57	50557.0	4.9
Arableland (10 years)	2165.35	216535.3	21.0
Grassland	2540.92	254092.1	24.6
Sparse Vegetation	0.00	0.0	0.0
Marshland Vegetation	0.00	0.0	0.0
Herbaceous and Mangrove	8.84	883.8	0.1
Desert Land	197.06	19706.1	1.9
Rocky Desert	0.00	0.0	0.0
Rock Surface	156.48	15647.9	1.5
Uncultivated (Abandoned farmland)	2041.50	204149.6	19.8
Total area	**10332.52**	**1033251.8**	**100%**

6.19. Duhok Province

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 39, Figure 40 and Table 20). The LULC classes in Duhok province can be broadly classified into urban, agricultural, forested, and natural vegetation classes.

- Urban areas cover approximately %1.73 (~182 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 %9.95 (941 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 %29.2 (~3071 km2) of the total area of Duhok province.

- Forested areas in the province consist of Dense Forest and Open Forest, covering around %39.1 (4107 km^2) of the total area. The Dense Forest class is dominated by natural forests and includes a mix of deciduous and coniferous trees, while the Open Forest 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 (1799 km^2) 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 (~110 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 province 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.
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.

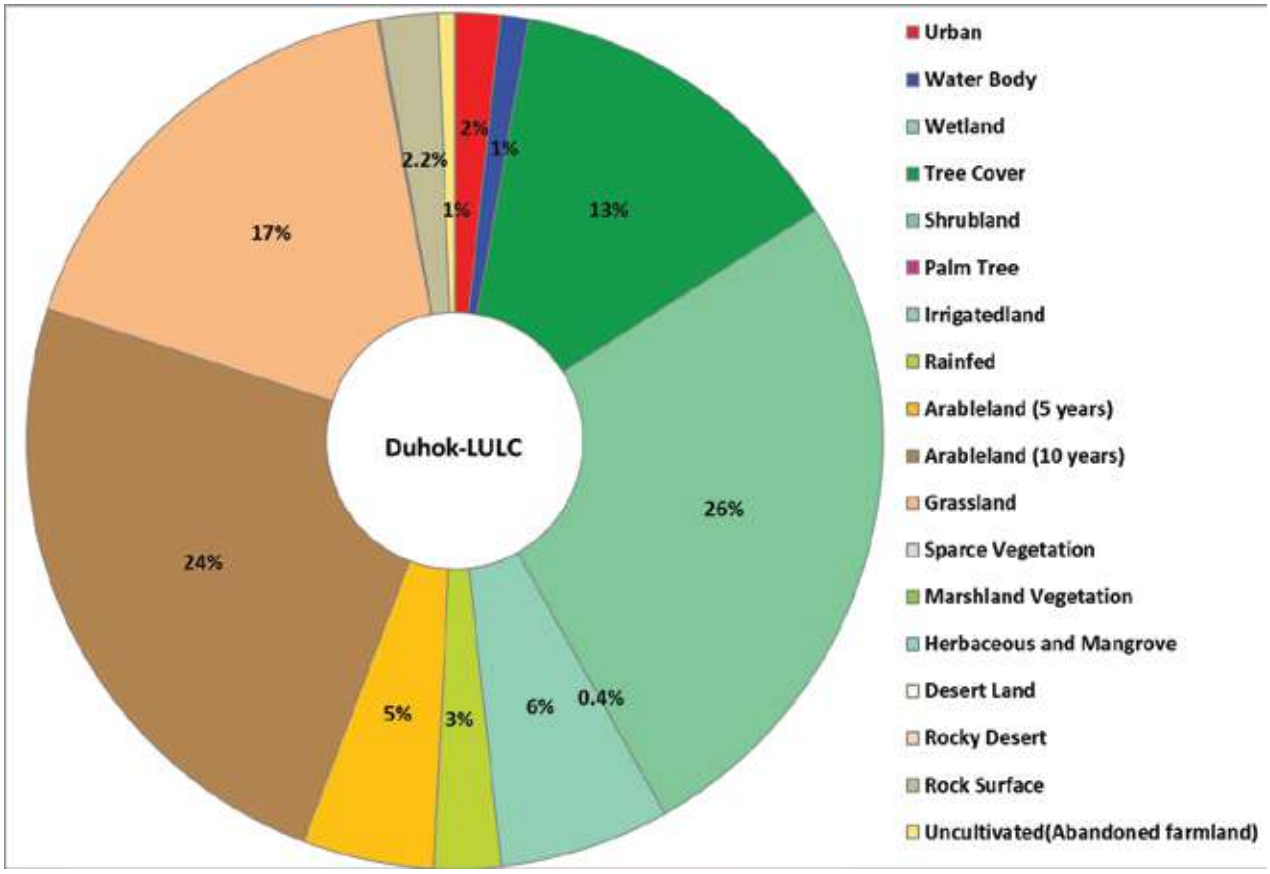


Figure 39 Land use and land cover (LULC) map produced for Duhok province.

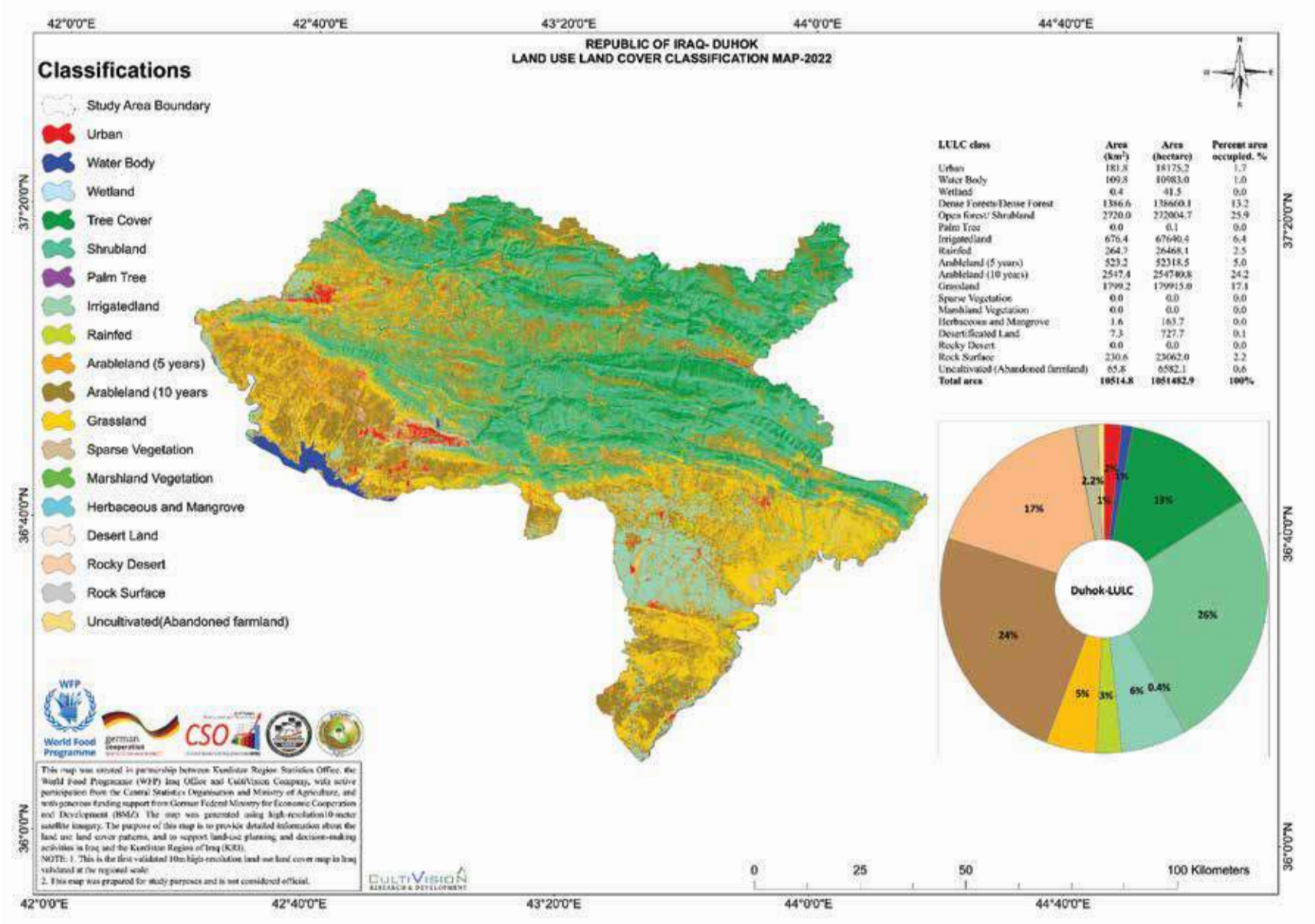


Figure 34 The spatial distribution of land use and land cover of Erbil province for 2022.

.and Percent Duhok Land use and land cover (LULC) Classifications Area Km2 20 Table

LULC class	Area (km^2)	Area (hectare)	Percent area occupied. %
Urban	181.8	18175.2	1.7
Water Body	109.8	10983.0	1.0
Wetland	0.4	41.5	0.0
Dense Forests/Dense Forest	1386.6	138660.1	13.2
Open forest/ Shrubland	2720.0	272004.7	25.9
Palm Tree	0.0	0.1	0.0
Irrigatedland	676.4	67640.4	6.4
Rainfed	264.7	26468.1	2.5
Arableland (5 years)	523.2	52318.5	5.0
Arableland (10 years)	2547.4	254740.8	24.2
Grassland	1799.2	179915.0	17.1
Sparse Vegetation	0.0	0.0	0.0
Marshland Vegetation	0.0	0.0	0.0
Herbaceous and Mangrove	1.6	163.7	0.0
Desertificated Land	7.3	727.7	0.1
Rocky Desert	0.0	0.0	0.0
Rock Surface	230.6	23062.0	2.2
Uncultivated (Abandoned farmland)	65.8	6582.1	0.6
Total area	**10514.8**	**1051482.9**	**100%**

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 %95.9, which means that approximately %99 of the pixels were correctly classified for all classes. 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 the results can be used with confidence.

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 locations 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 created a detailed map of the LULC in the study area. This 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.

8. General Discussion

Iraq is a country located in the Middle East with a population of approximately 40 million people. It is divided into eighteen provinces, each with its own unique land use and land cover (LULC) characteristics. The LULC are influenced by several factors, including climate, topography, and human activities (Hirtz and Pournelle 2015). The LULC classes in Iraq reflect the diverse natural and anthropogenic factors that shape the country's physical environment. The LULC classes are essential for understanding the ecological and socio-economic characteristics of Iraq and providing a basis for sustainable land management policies.

The most extensive LULC class in Iraq is desert land, which occupies %24.1 (105493 km2) of the total area. Desert regions in Iraq are primarily located in the western and southwestern parts of the country, including the vast expanse of the Anbar Desert and parts of the Syrian Desert. Desert lands are mostly occupying in Al-Anbar, Al-Najaf, Al-Muthanna, Kerbala and Al-Basrah provinces. These areas are characterised by extreme climatic conditions, including high temperatures, low precipitation, and limited vegetation cover. The desert land class in Iraq consists of various types, including sandy deserts, gravel deserts, and rocky deserts. The rocky desert class (%17.8 of total area of

Iraq) indicates the presence of rocky terrain in certain desert regions, which are mostly located in southwestern of Iraq in Al-Anbar province. This class is characterised by sparse vegetation, rocky terrain, and extreme weather conditions, such as high temperatures and low precipitation. Desert land covers immense areas of western and southern Iraq and is crucial for the country's oil and gas production. However, it also poses environmental challenges, such as soil erosion, water scarcity, and land degradation. The presence of such a large desert land area in Iraq suggests that the country experiences arid or semi-arid climatic conditions in these regions. The scarcity of water and limited vegetation cover make these areas challenging for human habitation and agricultural activities (van Zandwijk et al., 2021). However, it's worth noting that Iraq's desert regions also hold unique ecological significance and can support specialized flora and fauna adapted to desert environments in Iraq.

Another significant LULC class in Iraq is uncultivated land, which occupies %22.2 (97277 km2) of the total area. This class includes abandoned farmland, fallow fields, and other areas that are not used for agriculture within the last 10 years. Uncultivated land is predominant in central and eastern Iraq, where land use patterns have shifted due to socio-economic and political factors, such as population growth, urbanisation, and local and tribal conflicts as well as rural-to-urban migration. The conversion of uncultivated land to other land use types can have significant consequences for the country's food security, biodiversity, and rural livelihoods in Iraq.

The consequences of abandoned farmland are complex. A) Economically, it represents a loss of agricultural productivity and potential income generation for the current and a future generation. B) Socially, it can contribute to rural depopulation and impact the livelihoods of communities reliant on agriculture. C) Environmentally, neglected farmland may be prone to degradation, soil erosion, and invasive species invasion and finally potential desertification risks.

Efforts are needed in Iraq to address the issue of abandoned farmland and revitalise agricultural activities in these areas. Initiatives such as agricultural extension services, training programs, and access to credit are being implemented to support farmers and encourage them to return to their parental rural are and invest in cultivation (i.e., Agricultural activities such as crops, vegetable farming, animal breeding, grazing, orchard etc). Moreover, investments in rural infrastructure, irrigation systems, and technology are being made and essential to enhance agricultural productivity and attract farmers back to their abandoned lands to produce and supply sufficient

agronomic product for the country as well as exporting to other neighbouring countries. The reclamation of abandoned farmland has the potential to contribute to food security, economic development, and rural stability. It can also help to reduce dependence on food imports and strengthen local agricultural production. In addition, the restoration and sustainable practise of abandoned farmland can have positive environmental impacts where appropriate land management include soil conservation, water resource management, and agroforestry techniques, can help mitigate soil degradation, promote biodiversity, and enhance ecosystem services.

Urban land is a relatively small LULC class in Iraq, occupying only %1.29 (5659 km2) of the total area. However, it is essential for understanding the country's urbanisation patterns and the impacts of urbanisation on the natural environment. Urban land is mainly concentrated in the central and southern regions of Iraq, where the largest cities, such as Baghdad and Al-Basrah, are located. Urbanisation in Iraq has led to the loss of agricultural land, the destruction of natural habitats, and the degradation of air and water quality (Hirtz and Pournelle 2015).

Two studies have been done for the impact of urbanization and environmental changes on Iraq's natural resources challenges of sustainable land management in Iraq by Al-Ansari et al (2020&2019). The first study analysed the changes in land use and land cover in the Tigris-Euphrates Basin, which spans across Iraq and neighbouring countries. The study found that urbanization and agricultural expansion have caused significant changes in the LULC classes, leading to a decline in the natural vegetation cover and an increase in barren land and urban areas. The changes in LULC have also affected the hydrological balance of the basin, with a reduction in the availability of water resources. The second for the challenges of sustainable land management in Iraq, emphasised the need for sustainable land management practices to maintain the balance between urbanisation and environmental conservation. Therefore, it can be highlighted that the balance between urbanisation and environmental conservation is a vital and immediate strategy that Iraqi/ local governorates need to initiate in order to preserve the natural vegetation cover and to mitigate the impacts of climate change and desertification.

Water bodies and wetlands are also significant LULC classes in Iraq, occupying %1.25 (5496 km2) and %0.26 (1152 km2) of the total area, respectively. These classes are crucial for supporting biodiversity, regulating water cycles, and providing ecosystem services to human communities. Water bodies include natural and man-made bodies of water, such as lakes, rivers, reservoirs, and marshes. Water bodies play a crucial role in supporting biodiversity, providing

habitat for aquatic species, and offering various ecosystem services. The Tigris and Euphrates rivers are major water bodies in Iraq. These rivers serve as the lifeline of the country, providing water for irrigation, drinking water supply, and supporting various human activities. They are crucial for sustaining agriculture and supporting the economy. Additionally, there are other water bodies such as smaller rivers, lakes, and reservoirs distributed throughout the country. These water bodies provide important habitats for aquatic plants and animals, contribute to the biodiversity of the region, and offer recreational opportunities. Wetlands are areas where water covers the soil or is near the surface for a significant part of the year. They include marshes, swamps, and bogs. Wetlands are ecologically important as they provide breeding grounds for birds and support diverse plant and animal species in Iraq. They also act as natural water filters, helping to improve water quality.

However, these classes also face various challenges. Iraq has experienced water scarcity and a decline in water resources, which has resulted in the reduction of water bodies and wetlands. Factors such as upstream dam construction, reduced river flow, climate change, upstream water use by neighbouring countries (Iran, Syria and Turkey) and excessive water extraction have contributed to these challenges. Preserving and managing water bodies and wetlands in Iraq is crucial for maintaining ecological integrity, ensuring water security, and supporting sustainable development in the country. This requires a combination of conservation standards, policy involvements, and community participation to protect these important natural resources.

There are several classes related to agricultural land such as irrigated lands, rainfed lands, arable lands, palm trees and grasslands. The Irrigated Land class covers %5.78 (25299 km2) of the total land area. This class represents areas that are cultivated using irrigation techniques using surface and groundwater resources. Irrigation plays a crucial role in agricultural production by providing water to crops in regions where rainfall is insufficient. It enables farmers to grow a variety of crops and increase agricultural productivity. Rainfed class occupies %0.55 (2422 km2) of the total land area. This class refers to agricultural areas that rely solely on rainfall for crop cultivation. Rainfed agriculture is practiced in regions where the climate and rainfall patterns are suitable for crop growth without the need for irrigation mostly in the Kurdistan region.

Arable lands (5 years and 10 years) classes cover %3.10 (13582 km2) and %7.58 (33191 km2) of the total land area of Iraq. These classes include land used for growing crops within the last 5 or 10 years, respectively, before the land is left fallow for a period. Arable land in Iraq is primarily used for growing cereals, such as wheat, barley,Corn, and rice, as well as other crops such as

vegetables and fruits.
The agricultural classes mentioned above highlight the importance of agriculture in Iraq's land use. Agriculture plays a significant role in the country's economy, food security, and rural livelihoods. The different classes reflect the diversity of agricultural practices, including both irrigated and rainfed cultivation, as well as crop rotation practices. It is worth noting that Iraq faces various challenges in its agricultural sector, such as water scarcity, limited arable land, soil degradation, and climate change impacts. Sustainable agricultural practices, efficient water management, local soil conservation standards, and the promotion of resilient and adaptive farming techniques are essential for addressing these challenges and ensuring the long-term viability and sustainability of agriculture in Iraq.
Grassland and natural pastures cover 28941 km2, which is %6.61 of the country's area, mostly situated in north and west of Iraq. 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 Iraq.

Dense Forests are a significant land use, covering relatively low area (only 3217 ,%0.73 km2) of the country's total land area and mainly located in Kurdistan region (Duhok, Erbil and Al-Sulaymaniyah). 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 Dense Forest and Dense Forest is threatened by human activities, particularly deforestation, agricultural expansion, and urbanisation in Kurdistan region provinces. Deforestation is a threatening factor of forest loss and contributes significantly to global greenhouse gas emissions. Promoting sustainable forests requires a balance between economic development and conservation. Policies and practices that promote sustainable resource use are necessary in Iraq to prevent overuse 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.

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 Open Forests cover a relatively low area of Iraq, equivalent to around 7551 km2, which is %1.72 of the Iraq's area. 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. Open Forests are areas dominated by shrubs and provide many ecological, economic, and social benefits. Ecologically, it is used for agricultural production through agricultural practices such as planting orchards and fruit trees within forest lands. This is called Agroforestry 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 the tribal communities in mountainous areas and rangelands. Open forests and Open Forests 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). These regulations are required 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 major risks to 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 Iraq as a developing country where agriculture is the main source of livelihood for people. The impacts of desertification are particularly critical in 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 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 Iraq. Successful implementation of strategies to combat desertification in the Iraq would improve soil health, increase vegetation cover, and enhance groundwater recharge. This would contribute to sustainable development, reduction in poverty rate, and climate change adaptation and mitigation. In conclusion, the LULC classes in Iraq reflect the complex interactions between natural and human factors in shaping the country's physical environment. Effective land management policies that address the challenges posed by desertification, land degradation, water scarcity, and urbanisation are essential for achieving sustainable development in Iraq. The analysis of LULC classes provides valuable information for policymakers, researchers, and stakeholders involved in the management of natural resources in Iraq.

9. Conclusion

Land use and land cover (LULC) classes of Iraq provide valuable information about the country's land resources and their usage. The analysis of the LULC data reveals that a significant portion of Iraq's land is covered by desert and rocky desert, occupying %24.1 and %17.8 of the total area, respectively. The majority of the remaining land is used for agriculture, with %17.01 of the total area occupied by arable lands (5 and 10 years), irrigated land, and rainfed areas. The remaining land is used for various purposes, including urban areas, water bodies, wetlands, Dense Forest, Open Forests, palm trees, grasslands, sparse vegetation, marshland vegetation, herbaceous and mangroves, rocky surfaces, and abandoned farmland.

Understanding the land use and land cover patterns of Iraq is important for sustainable land management and natural resource conservation. The data presented in this report can provide insights into the current state of land use in Iraq, helping policymakers and stakeholders make informed decisions regarding land use planning, conservation efforts, and sustainable development initiatives. Further studies can explore the implications of these land use patterns on biodiversity, ecosystem services, and the well-being of local communities in Iraq.

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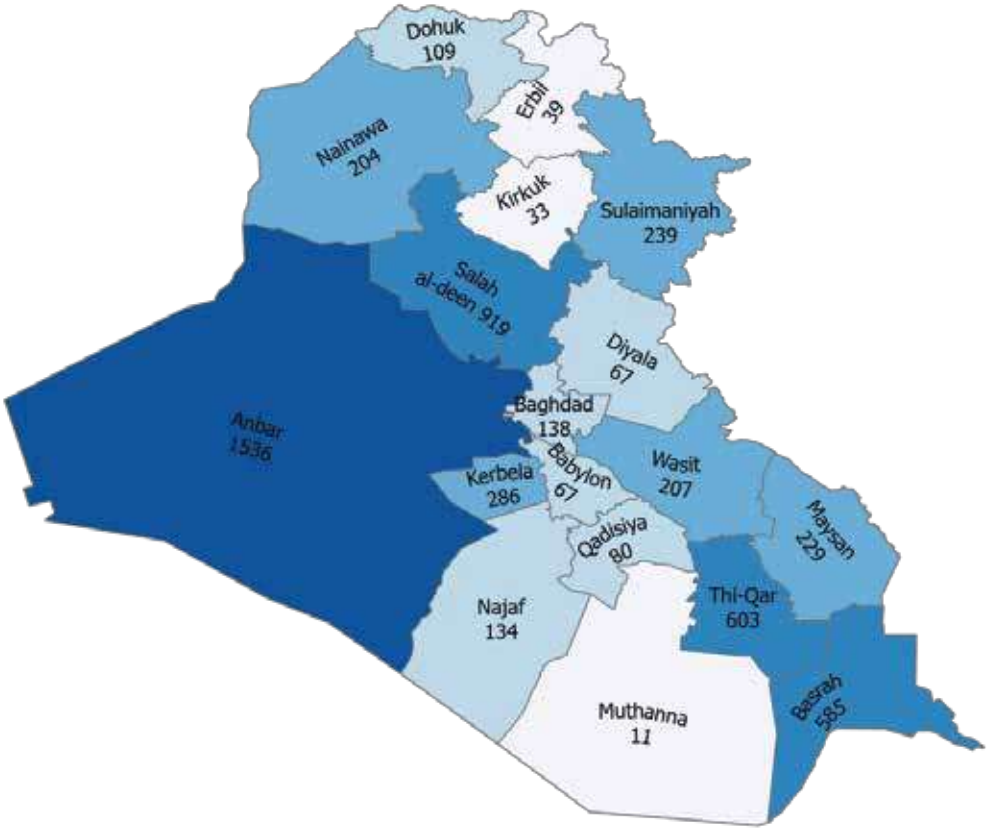
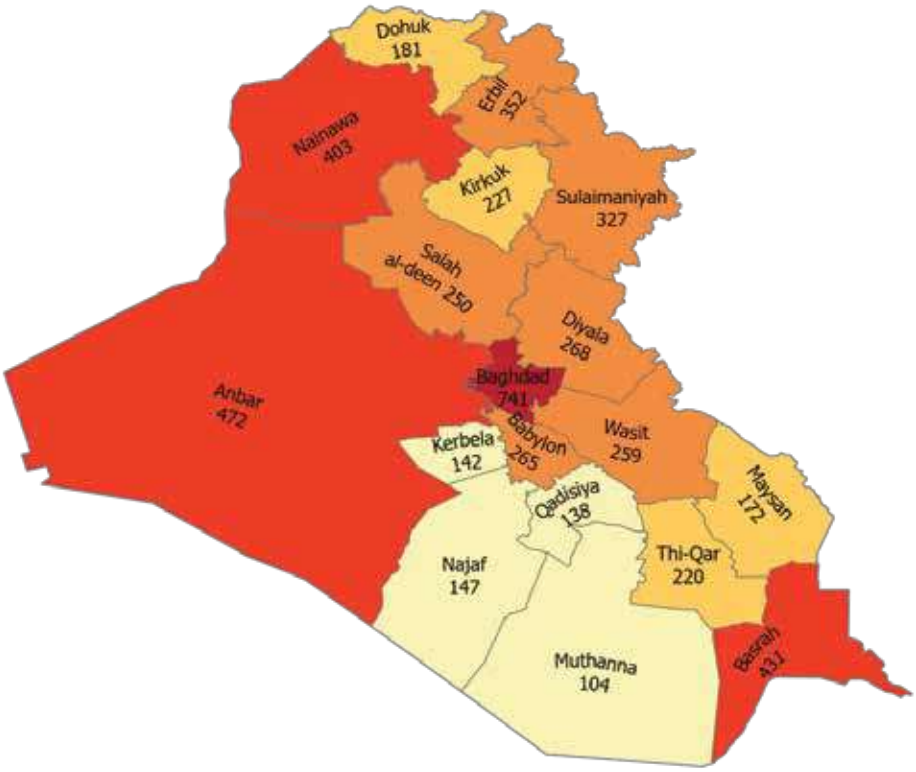
Appendices .11

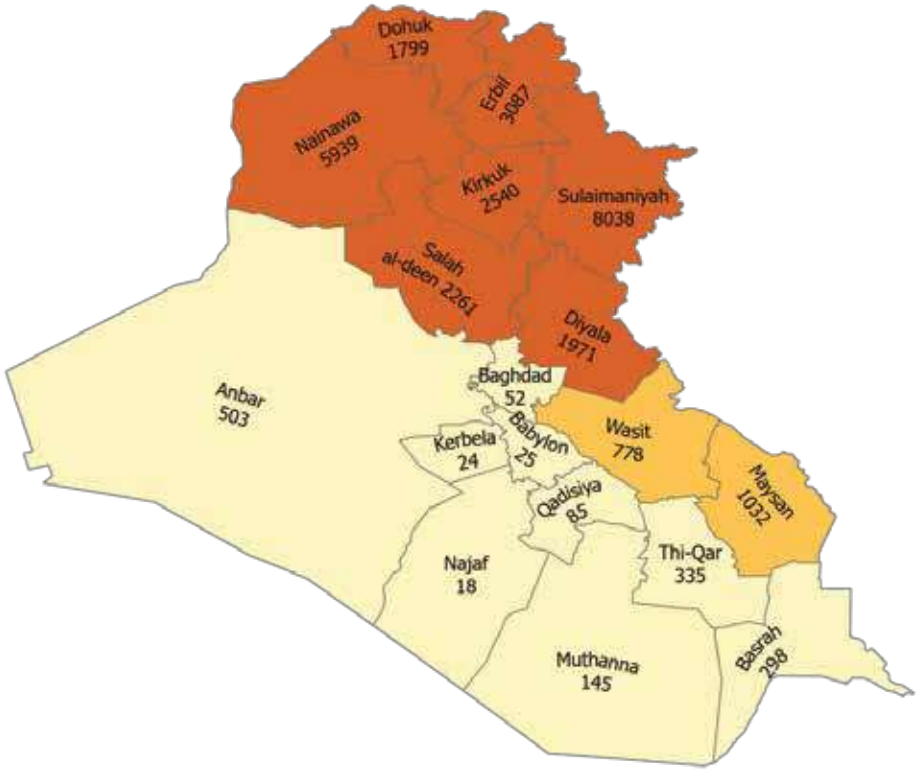
11.1.1 Appendix A-1. Distribution of LULC classes (Waterbody)on Iraqi provinces.



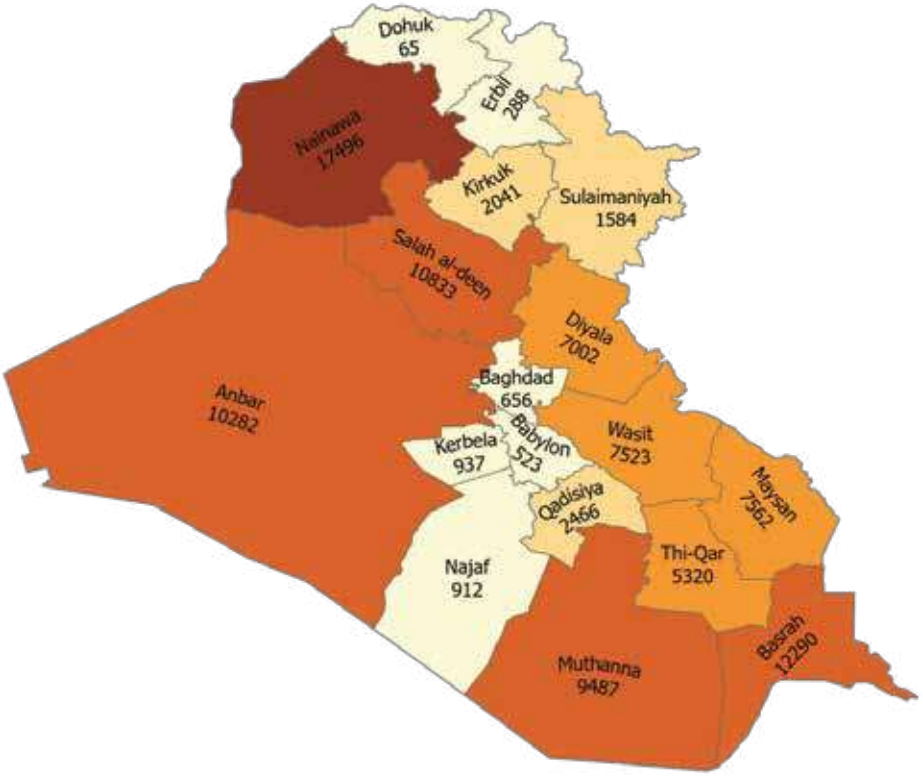
11.1.1 Appendix A-2. Distribution of LULC classes (Urban)on Iraqi provinces.



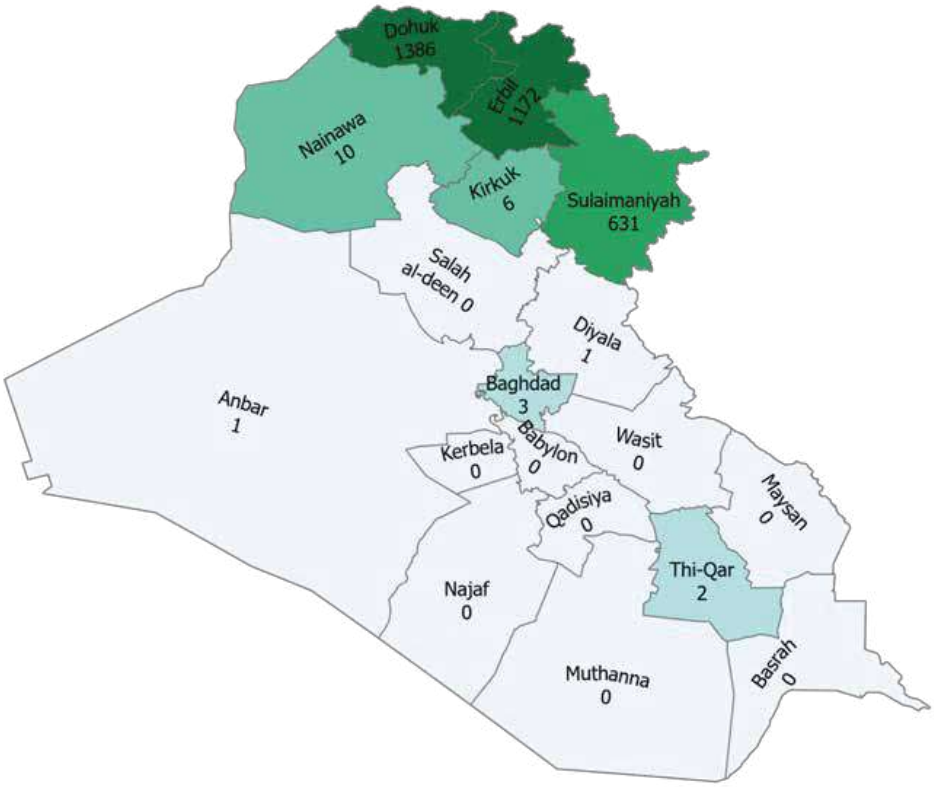
11.1.1 Appendix A-3. Distribution of LULC classes (Grassland)on Iraqi provinces.



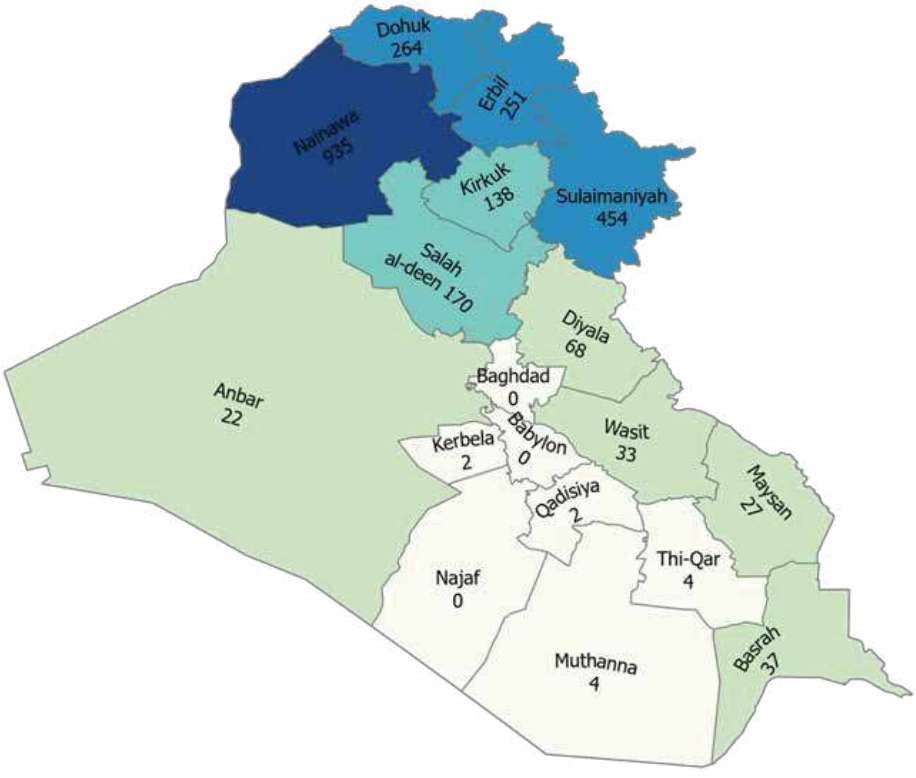
11.1.1 Appendix A-4. Distribution of LULC classes (Abended land) on Iraqi provinces.



11.1.1 Appendix A-5. Distribution of LULC classes (Forestry) on Iraqi provinces.



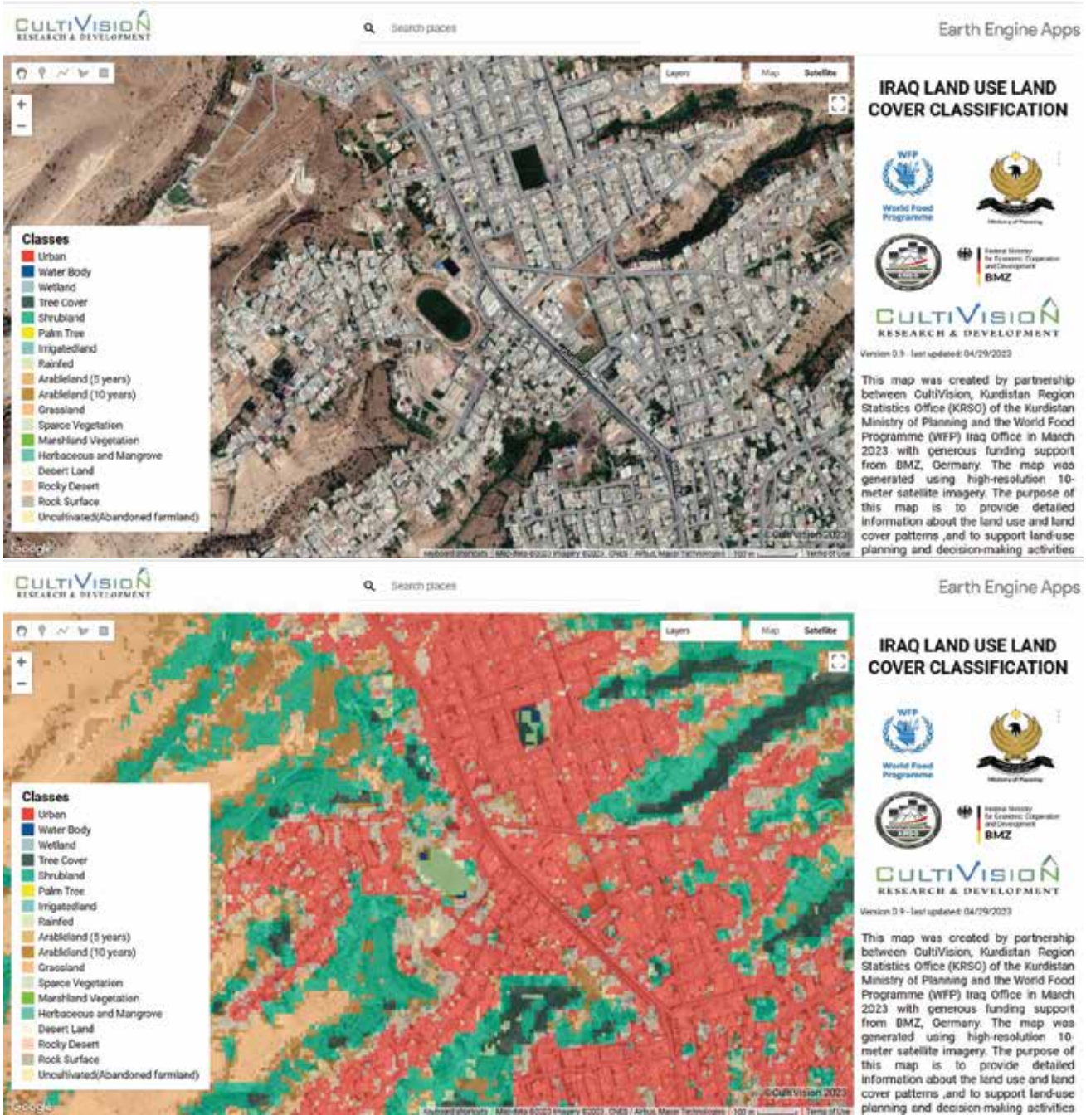
1.1.1 Appendix A-6. Distribution of LULC classes (Rainnfed) on Iraqi provinces.



Appendix 11.2

Appendix. Figure-A

LULC class, Urban, Water, Dense Forest Open forest/ Shrubland, Arableland (5 years), Arableland (10 years), Grassland, Uncultivated (Abandoned farmland



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Grassland
Sparce Vegetation
Marshland Vegetation
Herbaceous and Mangrove
Desert Land
Rocky Desert
Rock Surface
Uncultivated(Abandoned farmland)
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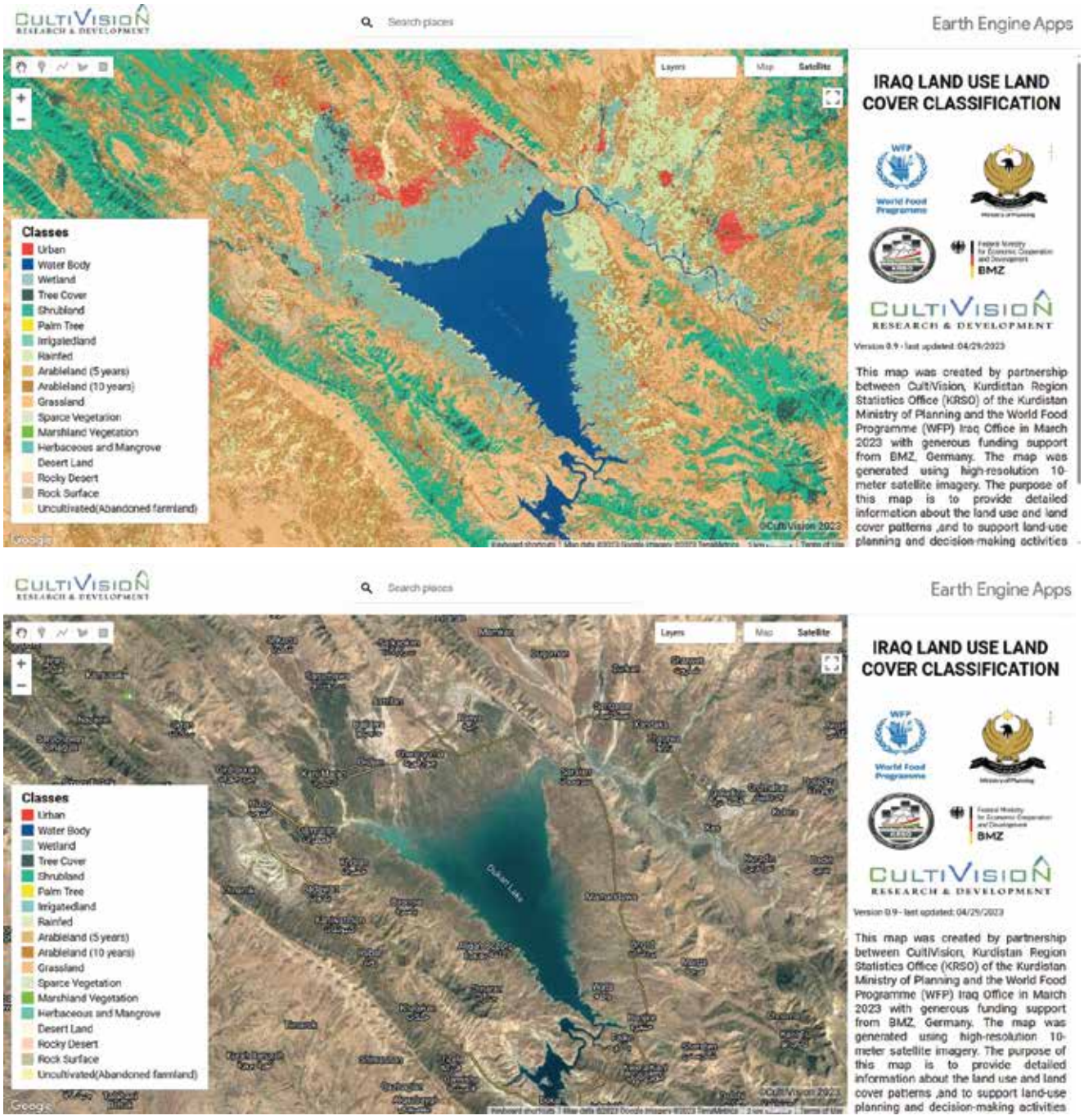
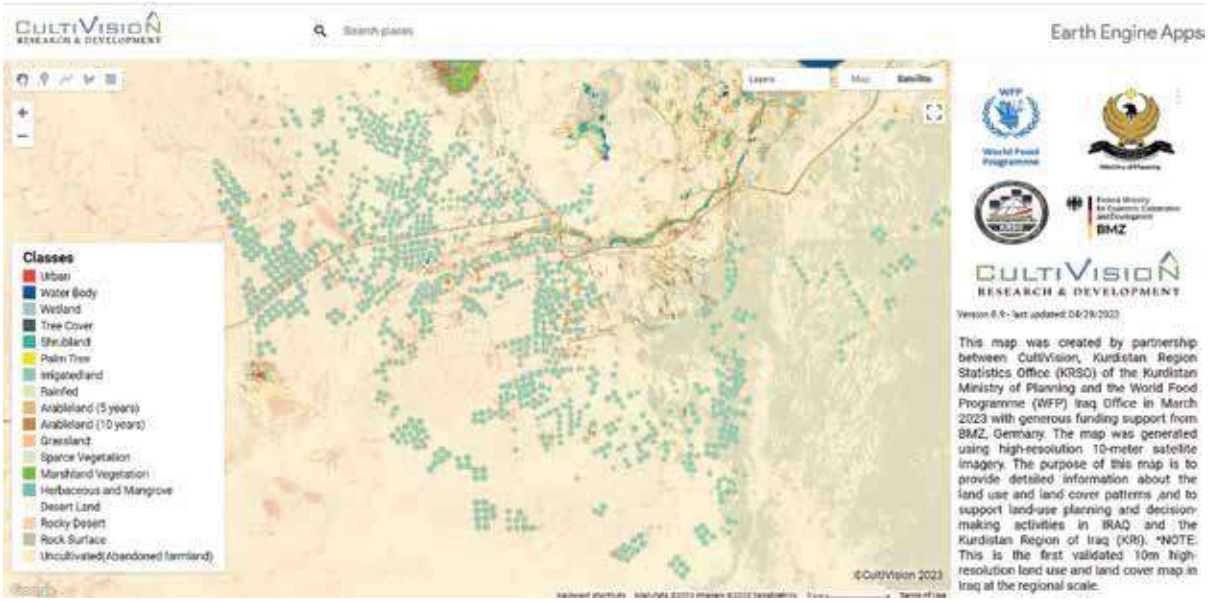
Appendix. Figure-B

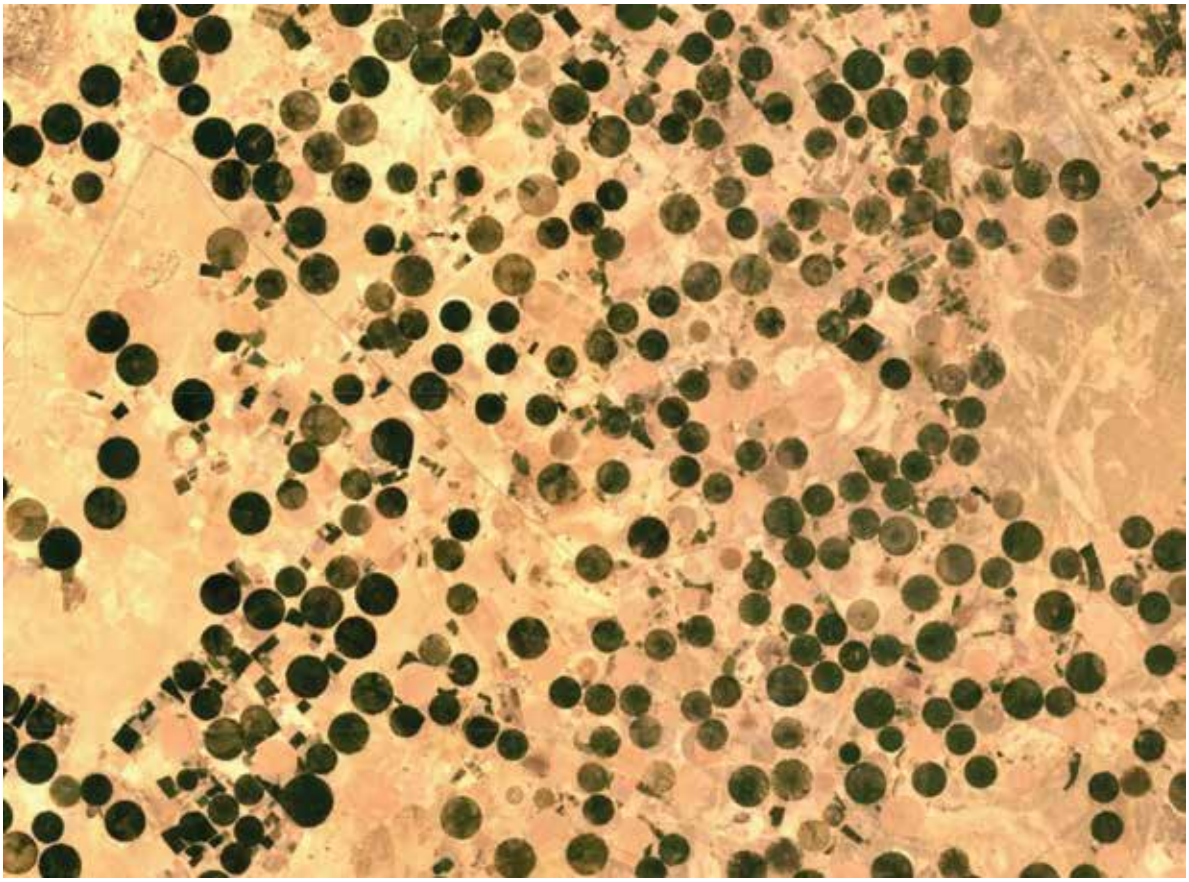
LULC class, Urban, Water Body, Wetland,Dense Forest Open forest/ Shrubland,Palm Tree,Irrigatedland,Rainfed Arableland (5 years), Arableland (10 years), Grassland, Rock Surface, Uncultivated (Abandoned farmland)



Appendix. Figure-C

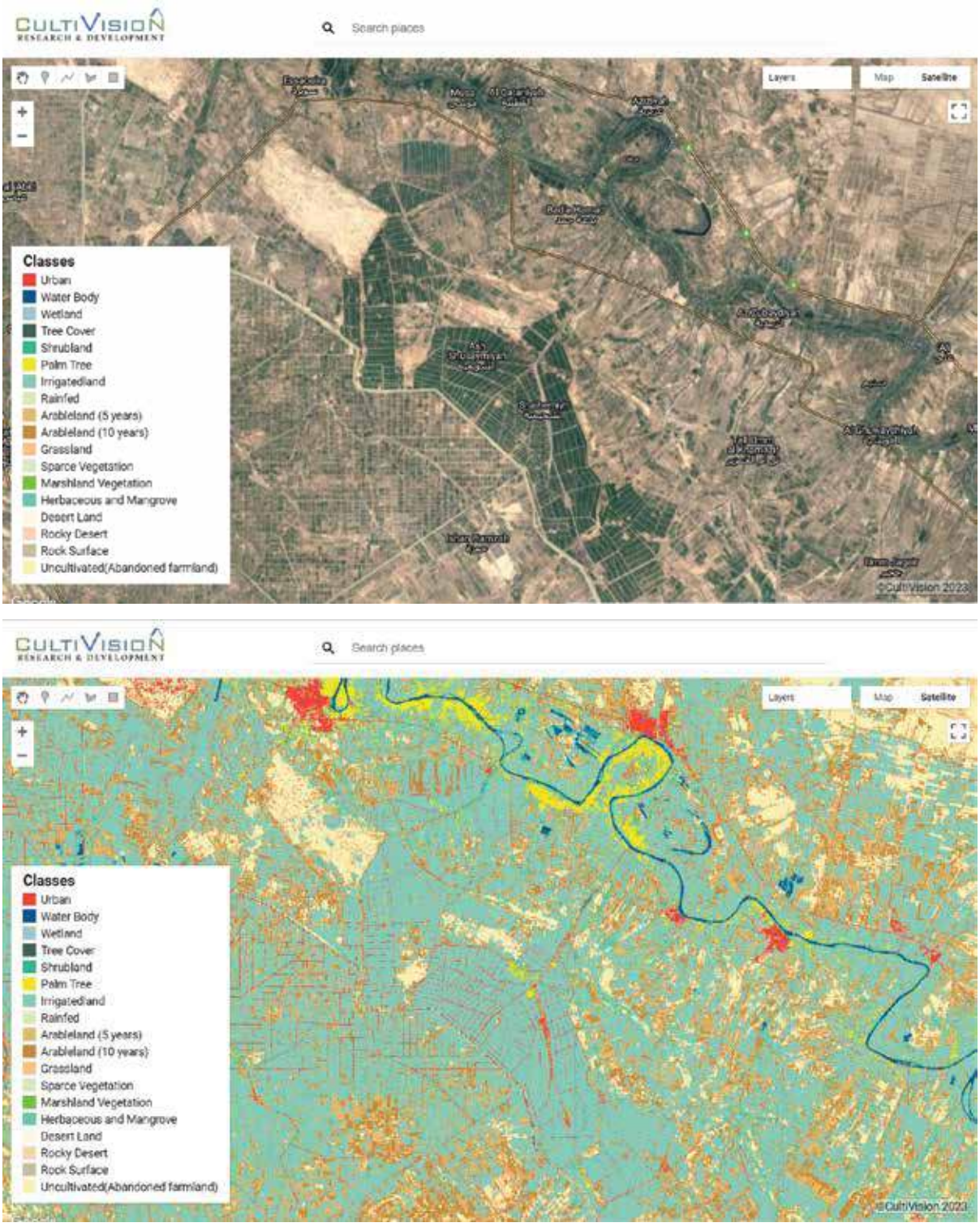
LULC class, Irrigatedland, Rainfed, Arableland (5 years), Arableland (10 years), Grassland, Sparse Vegetation, Uncultivated (Abandoned farmland)





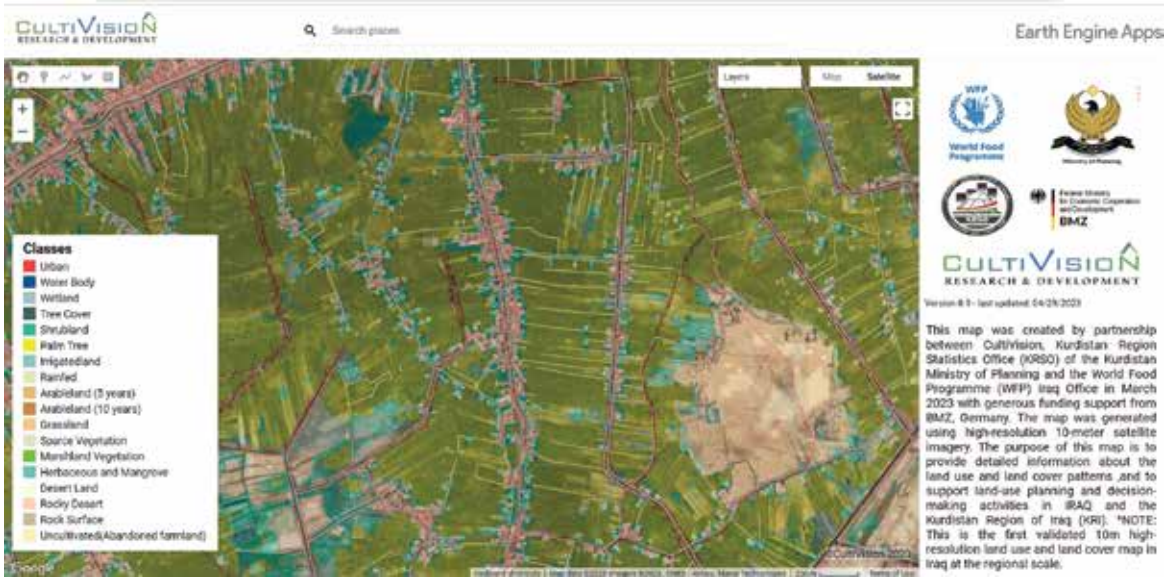
Appendix. Figure-D

LULC class, Urban,Water Body,Wetland, Palm Tree, Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Marshland Vegetation, Herbaceous and Mangrove, , Rock Surface, Uncultivated (Abandoned farmland)



Appendix. Figure-E

LULC class, Urban,Water Body,Wetland, Palm Tree, Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Herbaceous and Mangrove, Rock Surface, Uncultivated (Abandoned farmland)

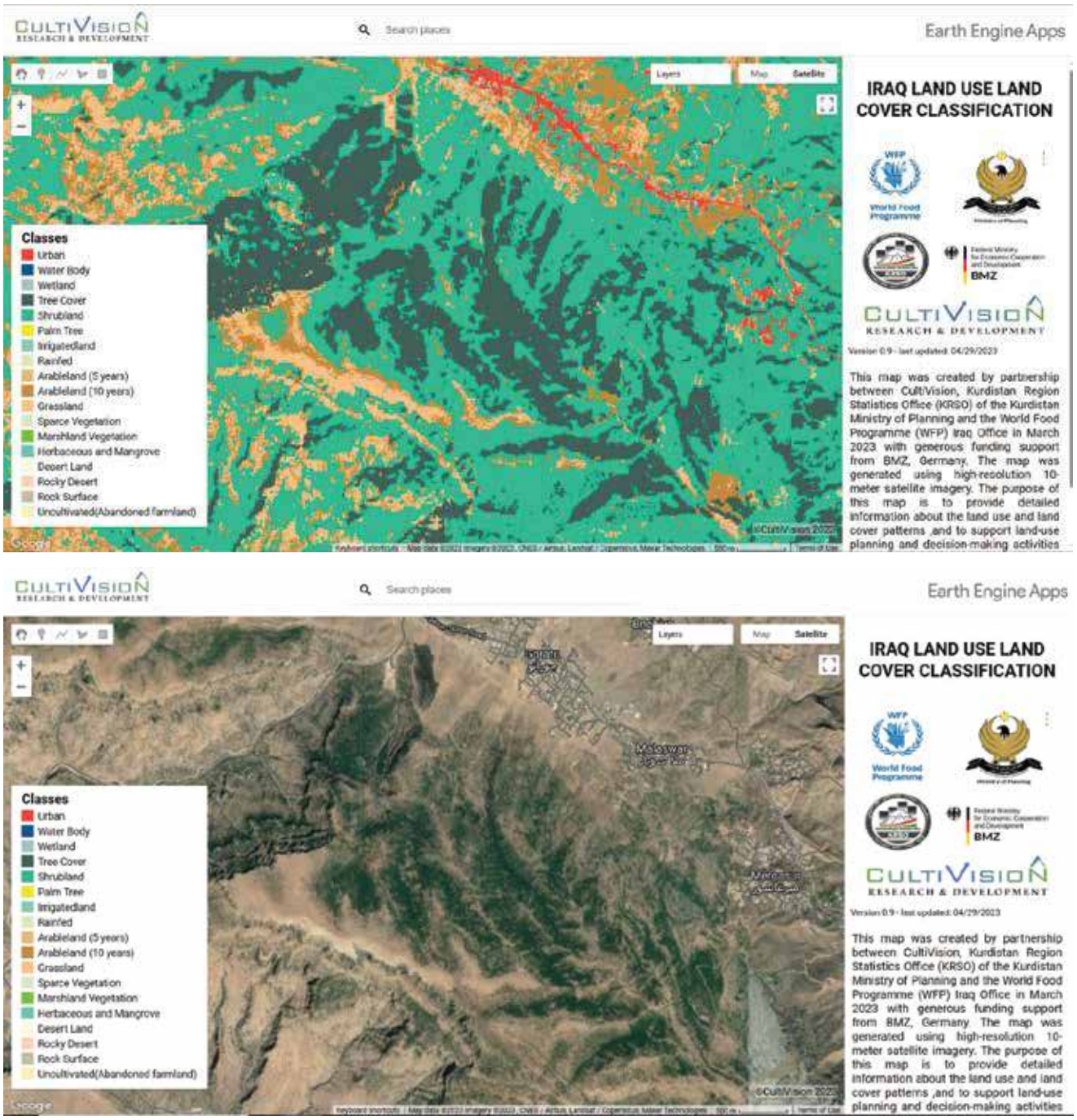


Appendix. Figure-E-1-

LULC class, Palm Tree, Irrigatedland

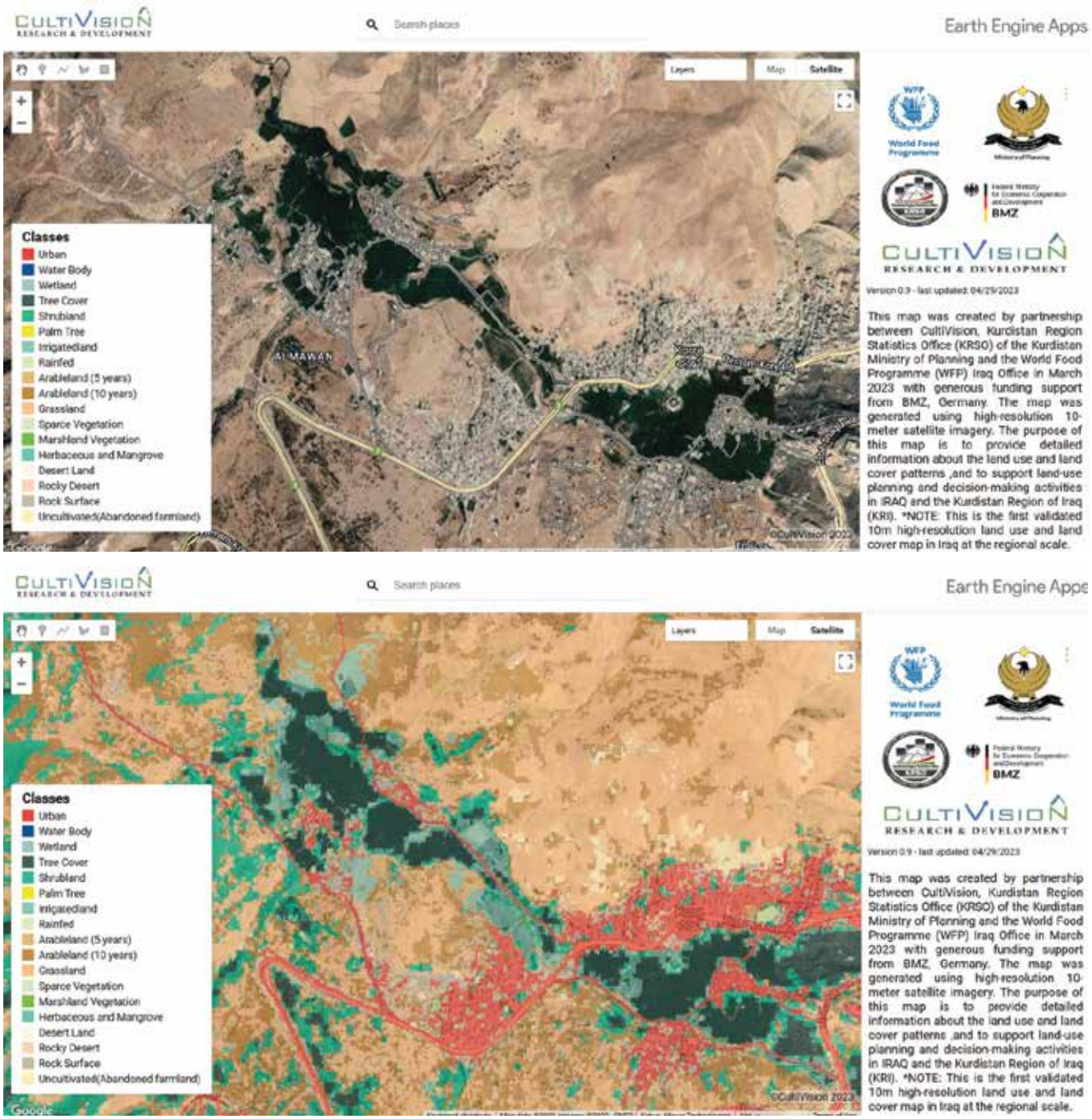
Appendix. Figure-E-2-

LULC class, Urban, Dense Forest, open Forest/ Shrubland, Arableland (5 years), Arableland (10 years), Grassland, Uncultivated (Abandoned farmland)



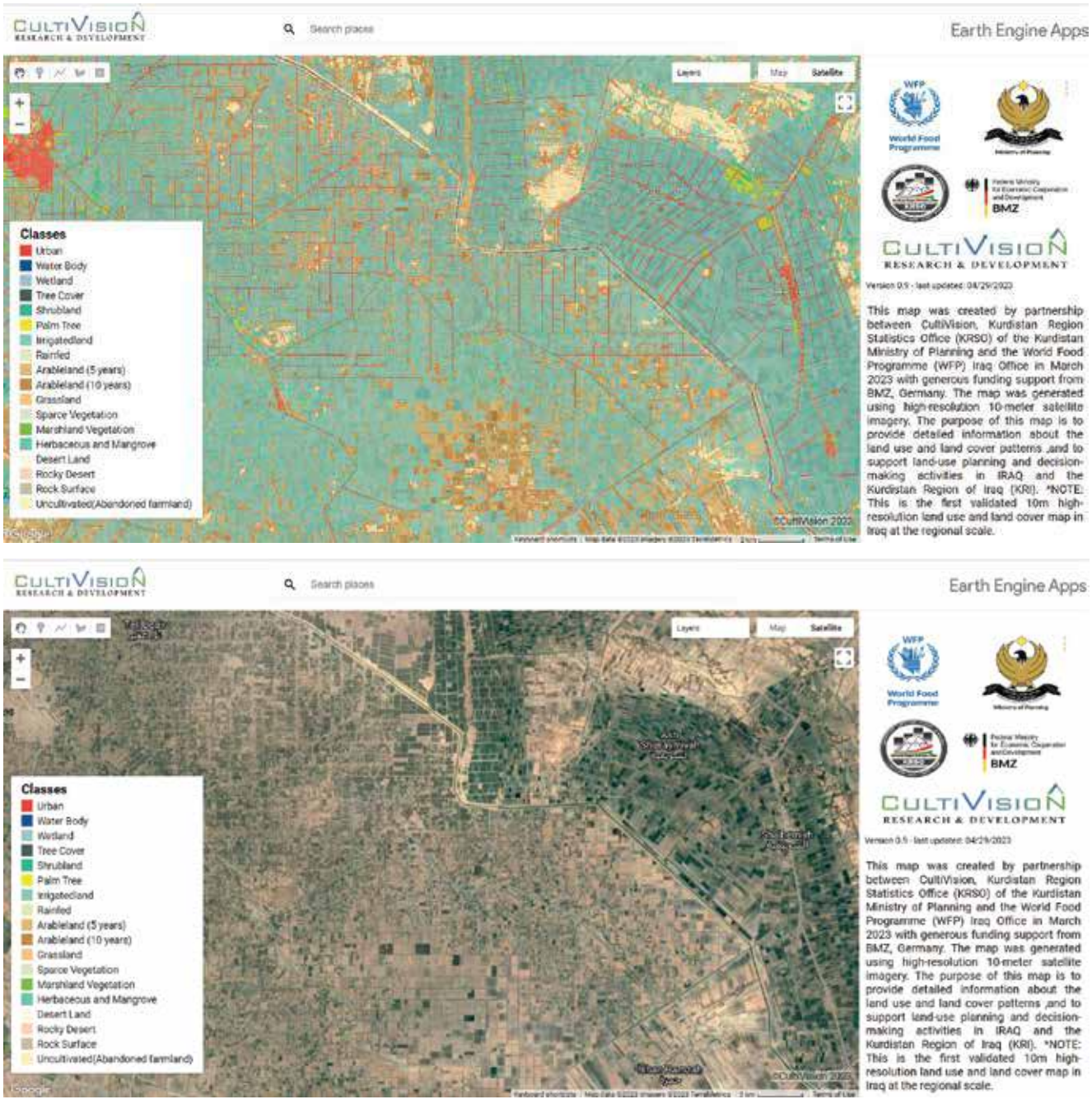
Appendix. Figure-F

LULC class, Urban ,Dense Forest Open forest/ Shrubland, Irrigatedland, Rainfed Arableland (5 years), Arableland (10 years), Grassland, Rock Surface, Uncultivated (Abandoned farmland)



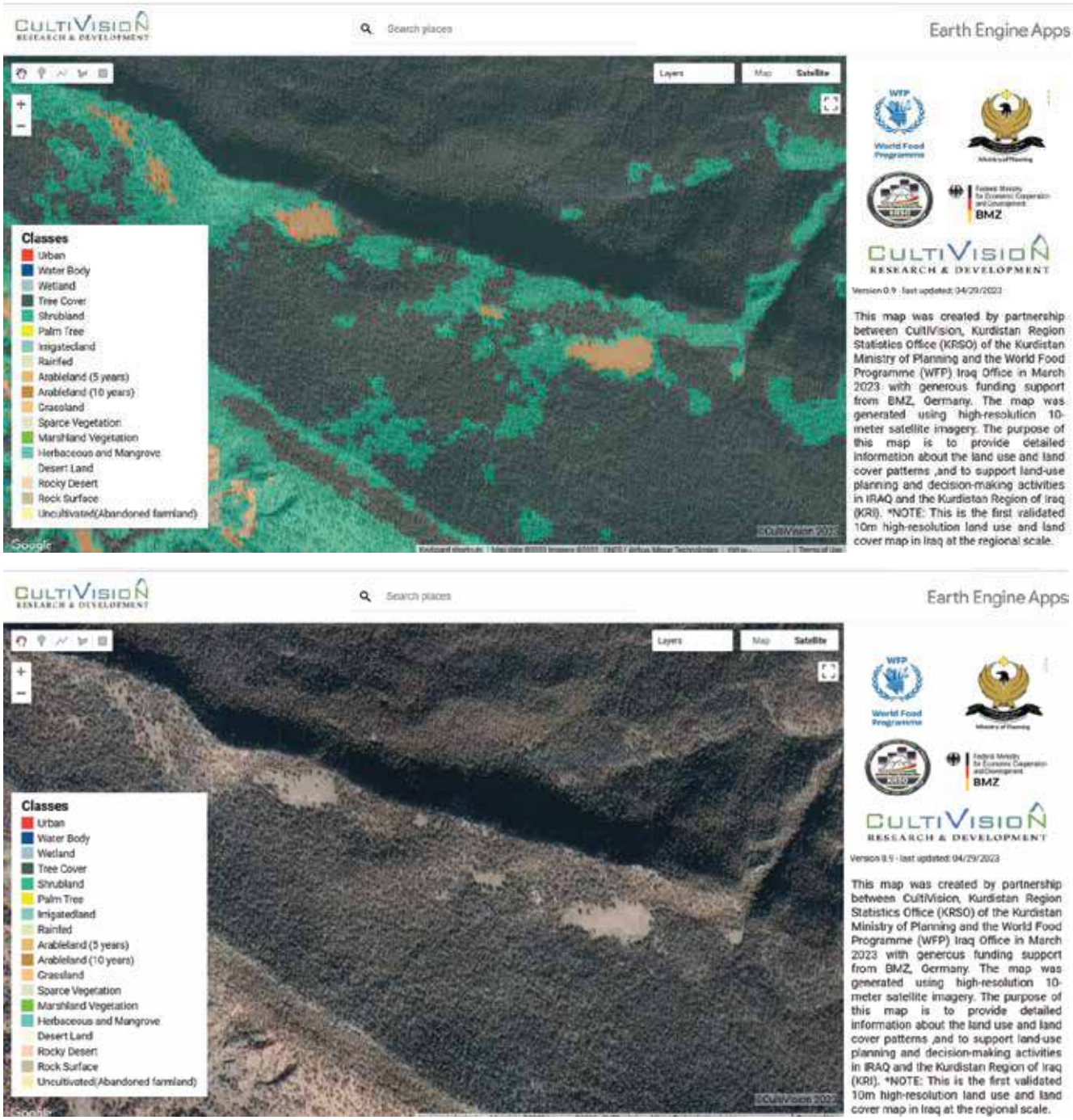
Appendix. Figure-G

LULC class, Urban, Palm Tree,Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Uncultivated (Abandoned farmland)



Appendix. Figure-H

LULC class, Dense Forest Open forest/ Shrubland, Grassland.



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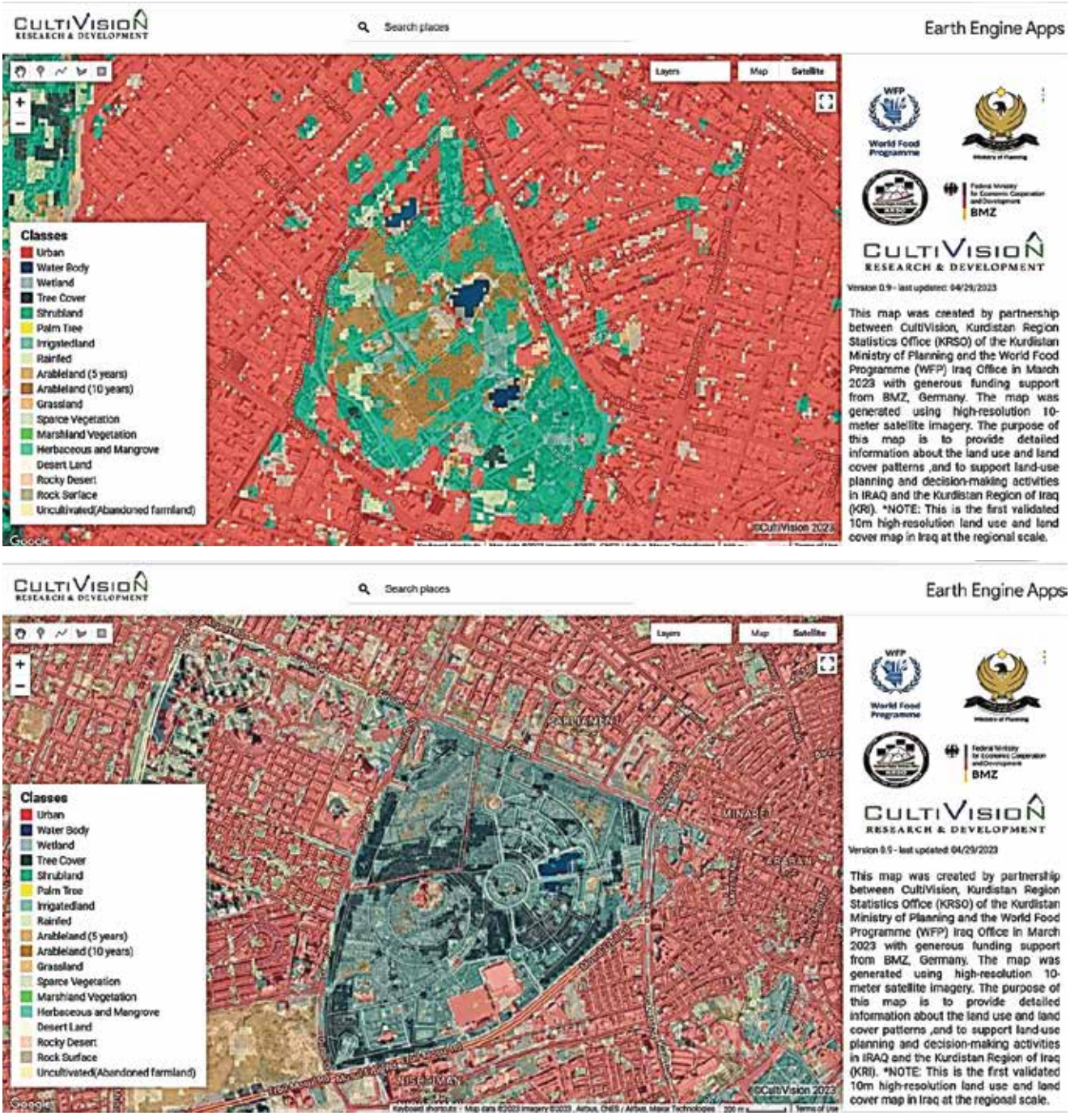
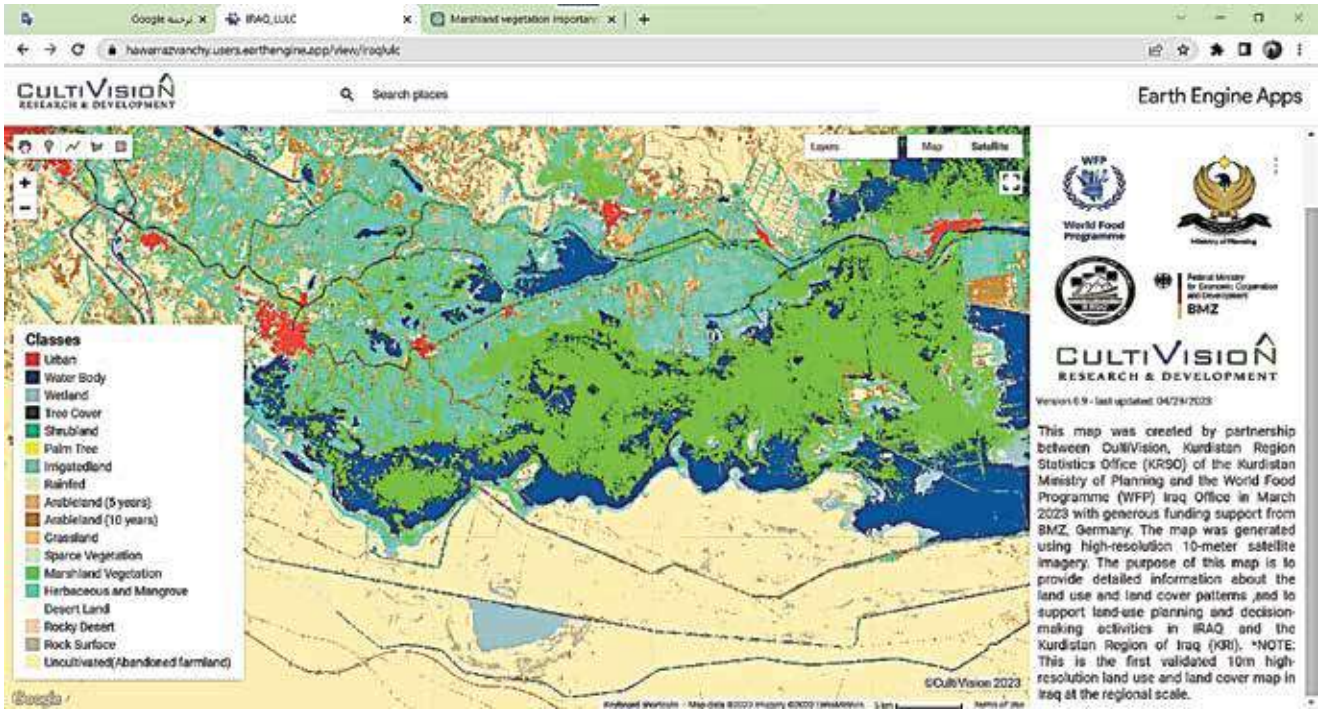
Appendix. Figure-I

LULC class, Urban,Water Body,Wetland,Dense Forest Open forest/ Shrubland,Palm Tree, Irrigatedland,Rainfed Arableland (5 years), Arableland (10 years), Grassland, Rock Surface.



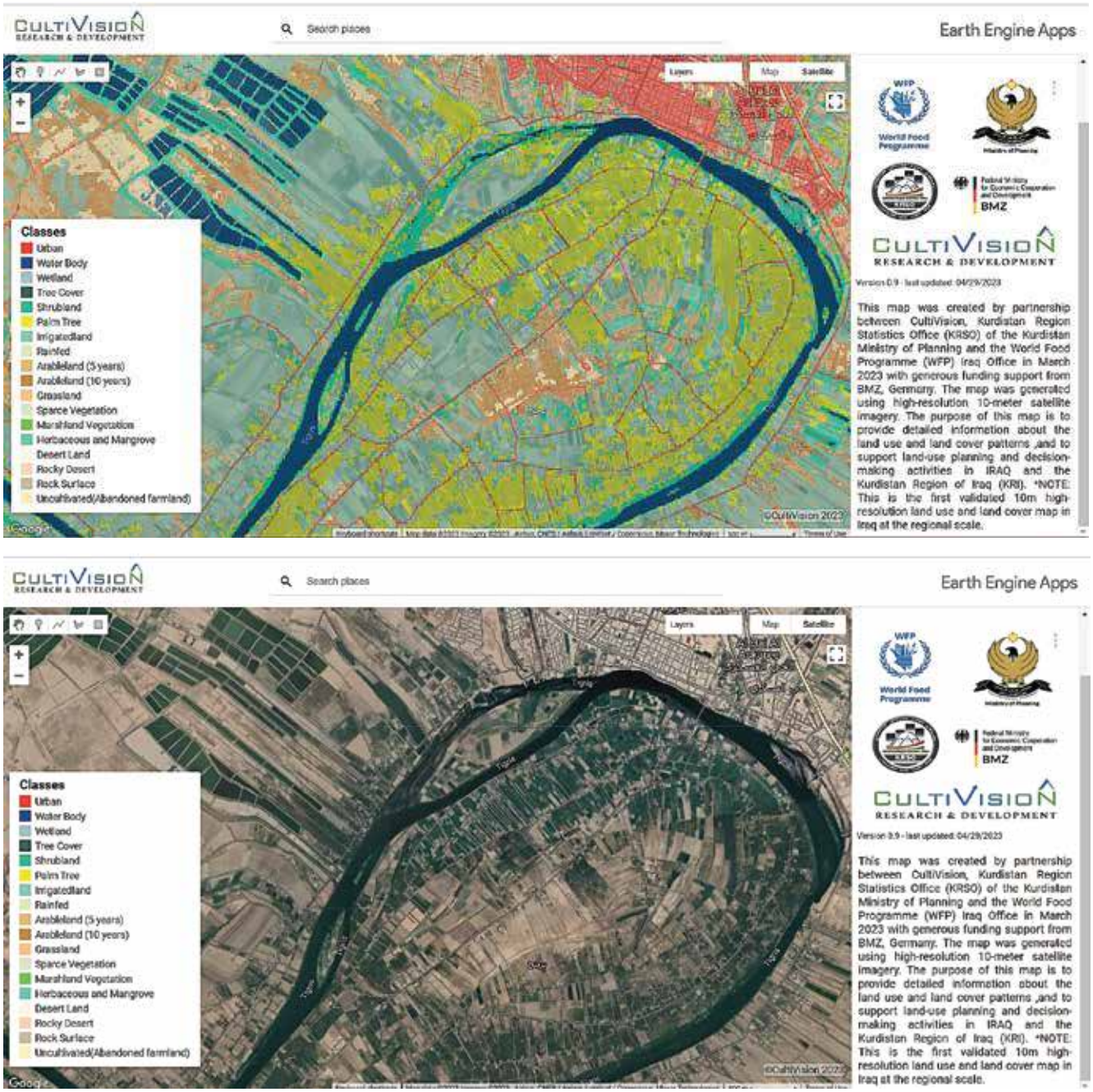
Appendix. Figure-J

LULC class, Urban, Water Body, Wetland, Dense Forest Open forest/ Shrubland, Palm Tree, Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Sparse Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Rock Surface, Uncultivated (Abandoned farmland)



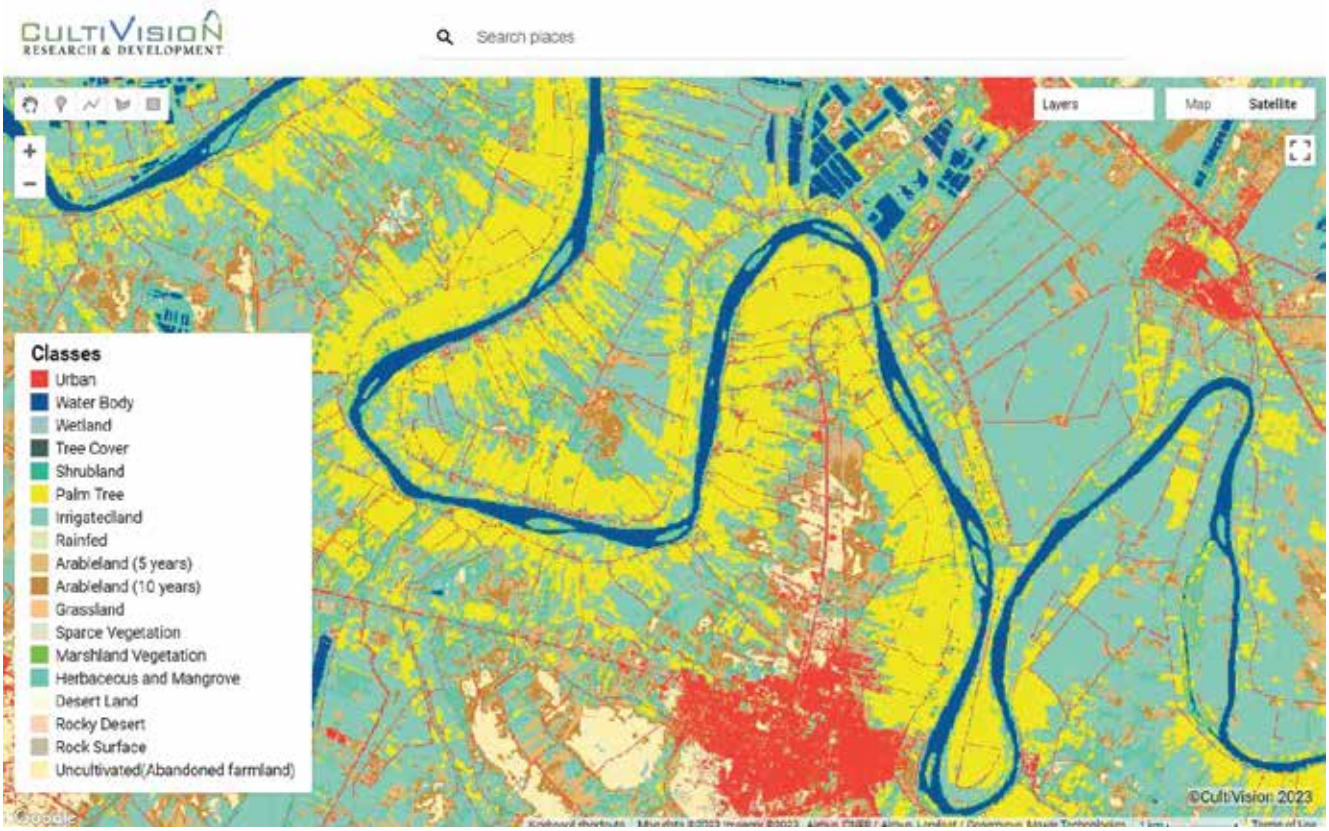
Appendix. Figure-K

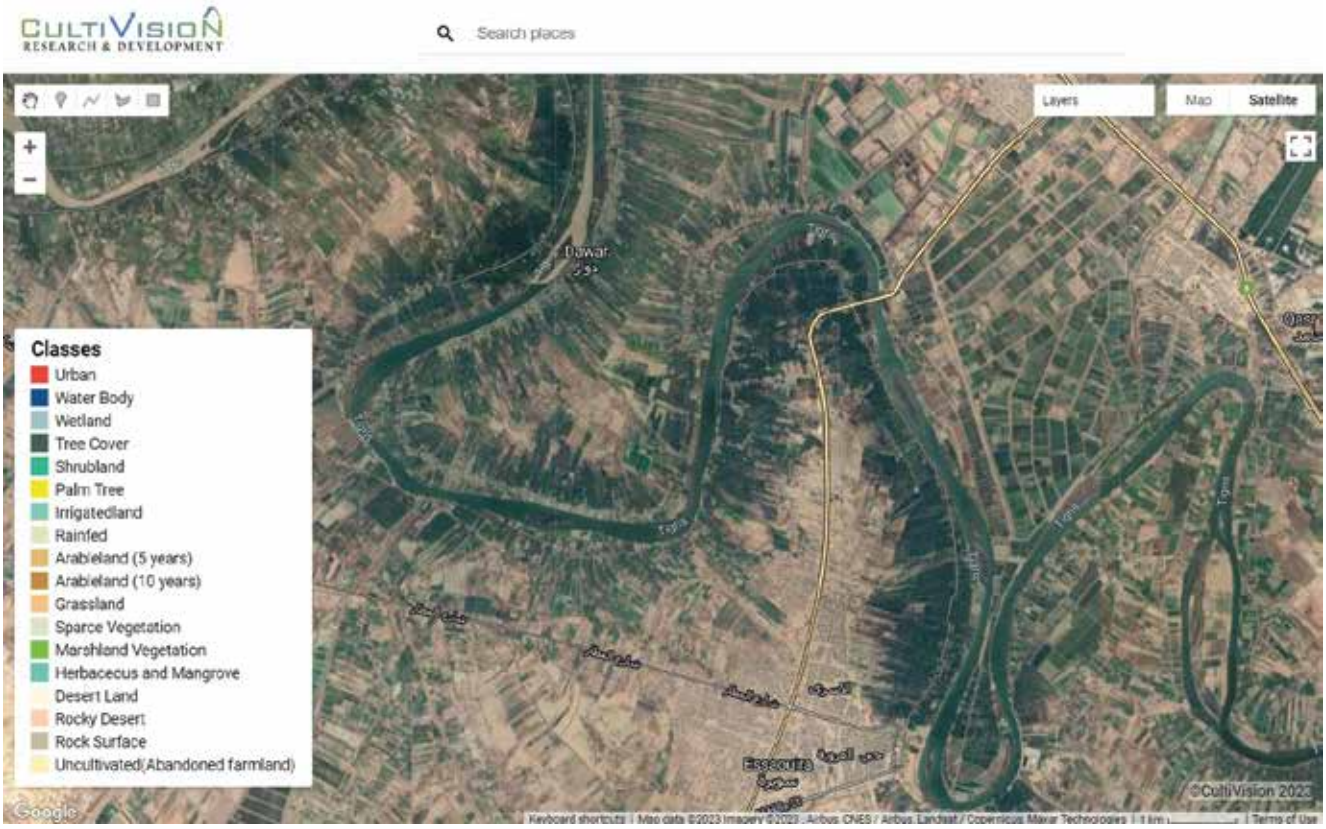
LULC class, Urban,Water Body,Wetland, ,Palm Tree,Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Sparse Vegetation, Herbaceous and Mangrove, Uncultivated (Abandoned farmland)



Appendix. Figure-L

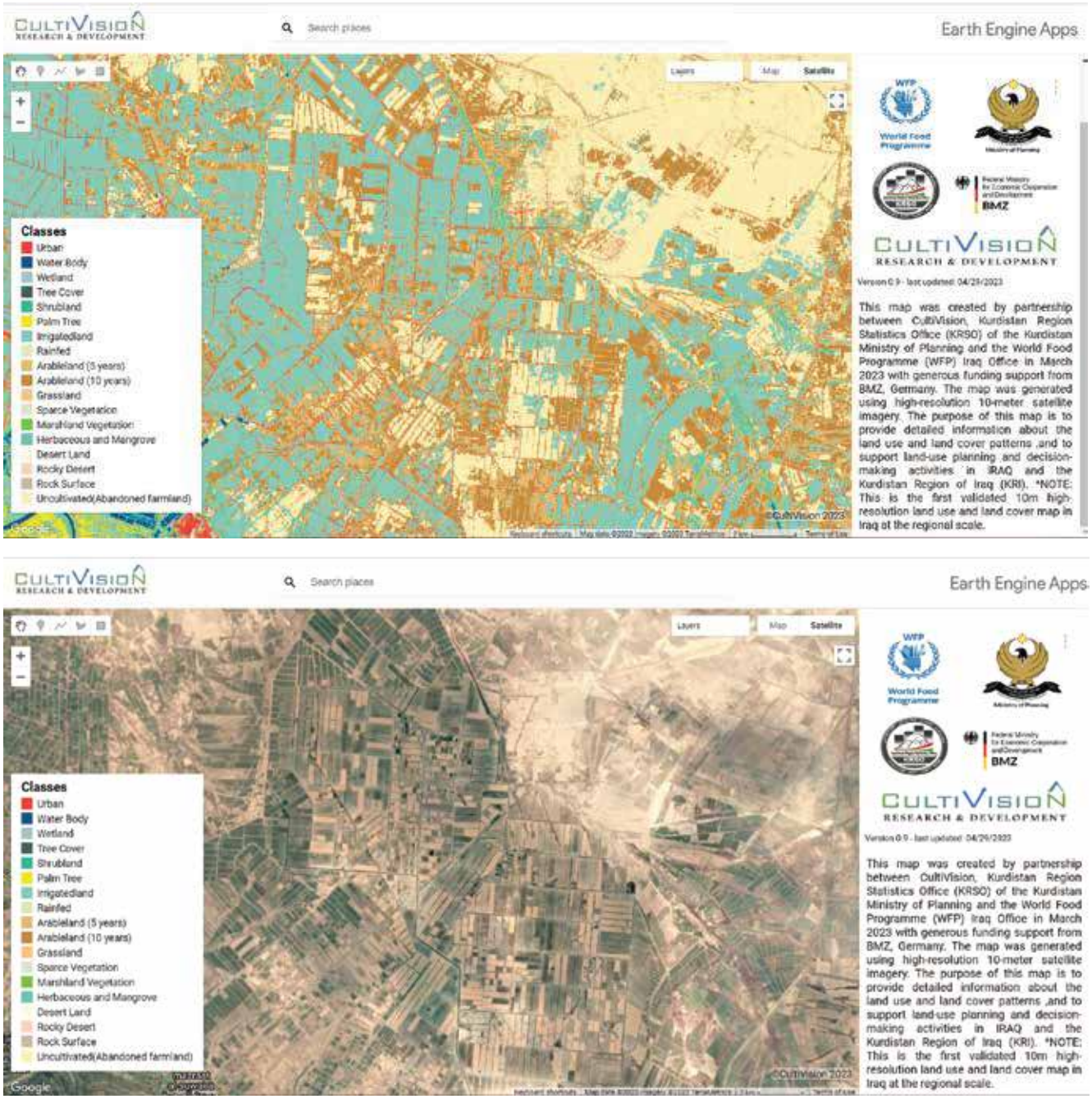
LULC class, Urban,Water Body, Wetland, Dense Forest Open forest/ Shrubland, Palm Tree, Irrigatedland, Rainfed Arableland (5 years), Arableland (10 years), Grassland, Herbaceous and Mangrove, Uncultivated (Abandoned farmland)





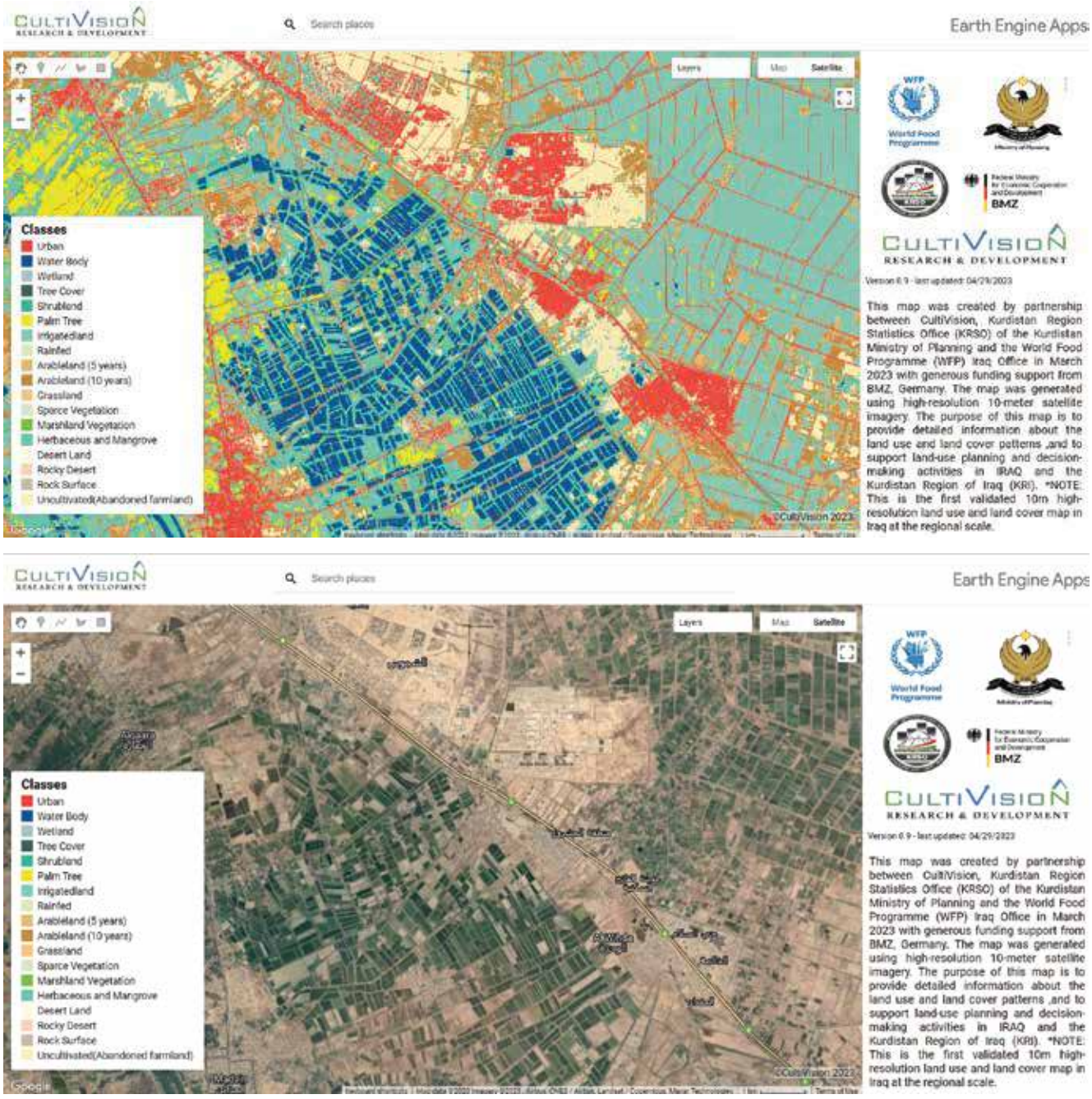
Appendix. Figure-M

LULC class, Urban, Wetland,Palm Tree, Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Sparse Vegetation, Marshland Vegetation, Herbaceous and Mangrove, Uncultivated (Abandoned farmland)



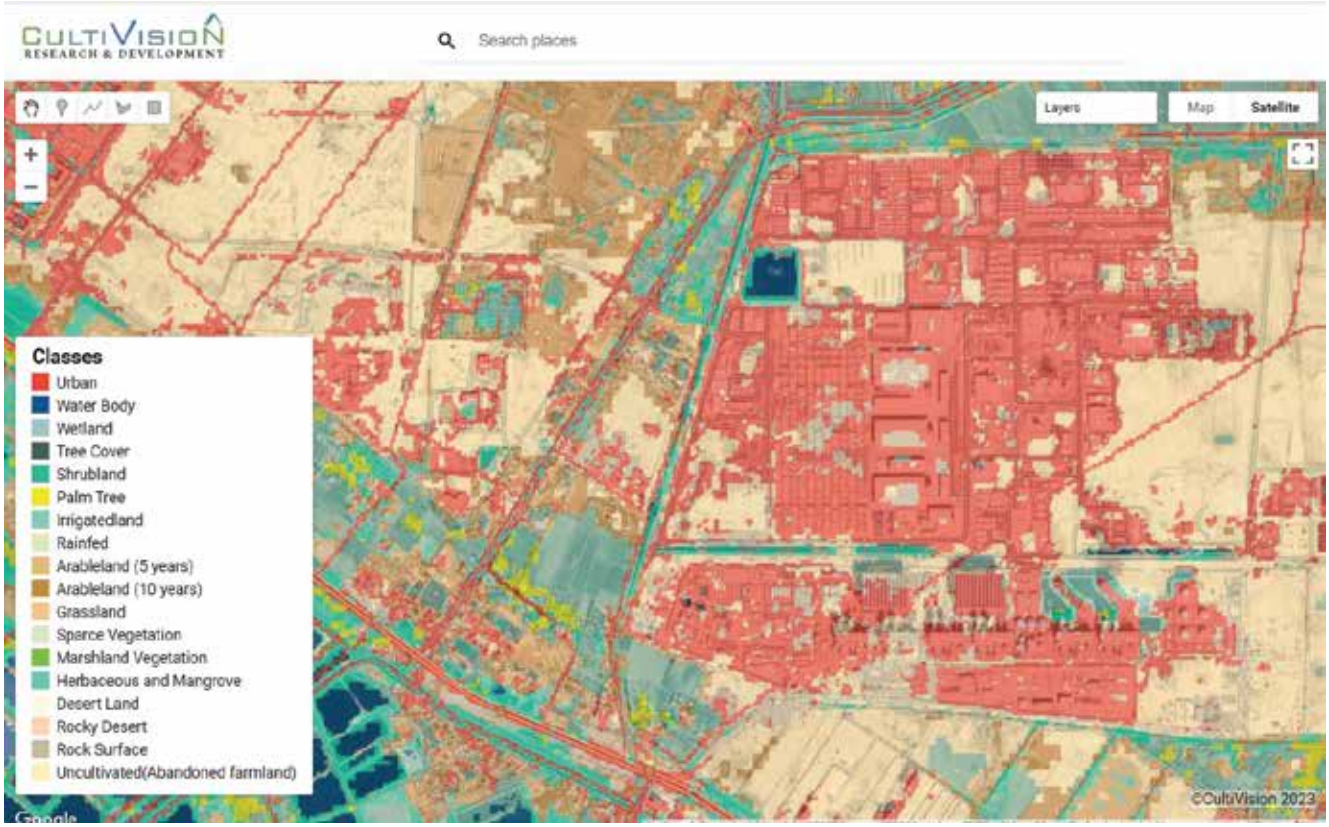
Appendix. Figure-N

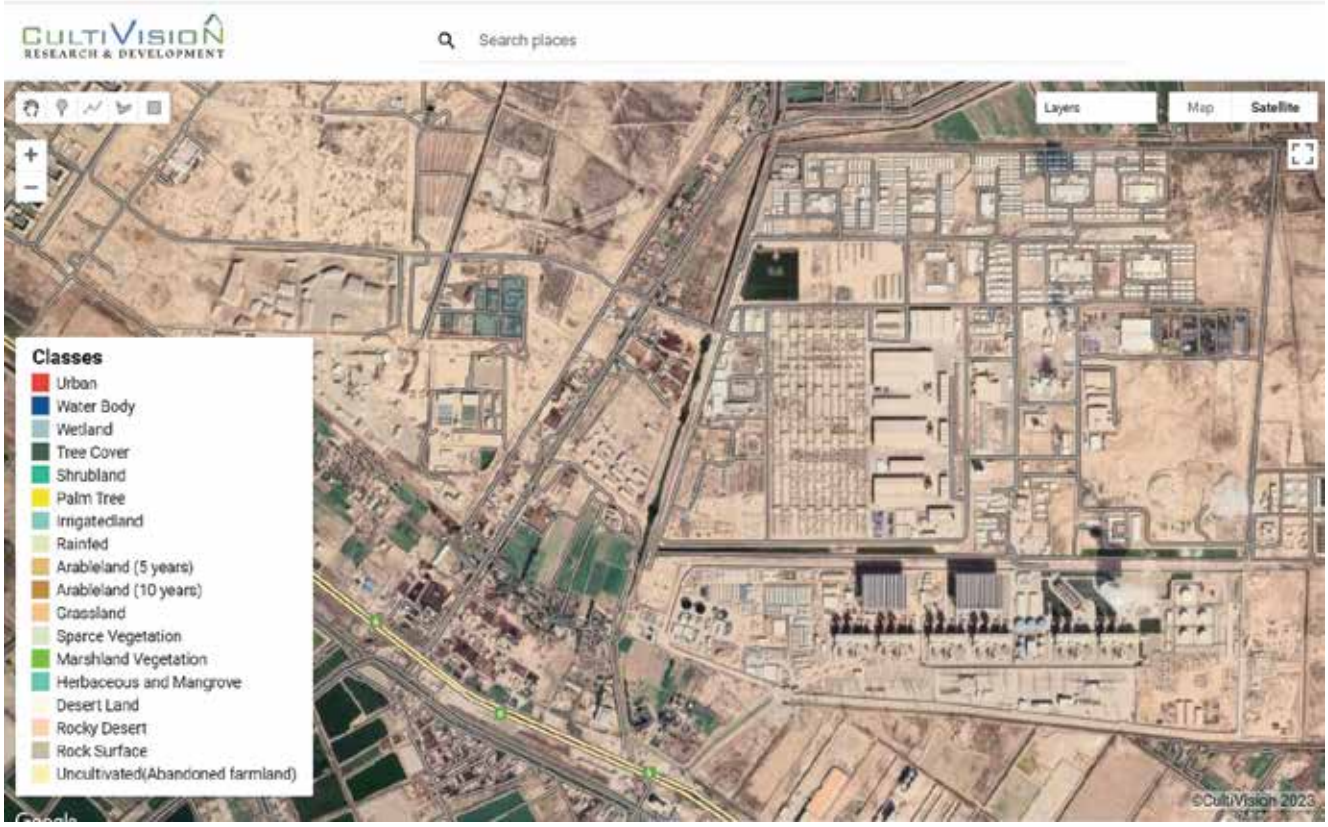
LULC class, Urban,Water Body,Wetland,Dense Forest Open forest/ Shrubland,Palm Tree,Irrigatedland,Rainfed Arableland (5 years), Arableland (10 years), Grassland, Herbaceous and Mangrove,Uncultivated (Abandoned farmland)



Appendix. Figure-O

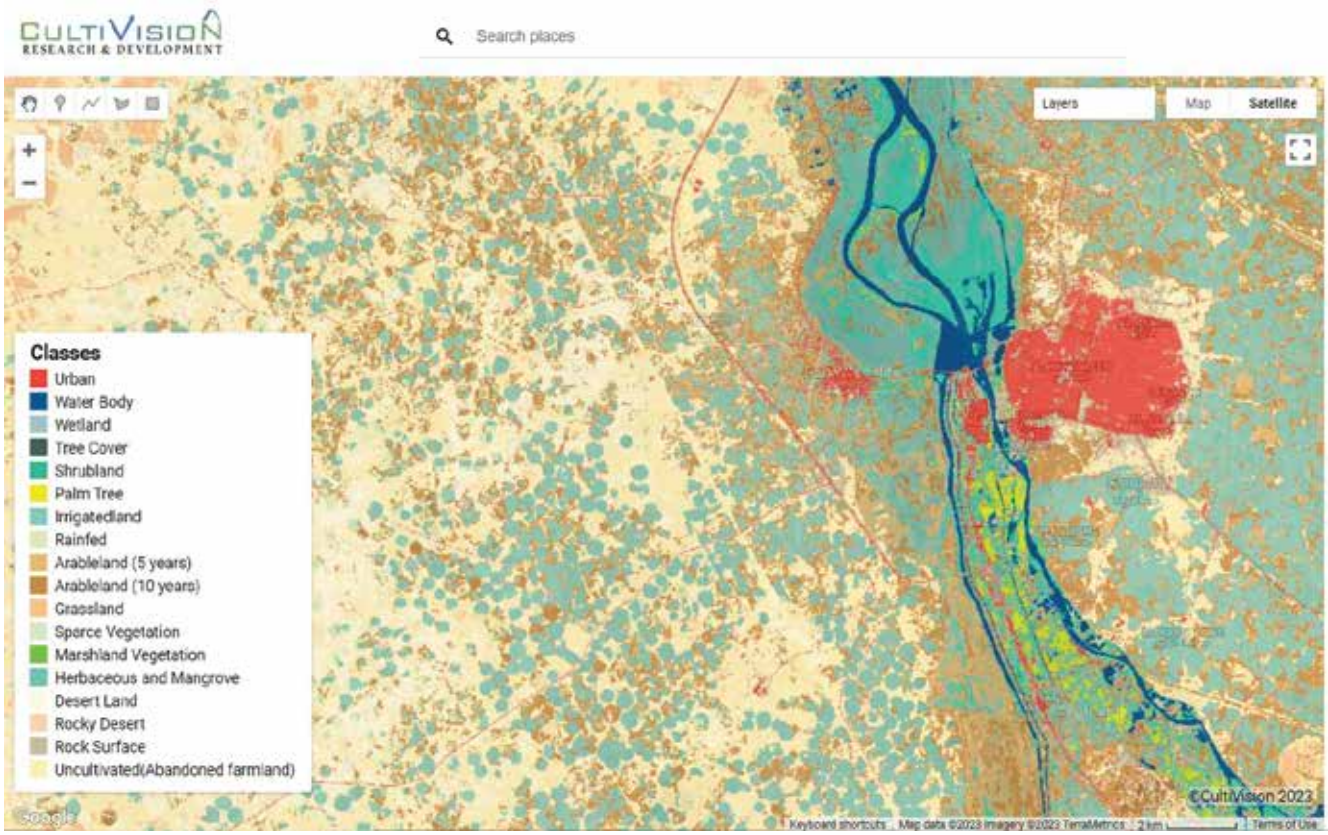
LULC class, Urban, Water Body, Wetland, Palm Tree, Irrigatedland, Rainfed Arableland (5 years), Arableland (10 years), Grassland, Sparse Vegetation, Marshland Vegetation, Surface, Uncultivated (Abandoned farmland)

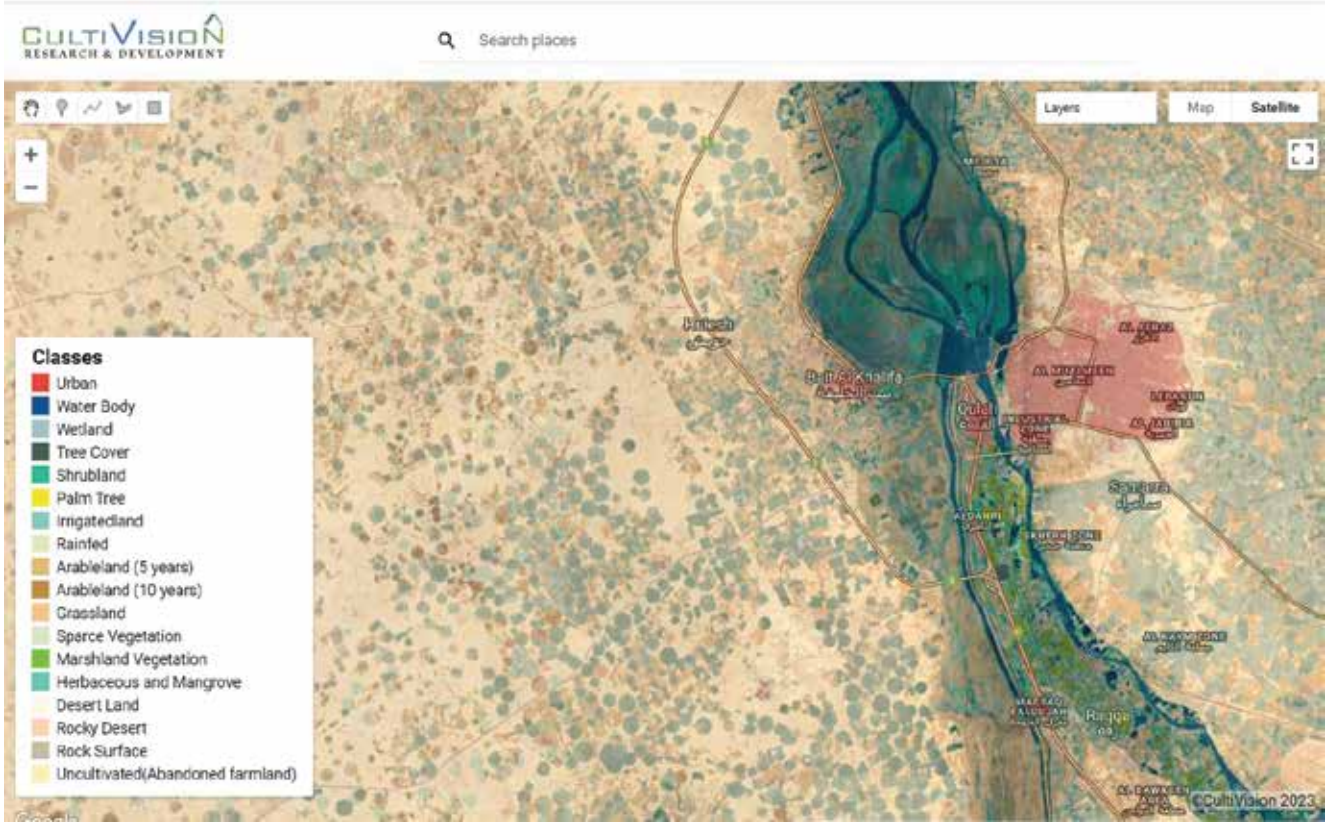




Appendix. Figure-P

LULC class, Urban, Water Body, Wetland, Palm Tree, Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Herbaceous and Mangrove, Desert Land, Uncultivated (Abandoned farmland).



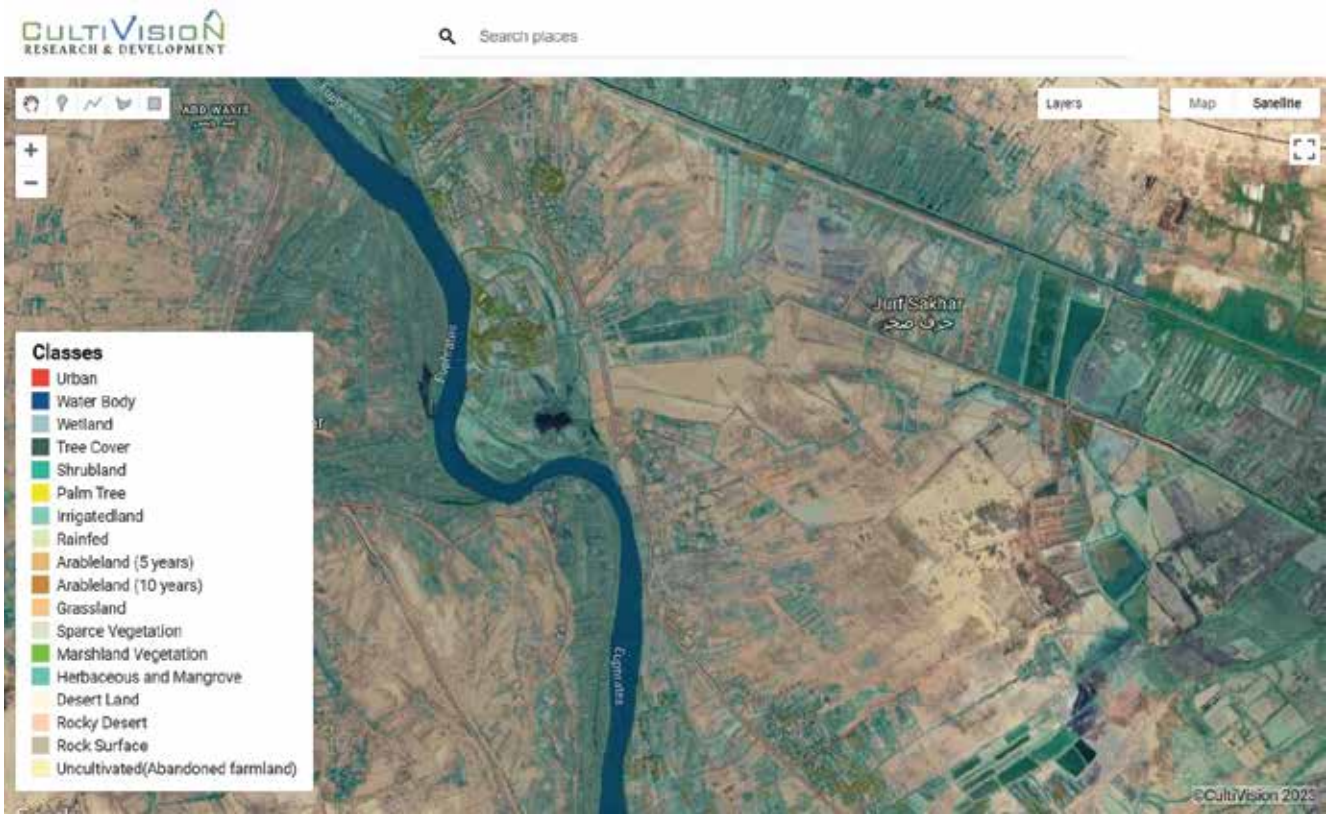


Appendix. Figure-Q

LULC class Water Body, Wetland, Palm Tree, Irrigatedland, Rainfed Arableland (5 years), Arableland (10 years), Grassland, Desert Land, Surface, Uncultivated (Abandoned farmland)

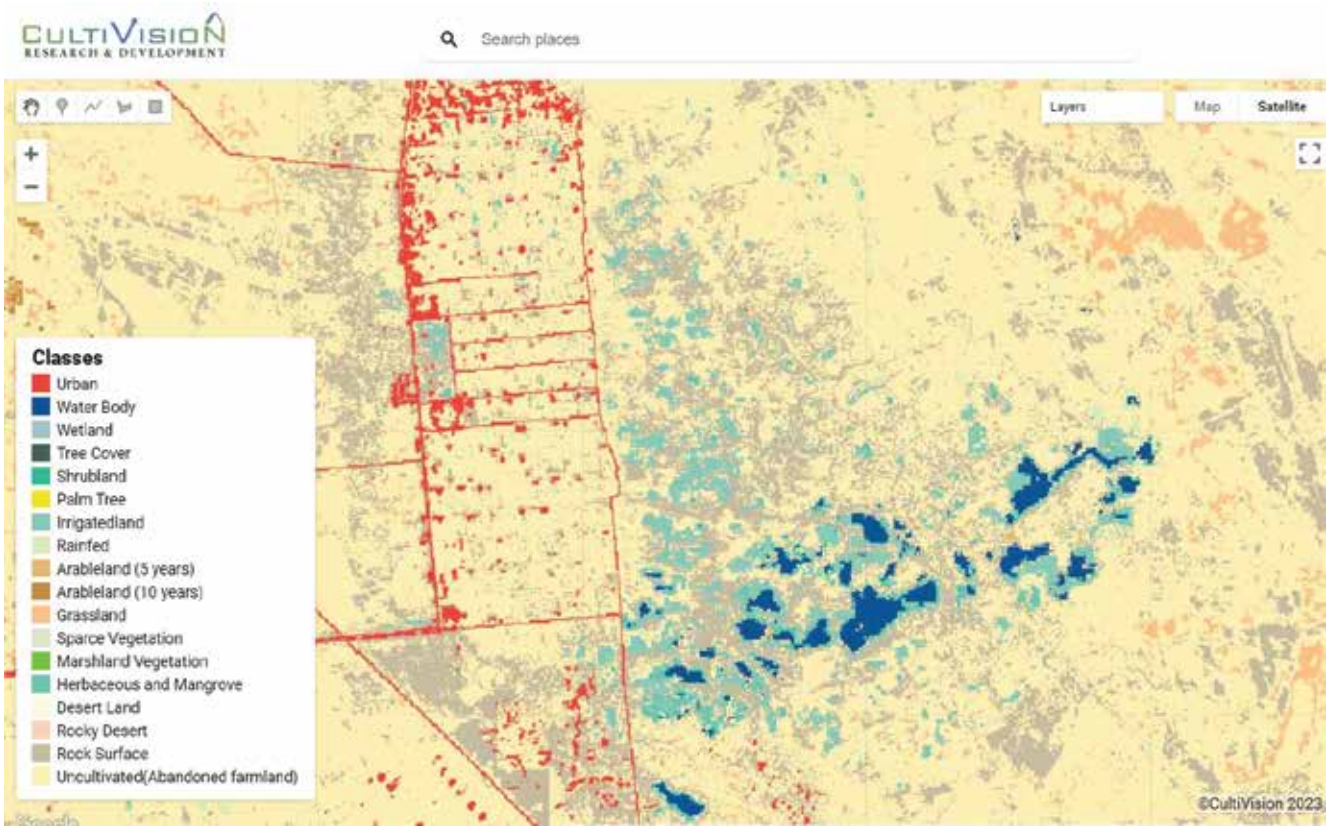
Appendix. Figure-R

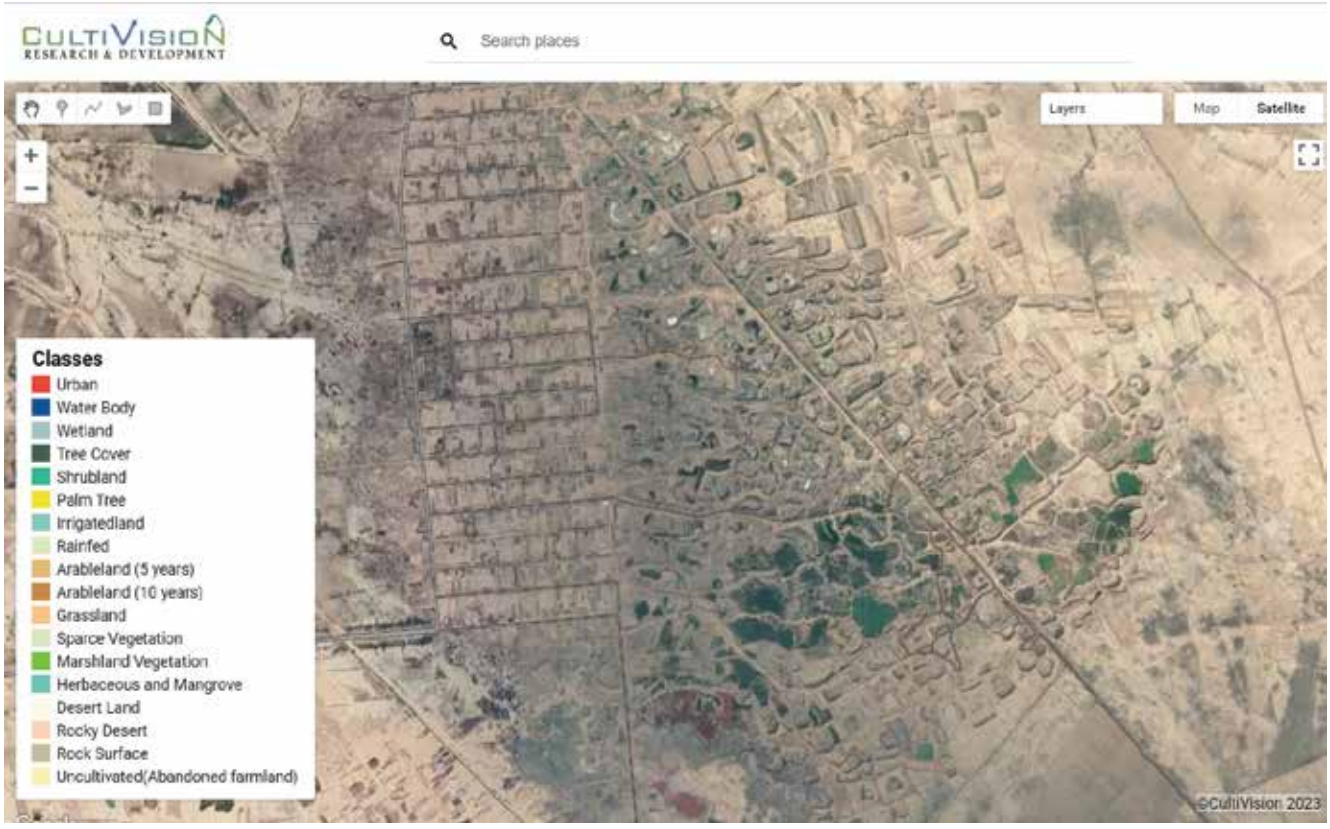
LULC class, Water Body, Wetland, Palm Tree, Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Uncultivated (Abandoned farmland)



Appendix. Figure-S

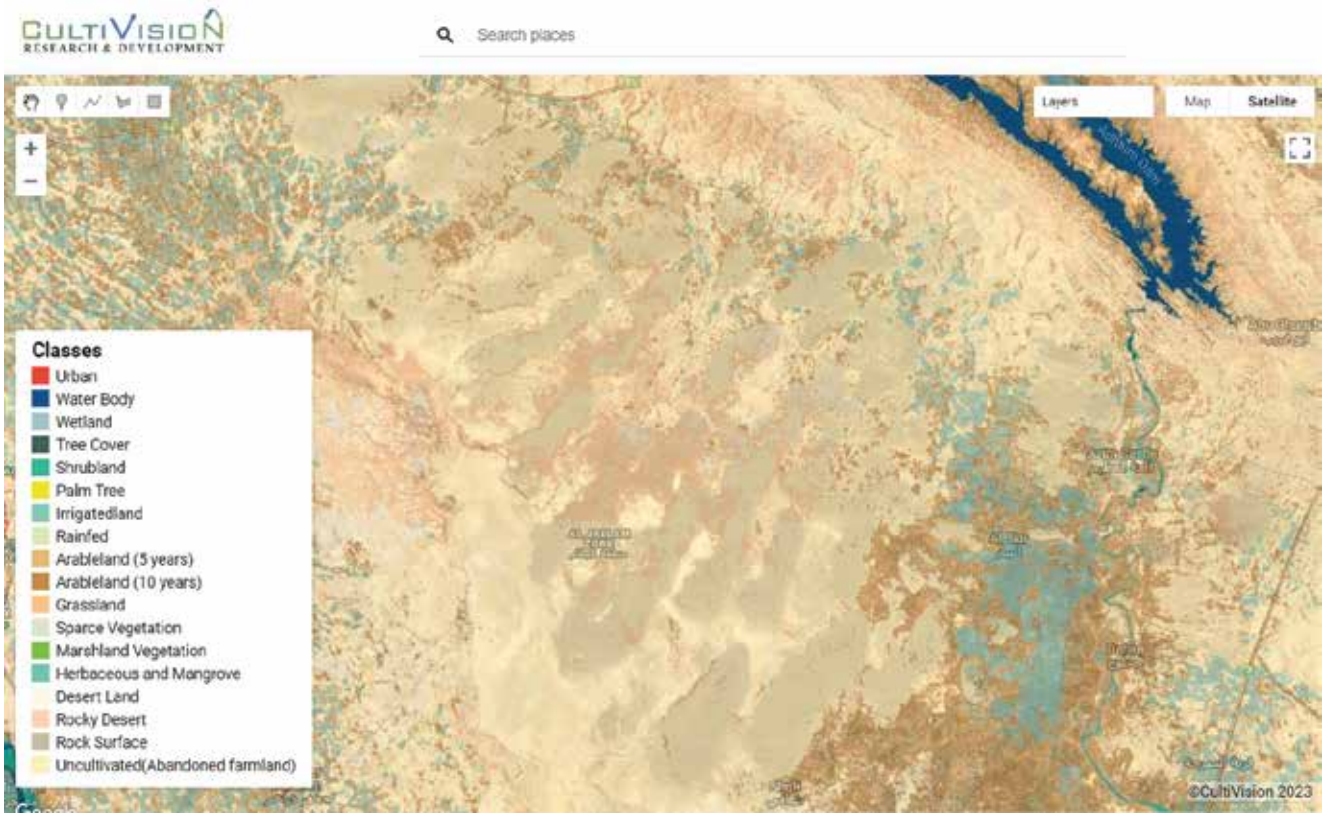
LULC class, Urban,Water Body , Sparse Vegetation, Marshland Vegetation, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland)

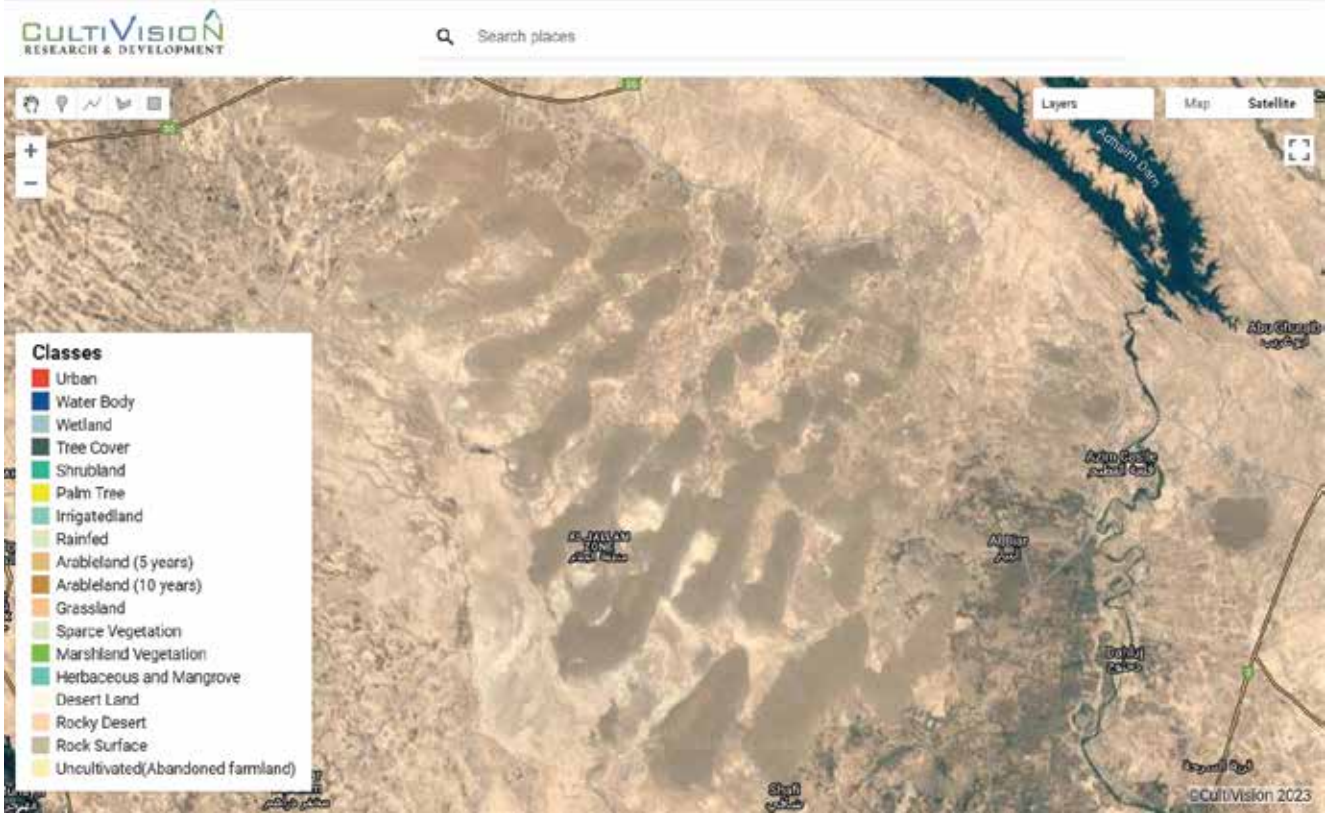




Appendix. Figure-T

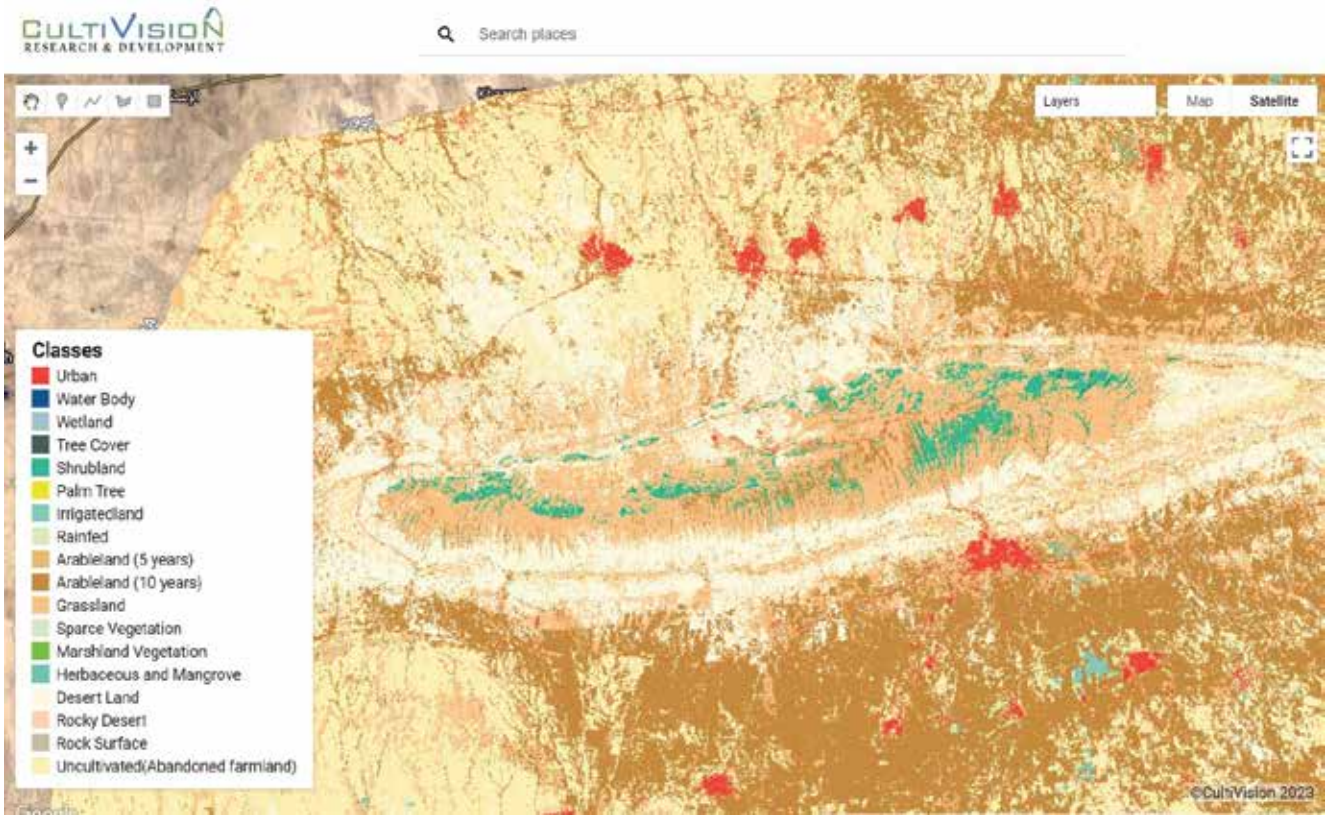
LULC class, Water Body, Wetland ,Irrigatedland, Arableland (5 years), Arableland (10 years), Grassland, Sparse Vegetation, Desert Land, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland)





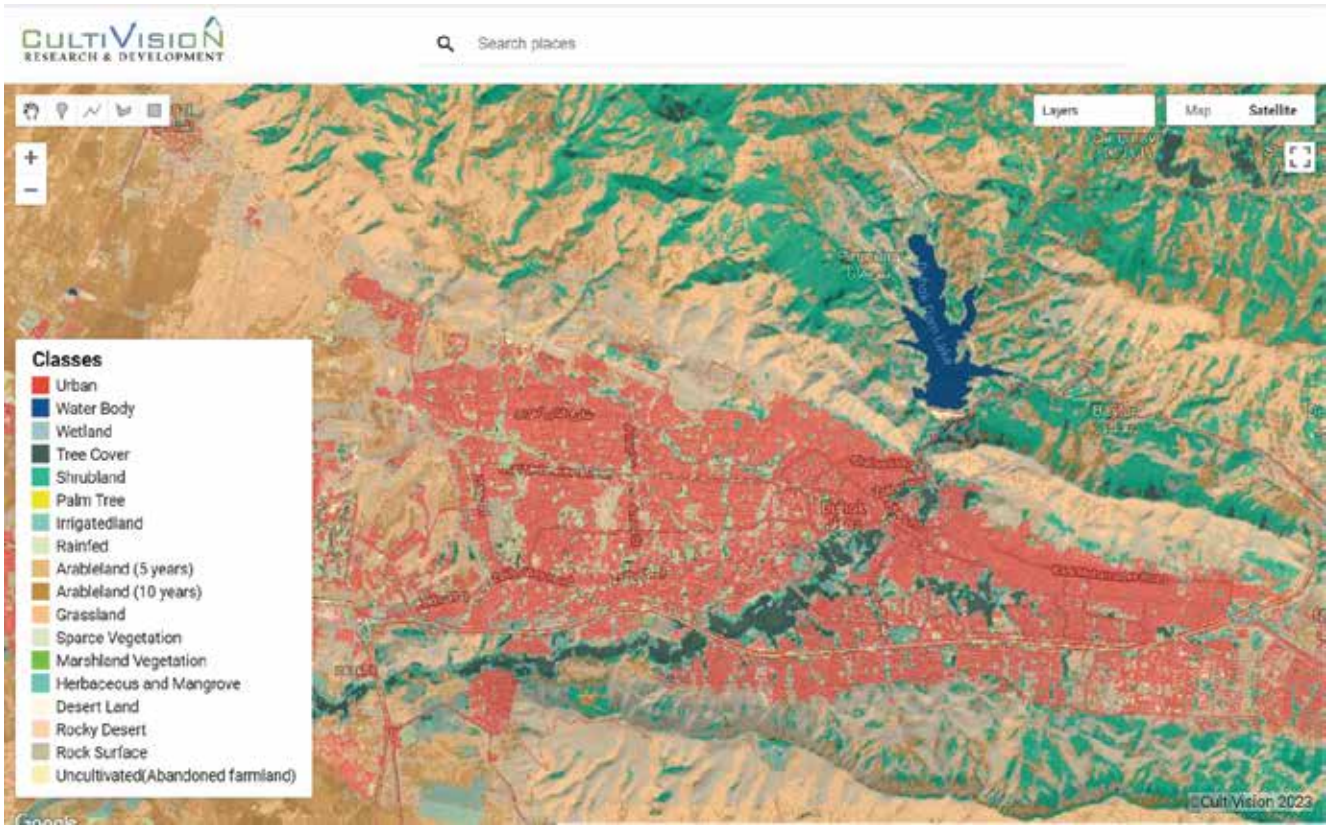
Appendix. Figure-U

LULC class, Urban, Open forest/ Shrubland, , Arableland (5 years), Arableland (10 years), Grassland, Desert Land,



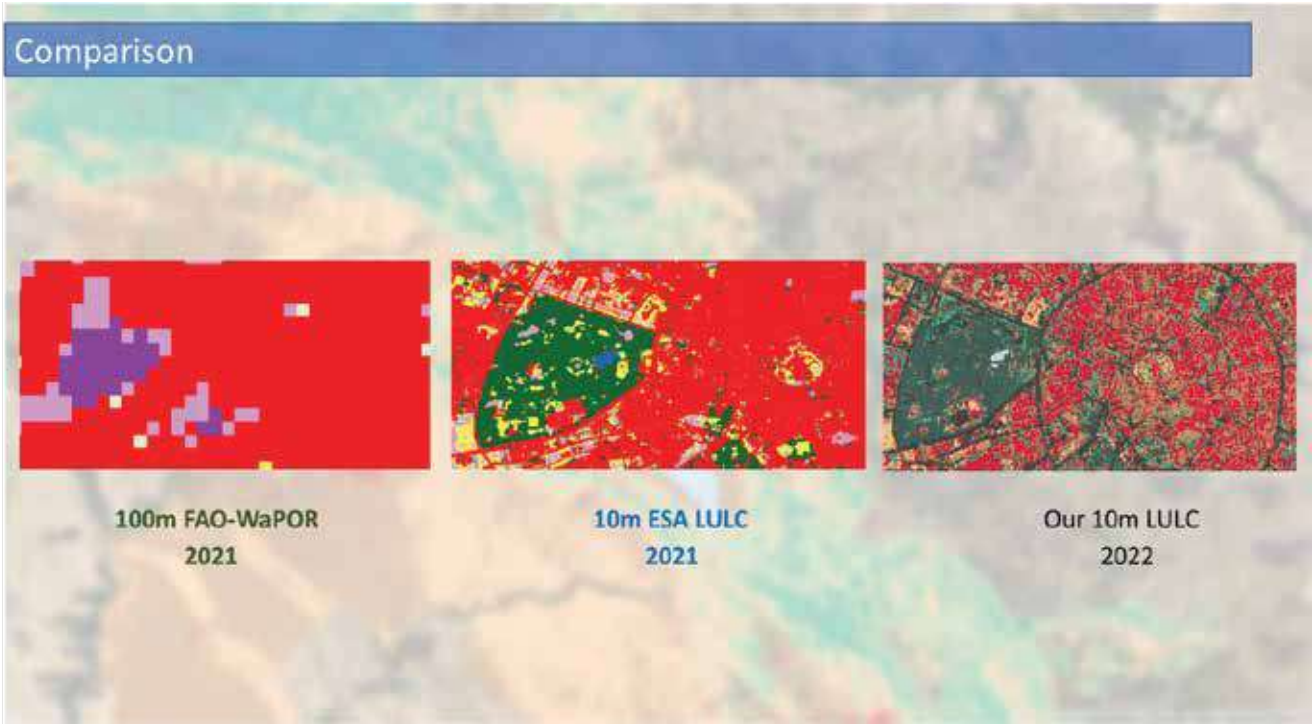
Appendix. Figure-V

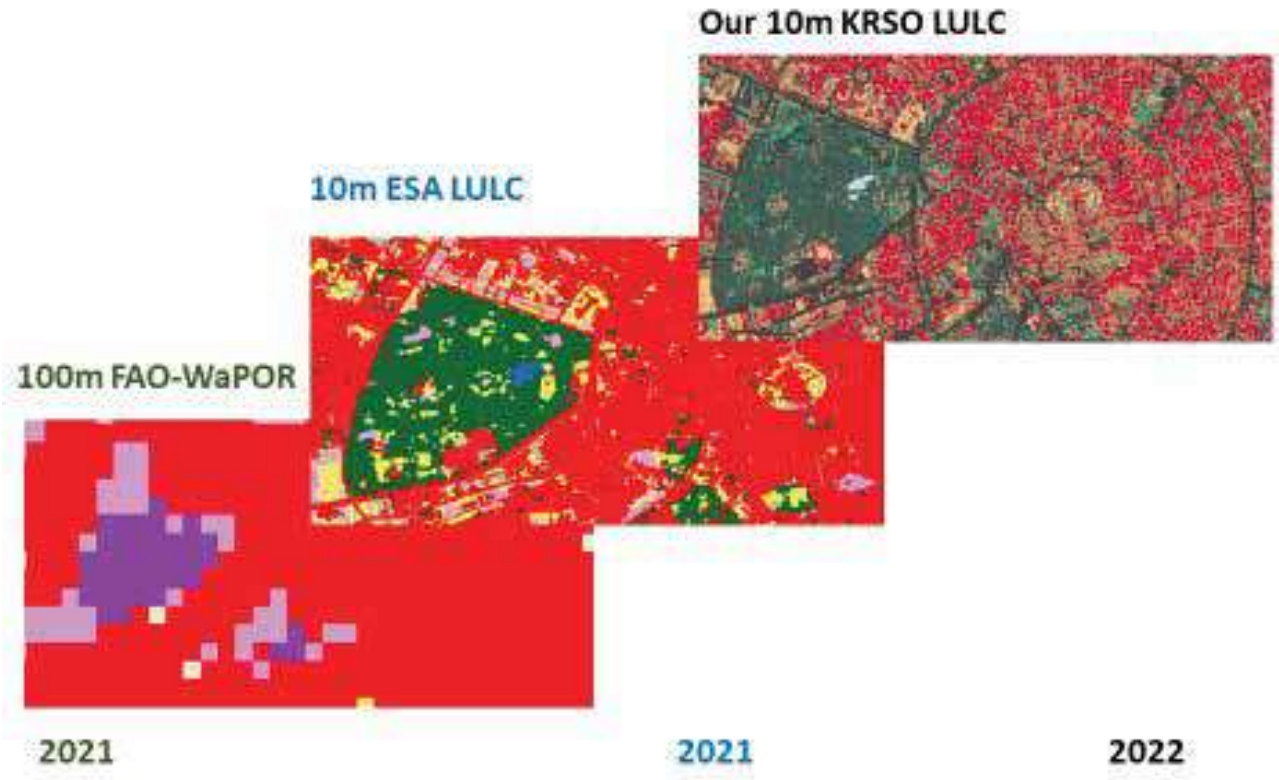
LULC class, Urban, Water Body, Wetland, Dense Forest Open forest/ Shrubland, ,Irrigatedland, Rainfed Arableland (5 years), Arableland (10 years), Grassland, Rocky Desert, Rock Surface, Uncultivated (Abandoned farmland).



6.3. Appendix C.

Comparison of the accuracy of different data sources (WaPOR, ESA and 10m our source data) for LULC classes.





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