An-Najah National University

Faculty of Graduate Studies

MONITORING AGRICULTURAL AND VEGETATION COVER OF THE WEST BANK, PALESTINE USING REMOTE SENSING AND GIS TECHNOLOGY

By

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Dedication

From the bottom of my heart, I thank everyone who has supported me during this journey. I am especially grateful to my thesis supervisor, Dr. Ahmed Ghodieh, for offering invaluable guidance, steady support, and thoughtful advice at every phase of this study. To my mother, whose love, prayers, and constant presence provided me with great comfort, and to my father, whose strength, encouragement, and faith in me have always inspired. I owe you both more than words can convey. My sincere thanks go to my dear brothers and sisters for their encouragement and constant support throughout my academic path. I want to express my gratitude to my beloved husband, whose patience, love, and unwavering support have made a profound difference as we share this partnership. Awaiting the arrival of my unborn daughter fills me with joy, hope, and motivation already. She has brightened my life even before coming into the world. To my second family, my husband's loved ones, I truly appreciate your kindness, love, and support, which have made me feel cared for and at home. Lastly, I thank all my friends and everyone who has shown love, encouragement, and support during this chapter of my life. Your presence has made this experience both meaningful and fulfilling.

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Eng. Maha Musameh

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

MONITORING AGRICULTURAL AND VEGETATION COVER OF THE WEST BANK, PALESTINE USING REMOTE SENSING AND GIS TECHNOLOGY

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **Maha Jamil Abdel-Karim Musameh**

Signature: 

Date: **27/10/2025**

Table of Contents

List of Figures

List of Tables

List of Appendices

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Abstract

Analyzing land cover and land use changes in the West Bank with the help of Geographic Information Systems (GIS) and Remote Sensing (RS) is important for recording the area development over time, especially under the conditions of the Israeli occupation restrictions. This research refers to satellite data from 2001 and 2021 to detect land cover changes with a close look at vegetation and agricultural areas.

The objective is to provide insights that ministries and specialists could utilize. The research area is split into three major parts: the mountainous highlands, the Jordan Valley, and the coastal plain. The analysis was run on the satellite images from Landsat 7 (ETM+) and Landsat 8 (OLI), taken on June 25, 2001, and June 24, 2021, respectively. Fourteen land cover classes were established to describe the study area, with the rocky terrain and the quarries merged because of their similar spectral features.

A supervised classification by means of the maximum likelihood method obtained a high accuracy level- 90.5% for 2001 and 94% for 2021. The Kappa coefficients were 83.13% and 86.66%, showing that the classifications were reliable. The results indicate that no significant increment of agricultural lands has been recorded between 2001 and 2021.

Nevertheless, the Ministry of Local Government data reveal that some areas might be irrigated and cultivated if they are classified as agricultural lands. The average Normalized Difference Vegetation Index (NDVI) for 2021 was 0.11, which is close to that of 2001. These findings show the necessity of the ongoing observation of land cover and use in the West Bank to ensure the protection of vegetation, the recovery of soil, and the prevention of the agricultural being taken by the Israelis.

Keywords: West Bank, Palestine, GIS, RS, LU/LC, vegetation cover, NDVI.

Chapter One

Introduction

Studying land cover, land use, and vegetation changes through satellite images is a vital practice. This method is very efficient as it offers high spatial data of land surface features for any time and place (Haj et al., 2023). Climate change is the main driver of these changes. However, annual rainfall still plays an important role in determining land use and vegetation cover (Lambin et al., 2003). By utilizing Geographic Information Systems (GIS) and Remote Sensing (RS), this study is intended to evaluate land cover and land use in the West Bank through the comparison of changes between 2001 and 2021, with a focus on vegetation and agricultural areas.

The first aim of this thesis work is to measure the amount of vegetation cover and make a point that, despite the increase in urban areas, vegetation has not grown significantly during the last twenty years. The research also serves as a vehicle to reach decision-makers and stakeholders with the message of the necessity of vegetation conservation and expansion. It considers examining agricultural and non-agricultural land use and directing the efforts towards land reclamation and cultivation.

There are numerous publications that have been conducted utilizing GIS and RS, including satellite imagery, for the investigation of land use and land cover changes. (Ghodieh A. , 2019)acquired these methods to scrutinize land use patterns, while (Abu Saa, 2014) studied urban spread in the West Bank during the years 1997-2016, and he achieved high accuracy of classification with high-resolution images. (Hamada, 2010) employed supervised classification to investigate land cover and use changes in Tulkarm Governorate between 2005 and 2011. Another research in Nablus Governorate studied the impact of the terrain on the vegetation cover using the 2000 satellite image, and the results demonstrated how landforms affect land cover.

To sum up, land use and land cover research have covered a wide selection of topics, such as urbanization, topography, and climate factors. These kinds of research are paramount for grasping the evolution of land cover and being a stepping stone for strategic planning in soil conservation, land reclamation, and environmental management.

1.1 Materials and Methods

1.1.1 Description of the study area

The West Bank is a region in southwest Asia, occupying the southern part of the eastern coast of the Mediterranean Sea. It is located between longitudes 34°53' and 35°31 "east of Greenwich and latitudes 31°20' and 32°38" north of the equator. The West Bank along with the Palestinian part of the Dead Sea covers an area of 5,860 km^2, with a length of 130 km and a width of 40 to 65 km (Ghodieh, 2023)

The area under study encompasses the four topographic and climatic zones. They are the Jordan Valley and the Jordan River, which together constitute an area of 400 km^2 with an elevation ranging from 0 m at sea level to 400 m below sea level. The eastern slopes of the Dead Sea extend over an area of 1,500 km^2 with an elevation ranging from 0 meters at sea level to 500 m above sea level. The mountainous highlands span an area of 3,500 km^2, with the highest point reaching 1,020 m above sea level and the lowest point at 500 m above sea level. The last zone is the coastal zone that covers an area of 400 km^2 and its elevation varies from 0 to 500 m above sea level (Alagha, 2003).

The study area is well-equipped with a diverse range of climatic elements. The coastal region has a Mediterranean-type climate. The West Bank climate varies from rainy winters to dry summers; therefore, the overall climate is considered moderate. Usually, winter lasts from November to the beginning of April, with 40 to 60 days of rain per year. Summer goes from April to the end of October, and during this period, there might be khamasin winds (Al-Dabbagh, 1991). In the summer, temperatures are quite pleasant in the highlands while the nights are generally cool. During winter, the maximum temperatures fluctuate between 10 and 15°C, and the minimum temperatures change from 5 to 8°C. The climate is Mediterranean (Al-Dabbagh, 1991).

While temperatures in the Jordan Valley and eastern slope regions are 20–23°C higher than in the coastal and mountainous regions, the climate is hot and dry (Ghodieh , 2019). As for the precipitation, the coastal and mountainous areas can expect between 500 and 700 mm of rain yearly, whereas the eastern slopes and the Jordan Valley only receive 100 to 350 mm of rain per year (Ghodieh, 2023).

The soils found in the West Bank are varied. The coastal area has several soil types such as sandy, clayey, and sandy loam, which are all mostly good for agriculture and are characterized by dense vegetation and high population density. The mountainous highlands are composed of red, basalt, and brown soils, which are good soils for agriculture and where olives and almonds are grown and the region is characterized by moderate vegetation cover (Mushtaha & Al-Louh, 2015). The soil in the Jordan Valley and eastern slopes is of a loamy nature, and the vegetation is scattered in the valleys and alluvial plains. Agriculture in this area is mainly done through the use of groundwater, as the land is not suitable for rain-fed farming (Ghodieh , 2023).

1.2 Research Problem

In the last decade, the West Bank has experienced major transition in both land use and land cover as a result of changes in natural environment and human activities. Rapid urban expansion, intensification in agriculture, infrastructure development, and the combination of land confiscation with political and military measures have all contributed to the transformation of the West Bank's landscapes jointly. These changes mean the region to face the various challenges on the environmental, social and economic fronts, one of the effects they cause being the decrease in land fertility and habitat fragmentation.

A number of research works have found LU/LC changes in the West Bank. However, most of them have been limited in their scope and have only focused on specific governorates while using datasets that neither involve long enough periods nor sufficient trends. Furthermore, the hilly areas and sometimes difficult-to-reach locations in the district make it hard to carry out field-based surveys that then create challenges for obtaining reliable, up-to-date, and accurate spatial information. The absence of a comprehensive and methodologically sound investigation of LU/LC changes at the regional level makes it almost impossible for planners, policymakers, and environmental managers to devise renovation strategies for land use management that are not only effective but also sustainable.

The West Bank landscape is different from those of other areas as it is primarily the result of not only the environmental and economic aspects but also the consecutive political limitations that worsen the problem. Patterns of land use are mainly dictated by land confiscation, settlement expansion, and headway restriction that usually leads to quicker disappearance of agricultural land and changes the spatial distribution of vegetation cover. Lack of a centralized, continuously updated spatial database for monitoring changes in real time makes it harder for different institutions to be aware of and respond to such changes proactively.

Considering these difficulties, an investigation done with the help of advanced geospatial techniques like GIS and remote sensing, aiming at accurate, comparable, and long-term LU/LC datasets, is highly needed. The present study is a reliable source of evidence for measuring vegetation change, pointing out the major factors causing such changes, and supporting sustainable land use policies in the West Bank through informing.

1.3 Importance of the Study

The importance of this research is reflected in the measurement of Land Use and Land Cover (LU/LC) changes in the West Bank that has not been figured out and thoroughly investigated previously. Using up-to-date methods in GIS and remote sensing (RS), it becomes crucial to comprehend the changes in LU/LC for:

a) Forecasting changes that will come,

b) Evaluating the status of nature and resources,

c) Preventing the occurrence of risky situations,

d) Offering an ample guidance of the most efficient land management practices and decision-making.

1.4 Objectives

1. To identify the factors affecting land use and land cover in the West Bank.
2. To analyse changes in land use and land cover using remote sensing data and Geographic Information Systems (GIS).
3. To assess changes in vegetation cover across a 20-year period (2001 and 2021).
4. To investigate challenges and problems impacting agricultural lands in the study area.

1.5 Methodology

The research used spatial analysis methods to unravel its puzzles. It employed Geographic Information Systems (GIS) and remote sensing (RS) to explore changes in natural and agricultural land cover, land use, and vegetation in the West Bank.

1.5.1 Data Collection

- Landsat 8 and Landsat 7 ETM satellite images, with the data being sourced from the USGS website.
- The data were manipulated using ArcMap 10.8, which gave the facility for the detailed maps to be created and produced.
- To better the precision of the land cover classifications, high-resolution photos from Google Earth were put in and then checked with the data from the Ministry of Local Government.

1.6 Literature Review

Understanding changes in land use and land cover (LU/LC) in the West Bank is not possible without first reviewing the existing research. RS and GIS have been employed widely at the regional and global levels to monitor, categorize, and analyze the changes in vegetation, agriculture, and urbanization resulting from these studies. They form a very significant source of methods, historical data, and benchmarking that underpins the stages and results of the study.

Abu Kubi (2003) examined LU/LC changes in the Jordan Valley using LANDSAT imagery. This study used remote sensing techniques to examine land use and land cover changes in the Jordan Valley. It helps maintain abundant natural resources and expand agricultural potential. Its goal was to use two classification techniques (supervised and unsupervised) and spectral mixture analysis to enable various classification methods to map (LU/ LC) utilizing remote sensing techniques. Moreover, the study aims to assess the magnitude of vegetation cover changes using various temporal data. In this study, two different types of data were used: remote sensing data and a collection of supplementary GIS data from the geographical database of the Applied Research Institute - Jerusalem (ARIJ). The findings demonstrated that a spectral mixture analysis classification method-based automatic classification is a reliable indicator for determining the extent and kind of (LU/ LC) in the Jordan Valley. The Jordan Valley has experienced significant growth in vegetation cover over the past decade.

On the other hand, the yearly rainfall rate decreased, leading to a continued decline in the amount of water in the aquifers. The findings showed that over the sixteenth year, the vegetation cover had undergone significant alteration. The Jordan Valley's extraordinary sensitivity to seasonal effects and changes in agricultural techniques during the preceding sixteen years are two causes of this phenomenon.

Sholi (2008) investigated land cover patterns in the Nablus Governorate using digital Spot satellite imagery. To investigate the patterns of variation in vegetation cover in the Nablus governorate using remote sensing technologies, the study examined land cover in the Nablus region. The study employed an analytical descriptive technique. A digital satellite image of the spot satellite served as the basis for the study. As there were 14 classifications, 10 of them (field crops, vegetables, greenhouses, dense, medium, and low-density olives, citrus fruits, forests, grass, natural plants, and quarries) were combined to form the directed classification. The accuracy was 75.3%.

The first study demonstrated the ability of remote sensing to create accurate land-cover maps. It also showed how remote sensing can be used to track land-use changes by obtaining photos and classifying them based on the sources. As the study area had diverse terrain consisting of both flat and hilly areas, a variety of data points, including those from field surveys and olive plantations, were considered for the dominant vegetation pattern.

Hamada (2010) analyzed the impact of topographic features on vegetation cover in the Nablus Governorate by using a combination of GIS and RS techniques. The study examined the effects of topographic features of the Nablus Governorate on the vegetation cover of the region. The research applied the analytical method together with remote sensing and geographic information systems (GIS). The main goal of this research was to identify the topographical features and patterns of plant cover in the study area and the effects of soil and different slope types on the vegetative cover. The research findings indicated that the degree and extent of the slope, as well as the altitude, influence the vegetation cover. This is because there is an inverse relationship between altitude above sea level and slope, and thus the northern slope has more vegetation cover compared to the southern slope. Overall, 72% of the land in Nablus was covered by vegetation. The total percentage of the other land covers, rocks, construction areas, quarries, and construction areas in the Nablus region amounted to 28%, and the overall accuracy of the classification was 88%, which is quite high.

Abu Saa (2014) employed GIS technology to study land use and cover changes in the Tulkarm Governorate from 2005 to 2011. The study, instead, used an analytical descriptive method. It describes the variation in land uses and utilizes GIS to analyze quantitative and descriptive data. The finding of the research was that the use of geographic information systems technology to generate land use maps at a high level of accuracy shows the extent of each use. The results disclosed changes in land cover and use in the Tulkarm Governorate between 2005 and 2011, using geographic information systems technology. The internal roads were found to be the most exploited area, and the governorate's predominant pattern is one of agricultural use because it is regarded as an agricultural area.

Mondal, et al. (2018) elaborated on the classification of images and how they are useful to mapping land-use/land-cover (LU/ LC) in Sagar Island, India. The main objective of the study was to produce the land use and land cover map through the use of geospatial techniques and to accurately assess whether the use of auxiliary data could bring about a better land use classification. The authors used unsupervised classification and change detection methods for a 40-year research period (1975-2015). In 1975, the research area was divided into 11 categories: water body, cropland, agricultural (mono-crop) land, settlement with homestead orchard, sandbar, mud flat, aquaculture, mangrove vegetation, mangrove swamp, and wetlands. In 2015, the classification was expanded to 13 sections adding forest and non-forest areas. The classification accuracy was 79.53%, and the kappa coefficient (K) was 0.7465. This enhancement of the classification accuracy of LU/LC Maps is very significant in terms of their possible use for land change modeling in the area and, thus, it supports the statement that geospatial technologies play a vital role in land use and land cover mapping.

The research by Ghodieh (2019) aimed to quantify urban built-up areas and identify the changes between 1997 and 2016 in the West Bank by using multi-temporal aerial and satellite images. One of the primary goals of the research was to investigate urban and built-up areas and find changes during the period 1997-2016 under complex geopolitical conditions. This work also included an assessment of different land uses in the research area such as agricultural and non-agricultural land uses. The study utilized a supervised image classification approach (maximum likelihood classifier) for land use and land cover identification in the study area. In order to discover urban built-up areas, the study created 10 classes from two Landsat images, which were then grouped into three categories: built-up areas, agricultural lands, and plowed lands. The agricultural lands were subdivided into three classes: vegetables and crops, olives and other trees, and plowed lands. Non-agricultural lands are classified into six categories: bare rocks, bare badlands, forests and bushes, untreated grasslands, and areas with rocks and natural vegetation. The classification accuracy for 1997 was 0.05. The findings for 2016 were 87.7% and 91.3%, respectively, which is of high accuracy. The Kappa coefficient was 86% and 90%, respectively. The results showed urban areas increasing at the cost of agricultural lands. Also, they revealed Israeli limitations on Palestinians in terms of building, especially in Area C, which makes up 61% of the West Bank.

Tewabe & Adametie (2020) analyzed land use/land cover (LU/LC) changes in the Tana River area, northwest Ethiopia, over the last 30 years until 2020. The research site was classified into six categories: 'water bodies, forests, grasslands, woodlands, cultivated lands, and residential lands'. Both descriptive and analytical methods were applied. The research findings revealed that agricultural and residential areas were expanding, whereas forests, bushes, and pastures were declining. The study also showed that the conversion of forests, bushes, and pastures into agricultural and residential areas might cause such problems as changes in water flow, soil degradation, and alterations in the hydrological regime of the Tana River. Ultimately, this has far-reaching effects on sustainable resource management and community living quality.

The study by Liaqat et al. (2021)explored how spatial and temporal changes in land cover affected land use (LU/ LC) and groundwater levels in the Al Ain Region, UAE, during 2006-2016. A descriptive methodology was implemented. The research area was divided into six parts, and land use/land cover (LU/ LC) was the main aspect. These were agricultural areas, farms, oases, gardens, stadiums, urban areas, sandy areas, lakes, and mixed urban and sandy areas. Agriculture/farms/oases.

The urban areas grew from 42,560 hectares to 45,950 hectares (7.38%) and from 8,150 hectares to 9,105 hectares (10.49%) in 2006-2016, respectively. The corresponding water consumption was increased by 9.56% and 22.22%, respectively. At the same time, the natural sandy area was decreased by 8.10%. As groundwater is the main source of water for agriculture in this area, spatial maps also show an average rate of decrease in groundwater depth by 40.44% over the last ten years due to the expansion of urban and agricultural areas.

Chaitanya & Kanak (2021) initiated a project that revolved around the collection of information through the assembling of maps and the detection of changes in land use/land cover (LU/ LC) for Policy Planning and the efficient management of the Environment, Land Use, and the hydrological system in the catchment area of Pangari (MS), India. The central point of the research was to identify (LU/ LC) in the given region for the years 2008, 2014, and 2017 and to prepare NDVI and (LU/ LC) maps. The four categories of land in these maps are classified as: agriculture, built-up areas, wasteland, and water bodies.

The outcomes of the NDVI maps revealed that the vegetation analysis ranges were 0.53, 0.066, 0.35, 0.11, 0.53, and 0.66 for the years 2008, 2014, and 2017, respectively. The study becomes essential because the research area is a village, and farming is the primary economic source. Besides, it is figured out that due to the number of people, the built-up lands are growing. On the contrary, these agricultural lands are declining as a result of environmental factors and human activities.

Asmar et al. (2021) studied the influence of land use and land cover changes on the volume of potential surface runoff in the Palestinian watershed of the Nablus Mountains. The shortage of freshwater is the result of the Israeli occupation's actions that regulate groundwater resources and some other pragmatic factors, such as land-use and land-cover shifts. The shortcoming of fresh water is due to the Israeli occupation's ways of regulating groundwater resources and practical considerations such as (LU/ LC) changes. Changes in (LU/ LC) are detected by GIS and remote sensing software.

GIS techniques and remote sensing data (Landsat 5, 7, and 8 images of 1984, 2000, and 2016, respectively) were utilized. Seven (LU/ LC) classes were recognized by the GIS10.5 supervised classification method. Urban, wasteland, and agricultural lands increased their areas by 116%, 22%, and 8%, respectively, from 1984 to 2016, according to the study's results. On the other hand, rangeland and forest areas shrank by 14% and

22%, respectively. The annual runoff's potential was altered by (LU/ LC) changes of about 7.8 MCM, thus leading to a significant increase of 5.8% between 1984 and 2016.

Haj et al. (2023) explored Morocco's land uses and land cover through several temporary remote sensing data. A set of Landsat images, including Landsat 7 (ETM+), Landsat 5 (TM), and Landsat 8 (OLI), taken during the period 2000-2020, were used to monitor changes in land cover as the main objective of the study was to investigate changes in the LULC of the sub-basin in Morocco and to monitor the vegetation condition that is influenced by precipitation and drought situation in the area. The study delineated the area into five classes: (1) water, (2) agriculture, (3) forest, (4) bare land, and (5) urban regions. Throughout the last twenty years, several changes have happened. The results of the supervised classification show that the vegetation cover was drastically reduced by 5%, and consequently, the expansion of arid lands and the urban environment has been witnessed during this period. The classification accuracy was verified through the confusion matrix which is used to find the margin of error between the classified images and the reference images with point control derived from the field survey.

Ghodieh (2024) investigated the impact of changes in the Normalized Difference Vegetation Index (NDVI) on Land Surface Temperature (LST) using satellite imagery in the West Bank. The research was directed towards spatial analysis of LST and its relationship with NDVI or land use/land cover in the study area as well as the influence of land cover types on NDVI and LST values. Data from Landsat 5 (TM) in 2001 and Landsat 8 (OLI) in 2021 were utilized. The findings revealed that the NDVI in 2001 was notably lower than in 2021, with an average Normalised Difference Vegetation Index (NDVI) of 0.25 for 2001, as compared to 0.32 for 2021. Land surface temperatures averaged 29.85°C in 2001 and 26.98°C in 2021, respectively, thus indicating that NDVI has an effect on temperature decrease in the West Bank.

Summarizing, GIS and remote sensing technologies have been proven in previous studies to be useful tools in detecting and analyzing LU/LC changes, producing highly accurate classifications, and monitoring vegetation cover in various geographical contexts. These research works offer significant methodological insights that are relevant to the West Bank. Nevertheless, the majority of them have been constrained either geographically or temporally and have only considered certain aspects of land cover change in specific governorates over short periods. Moreover, very few have combined multi-temporal datasets spanning twenty years or have systematically evaluated LU/LC changes concerning both environmental and political factors in the West Bank. This study fills these gaps by merging multi-temporal satellite images from 2001 and 2021 with sophisticated GIS and remote sensing techniques to yield a comprehensive, high-accuracy assessment of vegetation cover and LU/LC changes in the whole West Bank.

This study establishes a new research framework that focuses on spatial patterns and temporal trends. By combining (NDVI) analysis, supervised classification, and validation against auxiliary datasets, it also considers the influence of political factors, such as land expropriation, on environmental changes. This research enhances the understanding of LU/LC and furnishes the region with guidances for the sustainable land management and policy-making processes.

Chapter Two

Theoretical framework

2.1 Location of the study area

The West Bank lies between latitudes 31°20′ and 32°38′ north and longitudes 34°53′ and 35°31′ east, covering the central-eastern part of Palestine with a land area of about 5,860 km² (Ghodieh, 2019). The east side of the area is formed by the Jordan River and the Dead Sea, the west by the coastal plains, the north by Marj Bin Amer, and the south by the northern edge of the Negev Desert (Mushtaha & Al-Louh, 2015).

Figure 1

The study area

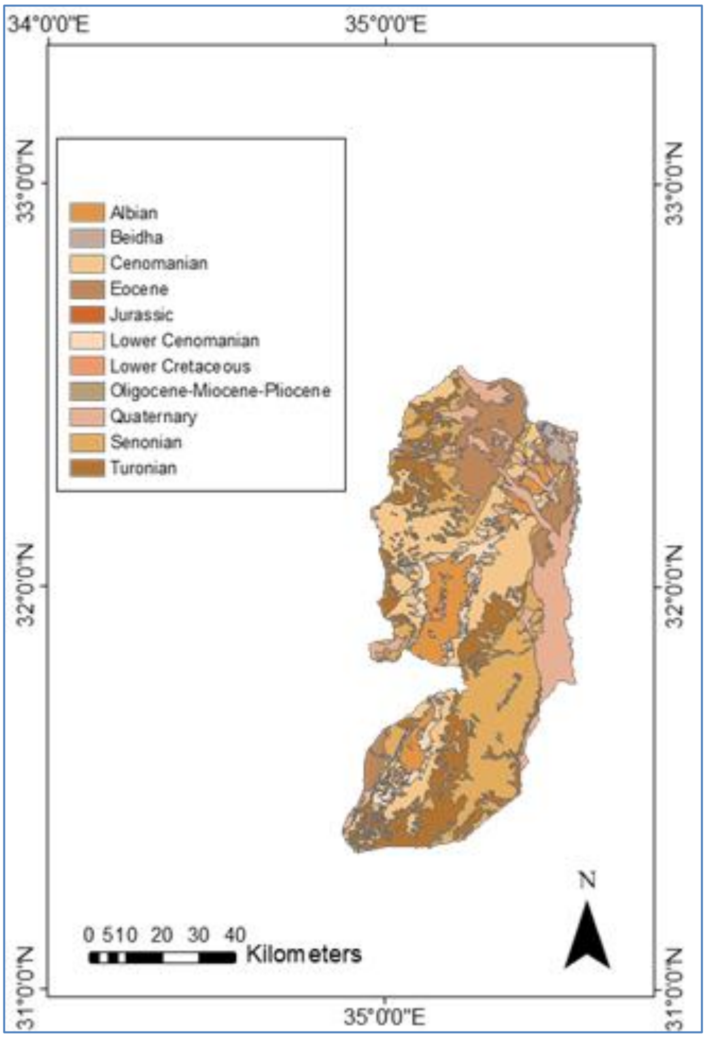
Resource: (Ghodieh, 2024).

2.2 Geological structure

Geological structure is the composition of the Earth's crust made of different rock formations changed by nature and various other factors. Palestine has very interesting geological features for which it is distinguished, such as the unique rock formations that are present not only in the country but also along the coastal plain. The central part is carbonate sedimentary rocks dominated while the coastal plain has clayey and sandy sedimentary rocks. The geological history of Palestine goes back to the Precambrian era and it continues through the Paleozoic era and stretches to the modern geological period (Mushtaha & Al-Louh, 2015).

Figure 2

Geological Map of the West Bank



Source: https://geomolg.ps/L5/index.html?viewer=A3.V1.

1. Paleozoic Period

The Paleozoic era goes back around 375 million years and the rocks of this era are found as sandstone in southern Palestine. The first life Cambrian period formations are dated to this era, and one of these formations is the Nubian Sandstone that is on top of the igneous rock masses. In addition to that, there are rocks made of a mixture of clay and sandstone that are up to 147 meters in thickness in southern Palestine. These formations vary in thickness of their rock layers, colors, and size of their sediments. The Permian formations are under the younger rock layers and their thickness varies from 370 to 480 meters. Their main rocks are limestone, sandstone, and clay (Mushtaha & Al-Louh, 2015).

2. Mesozoic Period

Uplift and subsidence processes took place in Palestine during this period. The result was the formation of a convex geological structure that covered most of the central part of Palestine and was overlain by successive layers of sandstone and limestone. This formation goes back 225 million years (Abed & Al-Washahi , 1999). The formation includes three geological eras (Abed & Al-Washahi , 1999):

The Triassic Period: The rocks of this period are found in southern Palestine, mainly in the Al-Ruman and Al-Aref regions, and the eastern shore of the Dead Sea. They are around 1,000 meters in thickness and consist of clay and limestone.

The Jurassic Period: The rocks of this period lie above the Triassic rocks in southern Palestine, but the larger area that constitutes the rest of Palestine is covered by multicolored clay rocks and is dominated by these.

The Cretaceous Period: Rocks of this period are spread over a vast area of Palestine, particularly in the north and center. Its formations are made up of limestone and sandstone.

3. Tertiary Period

The era was marked by mountain-building processes that resulted in the creation of mountains and volcanoes. These rocks are present all over the land of Palestine, such as the coastal plain and the northern area. The rock formations of this country are in the south and the center of Palestine, and also the Dead Sea Group in the southeast of Palestine. Among its formations is the Pliocene Formation, which is dominated by Cretaceous limestone and yellowish limestone. The Dead Sea Group in southern and eastern Palestine and the coastal plain is dominated by the Karkar Formation, sandstone, and some red clay deposits (Abed & Al-Washahi , 1999).

4. Quaternary Geological Period

This is also known as the era of significant climate change, during which rocks were subjected to erosion and sedimentation, and large quantities of debris were transported to distant areas. Its rock formations consist of gravel, sand, and clay. This period spans approximately 2 to 3 million years, encompassing both wet and dry climatic phases. This led to the accumulation of rock formations in the Negev, coastal plains, river valleys, and lakes. As a result of the Mediterranean Sea's closure to the west, the formation of Karkar rocks and red soil occurred (Abed & Al-Washahi , 1999).

5. Holocene geological time

It is called sediments, and its age is about 11 thousand years. It includes quicksand, beach, and clay deposits. In the coastal plain, there are dunes, and in inland areas, there are sand, limestone, floodplain soil, and aerated loess deposits (Abed & Al-Washahi , 1999).

2.3 Topography of the West Bank

Palestine has topo diversity that includes three main topographic regions:

1. The Coastal Plain Region

A narrow strip located northwest of the West Bank, with an area of 425 km², has an average elevation above sea level ranging from 100 to 300 meters. It slopes toward the west without any natural barriers. The region is interspersed with wide, fertile alluvial valleys and gently sloping hills, most of which are planted with fruit trees, while the rainfall rate ranges between 400 and 700 mm/year from east to west. Its climate is characterized by the eastern Mediterranean climate, with a range of humid to semi-humid conditions. Agriculture in the area depends on both irrigated and rain-fed agriculture. Groundwater is used in irrigated farming, while rain-fed farming involves crops such as olives (Al-Louh, 2004). Among the most prominent plains are the Jenin Plain, the Arraba Plain to the west, the Hawara Plain, the Askar Plain, the Wadi Al-Faraa Plain, and the Sanur Plain (Al-Louh, 2004).

2. Mountain highlands region

One of the most important terrains in the West Bank extends from north to south with a length of 130 km, and its width varies between 5 and 35 km from west to east. It has an estimated area of 2,400 km^2, and its elevation ranges from 300 to around 1,000 m. For example, Mount Halhul in Hebron, which reaches an elevation of 1,020 m, is considered the highest peak in the study area (Ayash et al., 2007).

The mountain highlands in the study area can be divided into three sections: The western mountain slopes area overlooking the Mediterranean Sea, a high mountainous region that can be called a plateau, and mountainous slopes towards the Dead Sea and the Jordan Valley to the east. The altitude varies between 600 and 700 meters above sea level, covering an area of approximately 2,000 km^2. This area is semi-arid and characterized by steep, rocky terrain. Winter crops, such as rain-fed grains, are cultivated there, and the principal water source is the collection of rainwater (Ayash et al., 2007).

The average rainfall in this region ranges between 350 and 650 mm per year, and the water source is rain, as the area of irrigated agricultural land is restricted to small areas around the springs scattered throughout the mountains. The mountainous areas are populated with natural and planted forests. The type of rock prevailing in these limestone areas influences the amount of water flowing through the valleys via the soil pores. Examples of mountains in the study area include the Jerusalem Mountains, the Nablus Mountains, and the Hebron Mountains (Ayash et al., 2007).

3. The Jordan Valley Region (Jordan Valley)

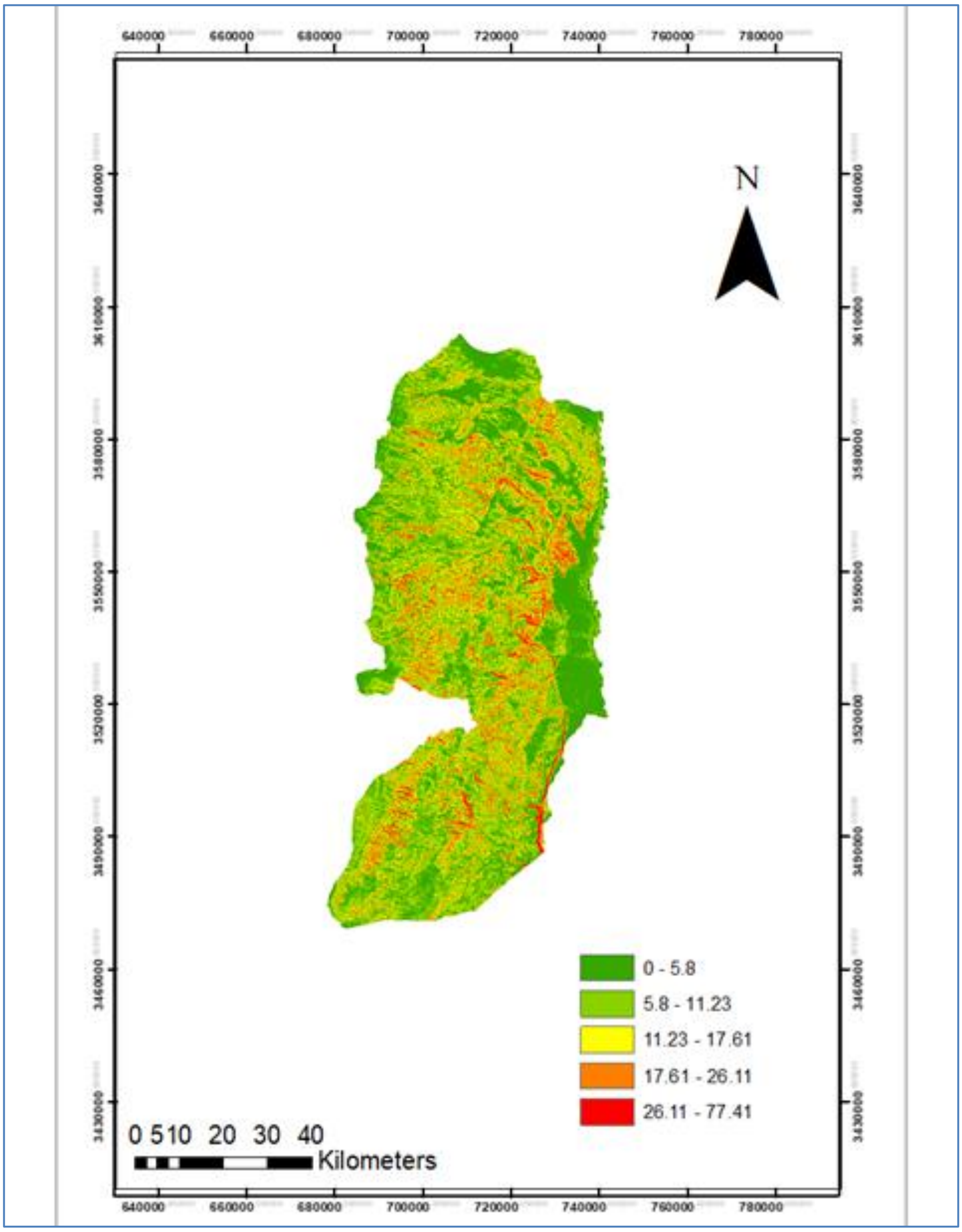
It includes the hills overlooking the Dead Sea and the Jordan Valley from zero elevation to a depth of 400 meters below sea level and is divided into two parts: hills sloping east towards the Dead Sea and the Jordan Valley, and the Jordan Valley region has a gentle slope towards the east and south (Ghodieh, 2019). The average rainfall in this region ranges from 100 to 300 mm/year from north to south. It contains various soil types and depends on water sources, including spring water and groundwater. It does not include irrigated crops. The area near the banks of the Jordan River is a natural reserve (Ayash et al., 2007).

2.4 Impact of slope on land use/land cover

A steep slope causes erosion, but a gentle slope increases thickness of the soil layer on top of all the rocks (Raddad, 2017). To analyze the degree of slope in the study area, a digital elevation model (DEM) map was used; the study area was divided into five slope categories.

Figure 3

Slope map of the West Bank



Source: https://geomolg.ps/L5/index.html?viewer=A3.V1.

The lowest slope category (0 - 5.8) can be found in the Jericho Governorate, northern Jenin Governorate, western Tulkarm Governorate and other areas, as depicted in Figure

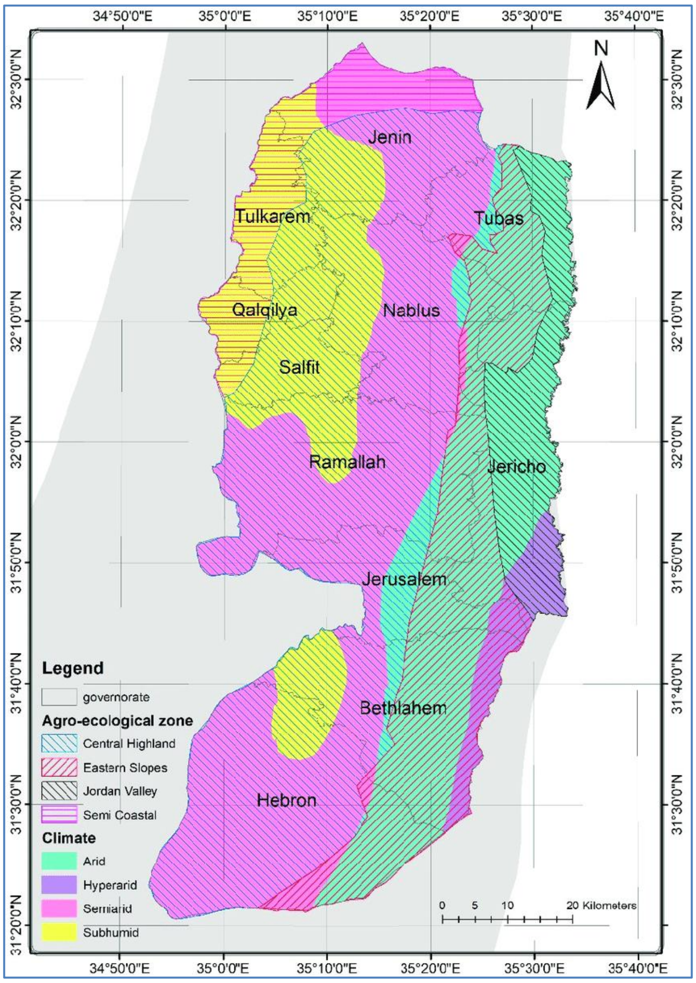
3. The steepest slope category (26.11 - 77.41) is distributed in the east and the west of the West Bank, the areas that have the slope.

2.5 Climate

Even with its small area, Palestine shows diverse climate regions, since the Mediterranean climate predominates (Al-Katri, 2014). This climate features warm, humid winters that tend to be cold, especially in the mountainous areas, and is influenced by cyclones and westerly winds. Consequently, rain occurs and the temperature decreases. The temperature is moderate in summer, with hot, northerly winds that tend to be particularly warm, especially in the valleys. Spring and fall are affected by the Khamasin winds, which are characterized by climatic fluctuations where atmospheric stability sometimes dominates (Totah & Khoury, 1923).

Figure 4

Agro-Ecological and Climatic Zones of the West Bank



Source: (Megan Blatchford, 2018)

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Climatic regions

Climatic regions in Palestine according to Koppen's classification are as follows:

1. The Mediterranean climate region is a humid area with warm summers. The average annual temperature of this region is 20°C. It spreads in northern and central Palestine. The average rainfall in this region is 400–500 mm (Hamada, 2010).
2. The desert and hot climate region affects the southern and southeastern parts of Palestine, including the Negev and the Jerusalem and Hebron Wildernesses, which are located on the eastern slopes of the Jerusalem and Hebron Mountains, overlooking the Jordan Valley and the Dead Sea. It has a continental climate characterized by high temperatures that often exceed 20°C and an annual rainfall of approximately 200 mm (Hamada, 2010).
3. The steppe climate region: It is a semi-arid and warm climate, a region in which the average annual temperature is more than 18ºC, and the average annual rainfall is between 200–350 mm (Hamada, 2010).

Climate elements

Several climatic elements influence the study area, and data from the Meteorological Center are referenced. Jenin station will represent the coastal plain area, Nablus station will represent the mountainous highlands area, and Jericho will represent the Jordan Valley area.

1. Solar radiation

It is the amount of solar radiation reaching the Earth's surface during daylight hours. The study area has a sunny climate, where the solar radiation is affected by several factors, including the amount of clouds in the atmosphere, which is inversely related to the amount of incident solar radiation, and the length of the day, which is directly related to the amount of solar radiation, and its variation from one season to another and from one region to another in the West Bank. The average sunshine in the West Bank is 3,400 hours annually (ARIJ, 2015).

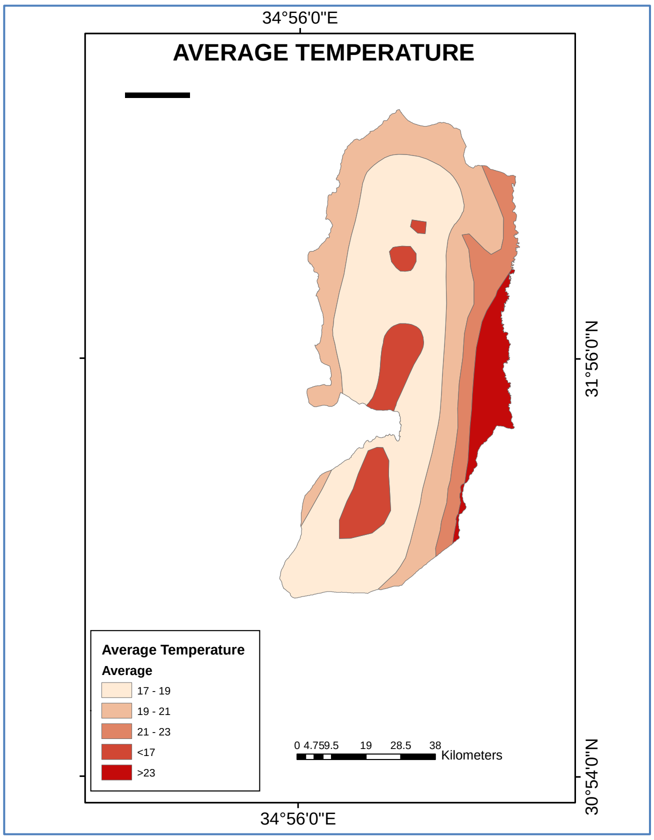
2. Temperature

The temperature in the West Bank is high in the low-lying areas, especially in Jericho and the Jordan Valley, which are the lowest locations in the study area. The higher the altitude, the lower the temperature. Therefore, temperatures are hot in the summer and mild in the winter (ARIJ, 2015).

According to meteorological data, the average temperature at Jericho Station during August was the highest among West Bank stations, at 33°C. The minimum was 7.9°C in January, and the maximum was 40°C in July. Jenin Station followed, with the highest average temperature reaching 29.05°C in August, the minimum being 8.5°C in January, and the maximum being 33.8°C in August. The highest average temperature at Nablus Station was 26.45°C in August, with the minimum being 7.2°C in January and the maximum being 31.7°C in August. The average temperature varies from year to year, either increasing or decreasing. However, at the global level, we have observed a consistent rise in temperatures as the years progress, largely due to climate change.

Figure 5

Average temperature in the West Bank



Resource: https://geomolg.ps/L5/index.html?viewer=A3.V1.

3. Atmospheric pressure and wind:

Atmospheric pressure: The West Bank is influenced by several air masses with different characteristics, including northern polar masses, humid northwestern air masses of marine origin, and southern continental air masses. Some of these are wet, while others are dry, and they are also affected by tropical conditions as they extend longitudinally from north to south, which has led to the partial disappearance of transitional seasons (Mushtaha & Al-Louh, 2015).

According to meteorological data, Jericho station had the highest average atmospheric pressure value in December, 1047.9 Pa, and the lowest value in July, 1032.6 Pa. This was followed by Jenin station, where the highest average value was recorded in December at 1000.5 Pa, and the lowest value was 991.1 Pa in July. Nablus station had the highest value, 954.9 Pa, in December and the lowest value, 946.1 Pa, in July.

Winds: The West Bank is influenced by winds with different characteristics and directions during the various months of the year. Among the winds that affect them are northern winds that vary in direction, north-easterly (hot and dry) and north-westerly (hot and humid). The study area is also affected by Khamasin winds in spring and fall, which are dry and hot winds laden with dust and dirt, because they move over the Negev Desert and the Sinai Peninsula, and their direction is primarily easterly (Mushtaha & Al-Louh, 2015)

The average wind speed in the West Bank for the years 2001-2021, according to meteorological data, was about 4.4 km/h at Jenin Station in July and 2.7 km/h in December. At Jericho Station, it was 3.6 km/h in May and 1.9 km/h in December. At Nablus Station, it was 3.9 km/h in July and 2.6 km/h in November.

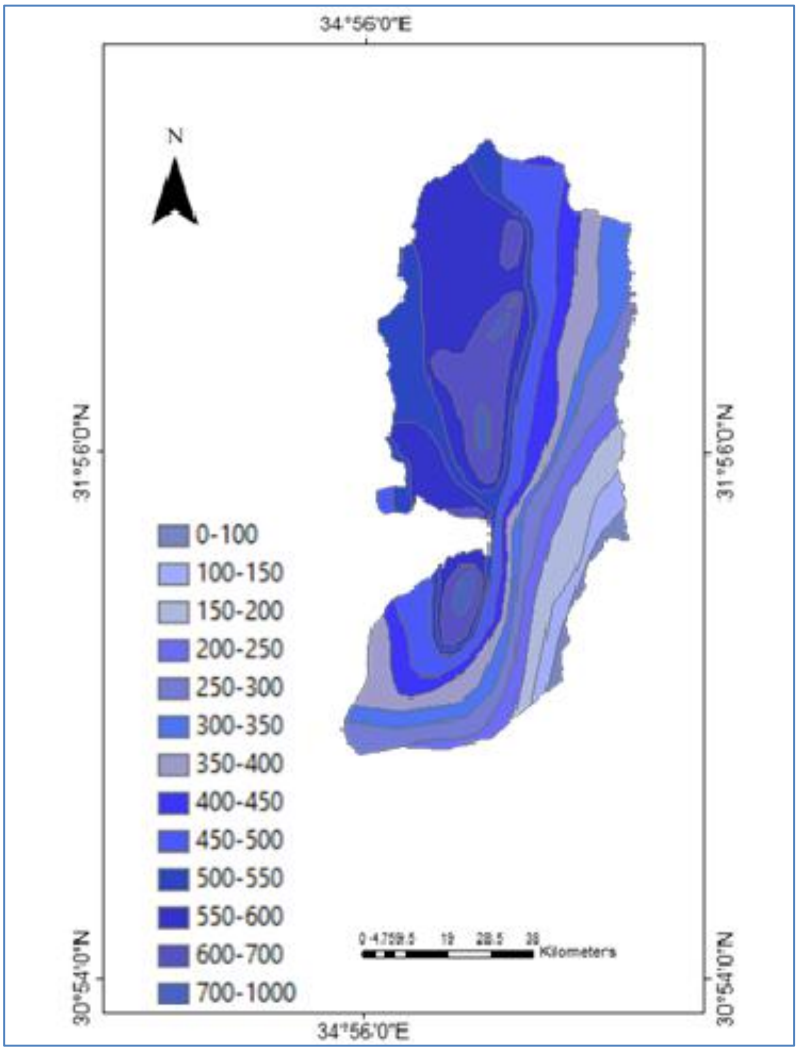
4. Rain

Most of the rain that falls in the study area originates from atmospheric depressions. Water vapor passes over the surface of the Mediterranean Sea and interacts with the land, rising, cooling, condensing, and forming clouds. The winds then transport these clouds to the highlands, where they precipitate on the slopes facing these winds. Autumn rain also occurs on the coastal areas. Rain falls on the West Bank in winter, and the amount of rainfall varies from year to year, but generally, the highest percentage of rain occurs in January, December, and February (Al-Katri , 2014).

Water availability is not stable; it is rising in the northern parts of the study area and going down in the southern region. Based on meteorological data, the rainfall records for the years 2001-2021 have been inconsistent. The most significant rain during this time was at the Nablus station in January when it reached 166.7 mm. The maximum precipitation was likewise at the Jenin station in January, and it went up to 118.8 mm. The minimum rainfall during this time was at the Jericho station, and it was only 38.6 mm. One of the most significant aspects of rain for the agricultural sector and farmers is that more rain usually means more prosperity and less chance of famine. So, farming cannot be solely based on rainfall. There must be some other irrigation sources used (Al-Katri, 2014).

Figure 6

Precipitation Distribution Map of the West Bank



Resource: https://geomolg.ps/L5/index.html?viewer=A3.V1.

5. Evaporation

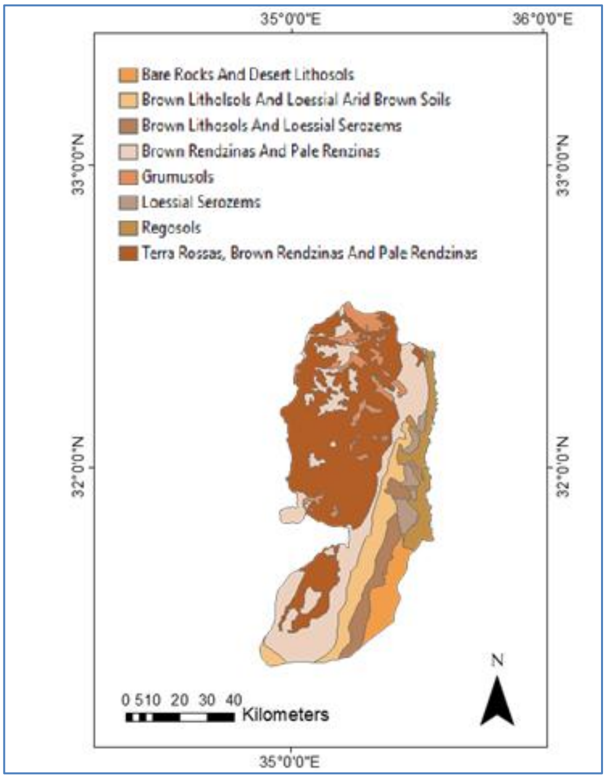
Evaporation is the method in which water moves from a liquid form to a gaseous one. The evaporation rate is a measure of how much liquid evaporates per unit area per unit time. As temperature goes up, this rate also gets higher, thus, during summertime when there are more hours of sunshine, evaporation is more considerable. The period from May to September experiences the highest evaporation rates, with July usually reaching the peak (Hamada, 2010). According to meteorological data, the highest evaporation rates were recorded at the Jericho, Jenin, and Nablus stations, respectively.

2.6 Soil

Soil is the thin layer that covers the Earth's crust. It is a fragmented layer of crustal rocks due to the interaction of various factors, including vegetation, climate, topography, and the basic material of the Earth's crust rocks, which have been exposed to different temperatures over the years and the amount of rainfall. As for Palestine, the soil varies. Because of its geological formation, the diversity of its plants and climate regions, and its geomorphology (Al-Katri, 2014).

Figure 7

Type of soil Map of the West Bank.



Resource: https://geomolg.ps/L5/index.html?viewer=A3.V1.

The soil types in Palestine can be summarized according to the terrain regions as follows (Mushtaha & Al-Louh, 2015):

1. Coastal plain soil includes sandy soils, karkarya soils, sandy clay or sandy clay soils, and red soils, in addition to black flood soils in the north and loess soils in the south. Most of these soils are suitable for agriculture; some soils require treatment before being used, such as sandy soils and those from quarries.
2. The soil of mountainous areas includes terrarosa (Mediterranean soil), basalt soil, and brown soil in the mountains of Jerusalem and Hebron. It is considered suitable soil for agriculture, with variations in fertility depending on the region. Additionally, it contains both mineral and organic matter.
3. Soils of the internal plains and valleys: They exist in the areas of the internal plains and extend into the mountains that separate them. They are found in the Jordan Valley, including alluvial clay soil. They are among the most fertile soils in Palestine and are appropriate for all types of crops.

2.7 Water sources

Water resources are a must for the good of agriculture, especially in areas where the water availability per year is very low. In Palestine, and more specifically in the West Bank, water is limited by both human and natural factors. According to (Mushtaha & Al-Louh, 2015), the main water sources in the West Bank are rainwater, groundwater, and springs. The annual water production of the region is estimated to be around 765 million cubic meters (Al-Mamluk, 2012). Nevertheless, it is the Israeli occupation that is the leading cause of the shortage of water resources in the West Bank. While the region is endowed with a number of water sources, the means to access them still pose a problem of great difficulty.

1. Rainwater

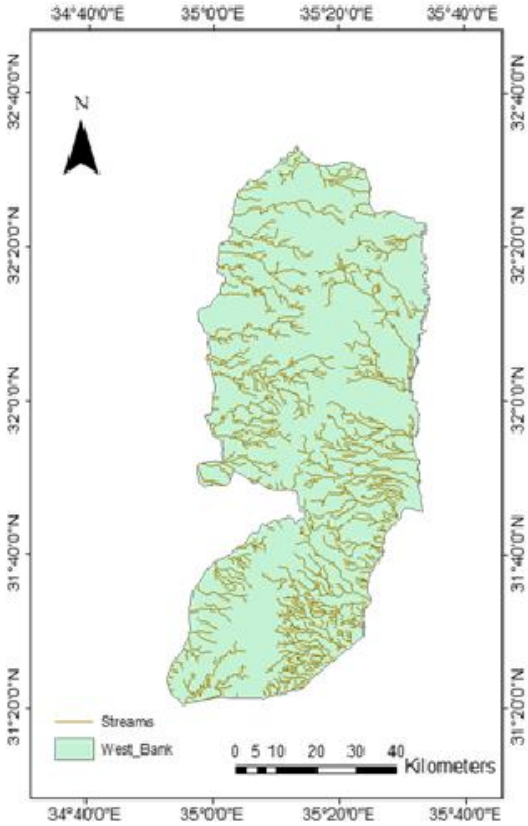
Rain is the primary source of water in the West Bank. It supplies surface water, the groundwater reservoir, rivers, and valleys. The greater the amount of rain in a year, the higher the water reserve. The quantity of rain varies from one region to another and from one year to another. It increases in mountainous areas and decreases in the Jordan Valley. Rainfall in Palestine usually begins in September and lasts until May (Al-Mamluk, 2012).

2. Surface water

As previously mentioned, the Israeli occupation controls water resources in the West Bank. The only surface water source in the study area is the Jordan River, but Palestinians cannot access it because of the Israeli occupation's closure of the adjacent areas (ARIJ, 2015). Valleys, streams, and springs. There are several valleys, streams, and springs in the West Bank, which depend on the annual rainfall. Regarding springs, the number of springs in the West Bank is approximately 300 active natural springs. However, 71 of these springs discharge water at a rate of 0.1 liters per second, yielding approximately 45-50 million cubic meters of fresh water (ARIJ, 2015).

Figure 8

Streams' Map of the West Bank



source: https://geomolg.ps/L5/index.html?viewer=A3.V1.

3. Groundwater

Groundwater ranks as one of the most vital water sources in Palestine and is mainly replenished by rainwater that falls on the West Bank highlands and goes down through the rocks into the water basins underground. The region's geological structure is the main factor that determines where and how much groundwater is available (Alqam, 2016). Three major aquifers hold the West Bank, and the volume of water in each aquifer is directly dependent on the amount of rainfall during the year. However, the management of these aquifers is still under the Israeli occupation, and the Palestinians are provided with only limited water allocations despite the existence of these aquifers (Alqam, 2016). These aquifers are explained in detail below:

a. The Western Basin

This basin's renewable potential is about 360 million cubic meters. About eighty percent of the basin's recharge area is within the West Bank. Palestinians extract their water from 138 groundwater wells in this basin, 120 of which are used for irrigation. However, this basin is shared between Palestinians and Israelis, and Palestinians receive only 7.5% of its water. The basin contains 35 springs with a flow rate of 0.1 liters per second (ARIJ, 2015).

b. The northeastern basin

The value of this renewable basin is estimated at approximately 145 million m^3 annually. According to the Oslo Interim Agreement, the Palestinians receive less than 37 million m^3 annually from this basin (Alqam, 2016)

c. The Eastern Basin

The renewable value of this basin is estimated at approximately 155-237 million cubic meters annually. The waters of this basin flow toward the Dead Sea and the Jordan River. The amount of saline water in the basin is estimated at 70 million cubic meters. It is considered the active basin in the West Bank, as 90% of the annual spring water originates from this basin. Although it is located entirely within the West Bank borders, the Israeli occupation controls two-thirds of the water of this basin. It is worth adding that wells have been drilled and water withdrawn by the settlements in the West Bank. In 2004, 32 deep wells were drilled on the high hills of the West Bank by the Israeli occupation (Alqam, 2016)

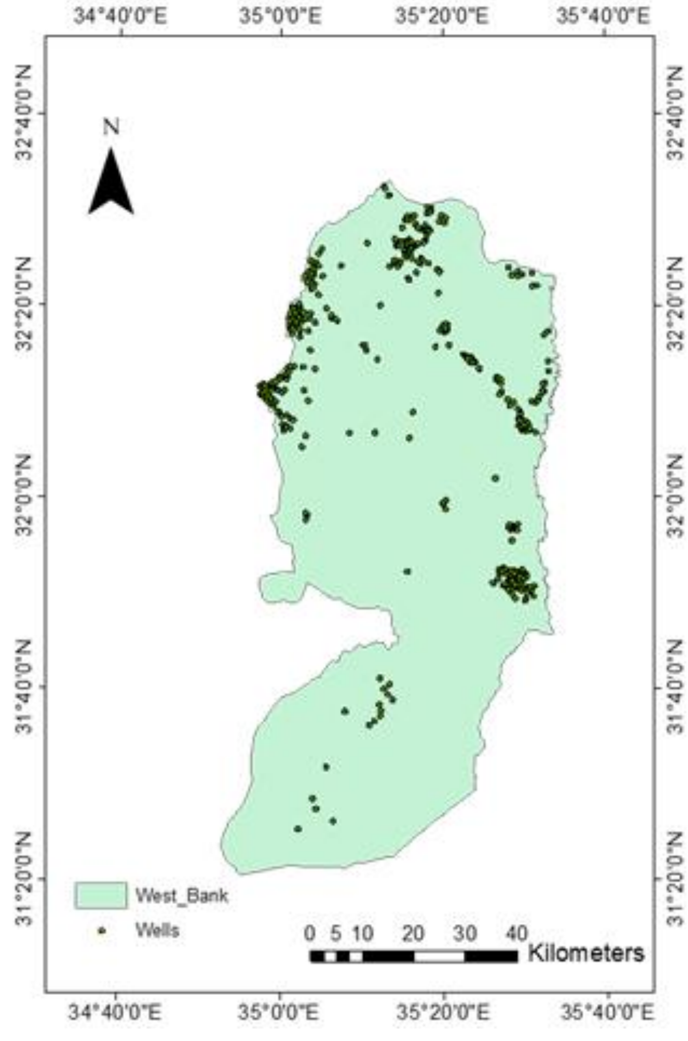
d. Wells

Wells are a major water resource in the West Bank. The number of wells in 2021 reached 369, including 70 for domestic use and 299 for agricultural use. The amount of water extracted from these wells amounted to 50.6 million m^3 for domestic use and 54.7 million m^3 for agricultural use (Statistics, 2021\2022).

The number of wells is small compared with the area of the West Bank. This is due to the high cost of drilling wells, the distance from the groundwater reservoir, the occupation's policy of denying permits for new well drilling, and restrictions on Palestinians, as well as the demolition and bulldozing of some existing wells. Settlements also control several existing wells. Therefore, Palestinians also rely on rainwater for drinking and on both rainwater and springs for agriculture (Mushtaha , 2013).

Figure 9

Wells Map of the West Bank



Source: https://geomolg.ps/L5/index.html?viewer=A3.V1.

2.8 Human Characteristics of the West Bank

Population

The West Bank comprises eleven governorates: Jenin, Tubas and the Northern Jordan Valley, Tulkarm, Nablus, Qalqilya, Salfit, Ramallah and Al-Bireh, Jericho and the Jordan Valley, Bethlehem, Jerusalem, and Hebron. In 2001, the total population of the West Bank was 1,992,577; by 2021, this number had increased to 3,256,906. The table below shows the population of each governorate for the years 2001 and 2021, as reported by the Palestinian Central Bureau of Statistics (Table 1).

Table 1

Area and population of West Bank Governorates, 2001–2021

Governorates	Area (km²)	Number of populations 2001	Number of populations 2021	Population change	change %
Hebron	996	444725	782,227	337,502	75.89
Nablus	601	274922	415,606	140,684	51.17
Ramallah	856	230556	355,202	124,646	54.06
Jenin	583	216078	338,919	122,841	56.85
Bethlehem	659	147037	234,802	87,765	59.69
Tulkarm	246	138793	198,856	60,063	43.27
Qalqilya	171	76704	121,671	44,967	58.62
Salfit	203	51053	82,099	31,046	60.81
Tubas	401	40269	65,915	25,646	63.69
Jericho	592	35162	53,317	18,155	51.63
Jerusalem	345	337278	471,834	134,556	39.89
Total	5653	1,992,577	3,256,906	1,264,329	63.45

source: Palestinian Central Bureau of Statistics (PCBS), 2001,2021

The Hebron Governorate recorded the highest population growth rate in the West Bank between 2001 and 2021, followed by Tubas, Salfit, Jenin, Bethlehem, Qalqilya, Ramallah, Jericho, Nablus, Tulkarm, and Jerusalem, as indicated in Table 1. The population of the West Bank in 2001 was approximately 1,992,577 people, and by 2021, it had increased to 3,120,448 people, with a population growth rate of 63.45% between 2001 and 2021.

2.9 Vegetation cover in the West Bank

Agricultural

The agricultural sector is the core sector of any economy, the source of income for farmers, and the engine of food production for society. The West Bank is famous, in particular, for the variety of its crops, where olives are the dominante. The production of olives takes up a large part of the area of the West Bank because the plant is an easy one and it takes very little water. Table (2) presents the area devoted to each crop type across the various governorates of the West Bank.

Table 2

Cultivated Area (in Dunams) of Field Crops, Vegetables, and Tree Horticulture in the West Bank by Governorate

Governorate	Field crops	Average %	Vegetables	Average %	Horticulture Trees (mainly olive trees)	Average %	Total	Average % (agriculture cover)
Jenin	77,182.66	38.96	45,393.10	32.24	45,393.10	7.08	281,119.23	28.69
Tubas	35,085.00	17.71	36,635.34	26.02	11,769.83	1.84	83,490.17	8.52
Tulkarm	1,529.13	0.77	12,494.57	8.87	69,421.15	10.83	83,444.85	8.52
Nablus	10,687.62	5.4	7,398.37	5.25	76,452.02	11.93	94,538.01	9.65
Qalqilya	1,217.91	0.61	1,970.83	1.4	41,889.82	6.54	45,078.56	4.6
Salfit	499.3	0.25	661.2	0.47	44,277.08	6.91	45,437.58	4.64
Ramallah	9,136.76	4.61	3,203.21	2.28	84,290.58	13.15	96,630.55	9.86
Jericho	1,635.24	0.83	22,041.80	15.66	29,103.41	4.54	52,780.45	5.39
Jerusalem	719.66	0.36	355.61	0.25	9,230.40	1.44	10,305.67	1.05
Bethlehem	8,073.80	4.08	1,790.70	1.27	41,239.72	6.44	51,104.22	5.22
Hebron	52,329.54	26.42	8,849.22	6.29	74,643.57	11.65	135,822.33	13.86
West Bank	198,096.62	100	140,793.95	100	640,861.05	100	979,751.62	100
average %	20.22		14.37		65.41		100	

Source: (Statistics, 2021 Agricultural Census Final Results - Palestine, 2021\2022):

The presence of plants is closely tied to natural factors, including climate, terrain, and soil. They are among the most important determinants of vegetation, and the difference in density from one region to another results from plants spreading heterogeneously across climatic regions (Anab, 1979).

Types of vegetation cover in the West Bank:

1. **Natural vegetation cover:**
   - **Weeds:**

     Most of the lands in the study area are mulched, as they do not require large amounts of water and can grow independently alongside other vegetation (Anab, 1979).
   - **Forests:**

     There are six types of forests in the West Bank: the artificially planted coniferous forest. This forest was planted in areas where the climate of the eastern Mediterranean basin prevails and on different soil types such as heavy and light red soils, white, gray, and dark rendzina, and alluvial sedimentary soils. The natural medium-sized leafy oak forest is found in the Mediterranean climate of the Palestinian territories in semi-coastal and mountainous areas. The green carob and the serious forest grow on the eastern slopes of the mountains of Palestine, such as Tubas and the east of Nablus Governorate. The deciduous tree forest is limited to this area in the east of Tubas Governorate (at an altitude of 250 meters above sea level or higher). The forest on the banks of the Jordan River is situated between the western (Palestine) and eastern (Jordan) banks. The marine and local forest are found on the northwestern shore of the Dead Sea (Ayash et al., 2007).

2. **Agricultural vegetation cover**

   Palestine is characterized by the diversity of crops and the timing of planting throughout the year. No fewer than 105 different crops are grown there: 38 types of fruits, 37 types of vegetables, and no fewer than 30 types of field crops. Among the crops grown in the West Bank are olives, citrus fruits, grapes, almonds, dates, guava, tomatoes, cucumbers, eggplant, okra, and other fruits and vegetables, as well as field crops such as wheat and vetch (Omar & Qaoud, 2013).

2.10 Natural Factors Affecting Agricultural Cover in the West Bank

Several natural factors influence the type of crops, their spatial distribution, production quantity, and quality, depending on the region's geographical and natural characteristics, including climate components, soil surface, and geomorphology. These factors change slowly, so methods must be found to reduce their impact by using human capabilities and civilization. These factors include:

1. Surface:

The topography has a significant impact on farming as a flat surface (a little sloping) makes the whole farming process easier. Besides that, a soil with more depth will increase the fertility of the soil. Moreover, flat areas allow us to use different irrigation methods easily and get rid of the excess water because they also enable the construction of transportation roads to and from agricultural areas. On the other hand, steep lands normally have less soil depth, resulting in low soil fertility, and additionally, they become a hard task to carry out agricultural works (Al-Barazi, 2000).

The study area is distinguished by its variety of land and slope ratios. There are plains like Marj Bin Amer Plain and Qabatiya Plain, and the mountains such as Nablus, Hebron, and the Jerusalem Mountains. This diversity opens up the possibilities of agricultural development, among them is the identification of neglected agricultural lands that can be used.

2. Climate:

The factor of climate is quite a necessary point to be taken into account as some crops have to be given only certain climatic conditions to thrive. Among the climate factors that have an impact on growth are:

- Temperature: Different crops heat requirements vary. Some crops, for example, tomatoes need high temperatures to grow, while others do not. The crop becomes more widespread the more different temperatures it can tolerate, as in the case of barley, which is more widespread (Zakarneh, 2012).

  The difference in temperature affects evaporation, atmospheric pressure, and humidity, so there was a need to establish greenhouses and tunnels to cultivate plants inside them, thereby overcoming low temperatures and creating a suitable environment for agriculture (Al-Barazi, 2000).

- Rain: Rain affects rain-fed crops because it represents the main source of fresh water, so the amount of water and its timing affect the type of crops, the date of planting, and the place of planting. Rain affects crops and their productivity, but it is not the primary reason for this decline. Other irrigation methods are used for crops that require a substantial amount of water. That is, there must be integration between rain and the irrigation method. If it rains and the rain stops before the crop ripens, the crops are irrigated to prevent damage, and cultivation continues until the crop is ripe. The most important rain-fed crops are wheat and rain-fed vegetables such as zucchini and cucumbers (Zakarneh, 2012).
- Dew: Dew impacts agricultural production, particularly for rain-fed crops. Dew at sunrise maintains moisture in the soil and reduces evaporation. It also protects plants from agricultural pests, insects, and others (Haroun, 2009).
- Solar radiation: Solar radiation affects crop cultivation and production through photosynthesis and its role in removing excess water from the plant through transpiration. Solar radiation also affects the shape and size of the plant (Haroun, 2009).

  The length of the day differs between summer and winter. In summer, the length of the day increases, along with the speed of plant growth and maturity. Consequently, the optimal place and season for planting vary according to the need of each plant for solar radiation. Solar radiation is also influenced by astronomical location, degree of elevation, proximity to sea level, and certain climate factors.

  In the study area, there are differences in the amount of solar radiation according to the location and region. In the summer, in the mountainous areas, i.e., at the Nablus station, the hours of sunshine reach 12 hours, and in the winter, 5.7. In the Jordan Valley areas, i.e., at the Jericho station, the amount of solar radiation reaches 11.6 in the summer and 5.6 in the winter. In the Jenin station, the amount of solar radiation reaches 11.4 hours in the summer and 5 hours in the winter.
- Wind: Air is important for crops because its components include carbon dioxide, which is necessary for the photosynthesis process, which helps the plant obtain food and absorb carbon dioxide during the day and oxygen at night. The air also contains nitrogen, which is a vital fertilizer for legumes. The importance of air in pollinating plants, but there are negative effects of air on crops, such as air may transport agricultural pests from one place to another or transport the surface soil layer of the

plant to another place, which contains minerals and materials useful to the plant. The leaves of the plant, flowers of the plant, or trees may fall (Zakarneh, 2012).

In the study area, the average wind speed during the period 2001-2021 in the summer is considered low at all stations, as it is 4.4 km/h in the summer at the Jenin station, 3.5 km/h at the Jericho station, and 3.9 km/h at the Nablus station, and in the winter 2.7 km/h, 1.9 km/h, and 2.9 km/h. This speed increases in the winter until the beginning of spring, when there are dry Khamsin winds that may carry dust, which leads to damage to crops, especially at the beginning of growth, especially zucchini, cucumber, and tomato crops, as the winds cause friction between the leaves, which leads to their breakage and damage.

- Soil: Without soil, agriculture will have no place to grow as soil is the main source from which crops are developed. Moreover, soil is the house of minerals and materials which are the food of crops. All the fruits and vegetables that we eat grow in different types of soil; some need sandy soil while others require clay soil. The depth of the soil is one of the factors that determine the quality of the soil. The deep soils that can let the extra water go, can also maintain their acid-base balance and keep the moisture in their pores, are the ones that are considered the best soils (Zakarneh, 2012). The slope that land has is an important factor that determines the condition of soil that has been cultivated. The perfect slope for agricultural land is from 3 to 5 degrees. The slopes below this level can result in the absence of drainage and thus the water may accumulate which will lead to the salt build-up, and the steep slopes will undergo soil erosion more easily (Zakarneh, 2012). Our research area covered different soils which have been described in detail. Our research shows that algae and mud are good for farming due to access deep water, plenty of rain, and moderate incline. Moreover, the most familiar places for oranges are the coastline where farming dominates compared to the mountains. The area has many coast areas such as the coastal plains of Tulkarm, Sha'rawiya, and Qalqilya (Safat, 2003). In addition, there are the plains of the country such as Hawara, Arraba, Sanur, Tubas, Zababdeh, and Beit Dajan together with the smaller plains of the Deir Sharaf and Anza (Safat, 2003). The mountain slopes are characteristically used for growing olive and almond trees, along with forested areas. The vegetation cover is dense on the eastern slopes and the Jordan Valley is also famous for the cultivation of banana and palm trees along with heat - and water-demanding vegetables (Safat, 2003).

2.11 Human factors

Several human factors have a major effect on the agricultural production system because people are the determining factor in the success of agriculture, controlling the amount, kind, and quality of the crops through the utilization of nature. Human factors are the key players to the enhancement of agricultural productivity (Al-Barazi, 2000). These factors comprise:

1. Labor: The number of workers for an agricultural project varies according to the type of agriculture. For instance, rainfed farming is likely to be low in labor requirements, while irrigated agriculture may need a large workforce, especially depending on the crop. In spite of the mechanization and modernization of agriculture, some crops still require manual labor for the stages of planting and harvesting, and this is also true for greenhouses, which still need human intervention (Abu-Ghraib, 1995). Moreover, the knowledge and experience of the farmers and workers are also major contributors to the success of agriculture. The more qualified the agricultural engineers and the more experienced the workers, the smoother will be the agricultural process. The provision of training and courses on agricultural methods to farmers and workers also leads to a rise in productivity (Abu-Ghraib, 1995). Cultivated land in the study area in 2001 was 24.8% of the total land of the Palestinians. Of this, 89.2% was allocated for rainfed crops and 78.6% for permanent crops (Palestinian Central Bureau of Statistics). The area of cultivated land has grown to 1,096.3 km^2, which is 19.37% of the Palestinian land as of 2021. The area for rainfed agriculture was 187,913.36 dunams, while that for irrigated agriculture was 10,183.26 dunams, consisting of: 3,237.41 dunams under surface irrigation, 5,663.58 dunams under drip irrigation, and 1,282.27 dunams under sprinkler irrigation (Palestinian Central Bureau of Statistics, 2021 Agricultural Census).
2. Capital: Capital is the lifeblood of agriculture, and it is what allows the use of the latest techniques such as mechanical farming, the application of fertilizers and pesticides, and the employment of the latest irrigation methods (Zakarneh, 2012). In the study area, the farmer's first source of capital is usually their own. To some extent, agricultural cooperatives have come to the rescue by offering some agricultural inputs at a lower rate. Nevertheless, the ever-increasing input prices combined with the inefficient marketing strategies due to the reliance on the Israeli markets and the export restrictions have put the farmers in a financial crunch. Besides that, Israeli occupation

policies, such as road closures, make these financial difficulties worse and thus prevent farmers from taking bank loans, which is usually due to fear of default, and this default is mostly caused by weather conditions such as drought or frost, which are hard to predict (Zakarneh, 2012).

3. Markets and Transportation: Markets are the lifeline of agricultural products, and closeness to the markets is very important for certain products that are not capable of long-distance transportation. Improper packaging, storing, or cooling may result in damage to products, thus their value and marketability will decrease. The Israeli occupation worsens this matter by closing roads, establishing checkpoints, and restricting transportation, so that the products will be delayed or their delivery will be hindered, thus they will be spoiled. (Al-Barazi, 2000). The inflation of local products' prices compared to Israeli imports is due to the large quantities of Israeli products that are available in Palestinian markets. Introduction of Israeli products is controlled, and input costs for the region are increased, and that is the reason why the prices of local products are higher than those of Israeli imports, while the existence of commercial crossings facilitates the implementation of the policies of the occupation on local products and farmers. These and several other factors have an impact on the process of agricultural production in the region (Palestine Economy Portal, 2021). It is of great importance to defend local products, and the authorities that bear the responsibility for it must take action by enforcing regulations, obligations, and laws that will support Palestinian farmers and their products in their domestic markets. For example, setting market prices for crops may limit Israeli imports and at the same time help farmers assess market orders so as to produce the right amount needed and thus achieve supply-demand balance. On the other hand, the Israeli occupation is the one that obstructs the transportation of crops by closing roads, establishing military checkpoints, demolishing streets, and restricting the movement of people and trucks from one city to another. As a result of these activities, crops can be damaged because of some of the things such as potholes, dust, and so on that they have been exposed to during the transportation process (Palestine Economy Portal, 2021).

Chapter Three

Land Cover Classification in the West Bank Using Remote Sensing Data

3.1 Introduction

Farmers have been able to effectively monitor and manage their agricultural operations due to progress in remote sensing and geographic information systems (GIS).

Agriculture is a vital sector in every country's economy. Understanding crop characteristics, such as type, area, and expected yield, is essential for better farm management and improving overall economic outcomes. Besides, the remote sensing application in crop management goes a long way in resource conservation and ensuring the sustainability of the agricultural sector.

Remote sensing technologies offer spectral data that can be utilized to recreate crop patterns and evaluate different agricultural variables. Through the fusion of RS and GIS, farmers can pinpoint the exact locations of the cultivated lands and measure the effects of the environmental stressors, such as drought, floods, and extreme weather, on them. Likewise, the combination of meteorological data with vegetation indices derived from remote sensing helps in the monitoring of agricultural meteorology, thus giving very early warnings of pest infestations and diseases.

Crop production is influenced by numerous factors, which include soil quality, weather conditions, and farming practices. By implementing RS and GIS technologies, farmers can increase their decision-making capacities, achieve higher productivity, and be in a position to mitigate risks that are related to climate variability and pest outbreaks (Kumar, et al., 2022).

Downloading Satellite Imagery

Visual satellite images are very important instruments for gathering data from the earth and revealing the geographical changes happening in a certain area. Monitoring and analyzing such changes through satellite images over long periods allow scientists to see their growth also in very old and very recent times.

Their comparison is a supporting tool for the strategic planning that is targeted at solving problems and increasing the positive factors. This research mainly depends on historical satellite data to investigate land use and land cover (LU/LC), concentrating mostly on vegetation cover in the West Bank. It points to the growth of built-up areas at the cost of the disappearance of vegetation and agricultural lands due to causes like the lack of attention for the development of agriculture, the use of outdated irrigation methods, and the shortage of water in the region. To accomplish this, the land cover data for the years 2001 and 2021 will be analyzed.

The year 2021 was chosen rather than 2023 because there was no recent agricultural data available; 2021 is the last year for which the Palestinian Ministry of Agriculture has provided the data. Satellite images for the year 2001 came from the United States Geological Survey (USGS) website and were taken on June 25, 2001, by the Landsat 7 satellite.

Landsat 7 carries the Enhanced Thematic Mapper Plus (ETM+) sensor, which can provide multispectral images with a spatial resolution of up to 30 meters and a panchromatic band with 15 meters. Operating in a sun-synchronous orbit at approximately 705 km altitude, Landsat 7 revisits the same location every 16 days (NASA, n.d). For the year 2021, satellite images were downloaded from the USGS using Landsat 8, part of the same Landsat program by NASA and the USGS, captured on June 24, 2021. Launched on February 11, 2013, Landsat 8 provides accurate Earth observation data for monitoring vegetation changes, assessing water quality, and tracking thermal phenomena such as volcanic activity and forest fires. It carries the Operational Land Imager (OLI), which captures data across eight spectral bands (VIS/NIR) and a panchromatic band, along with the Thermal Infrared Sensor (TIRS), which supplies thermal data across two spectral bands. The spatial resolution is 30 meters for most bands, 15 meters for the panchromatic band, and 100 meters for thermal bands (NASA, n.d)

3.2 Image classification

Image classification typically follows two main approaches: supervised classification, where the algorithm is trained using labeled data, and unsupervised classification, where the algorithm detects patterns or clusters in the data without prior labeling.

1. Supervised classification

Involves selection of uniform sample regions—referred to as training data—based on the knowledge of the study area within the image. The algorithm of classification then extends these samples over the whole image by searching for pixels that have the same spectral characteristics (Baroud, 2019).

2. Unsupervised Classification

This is fully dependent on computer-based algorithms and numerical analysis, without any involvement of prior knowledge of the classifier It does not require samples from the study area that have to be identified beforehand. Instead, it uses mathematical algorithms and digital spectral features of the image. Pixels with similar spectral values are grouped based on the number of classes set by the user. Each geographical phenomenon has a unique spectral signature (Baroud, 2019).

The MLC maximum likelihood classifier, which is essentially a supervised classification method, was chosen on account of its high accuracy. By using the training data, this method evaluates the probability of each pixel belonging to a particular class. During this operation, a signature file is generated which houses the spectral characteristics of the training samples. This file can be later changed or supplemented with the same satellite image, thus providing relaxation and fining.

The classification phase is initiated by a comprehensive examination of the satellite imagery, through which the best representatives are selected from the study area, and according to their spectral properties labeled. This step, besides the visual analysis of the images, also uses the classifier’s prior knowledge of the region to make sure the class labels are reliable. The satellite images, in total, were categorized into 14 classes of land cover.

The classification includes the following steps:

A. Visual Analysis of Satellite Images of the West Bank

Before the selection of training areas, a visual understanding of the satellite image was carried out that focused on the West bank and was based on the spatial and spectral characteristics of different land cover types. This step brought about the recognition of the features like urban areas, forests, field crops, rocky terrain, and quarries. The correct outlining of these features was facilitated by the reference to other satellite images of the region. Subsequently, the spectral reflectance of the different bands was compared to decide which bands would be the best for classification.

B. Training Areas

Training areas were the main focus in representing the entire range of land cover types in the West Bank. These areas were used as a source for the production of the classification signature file. Table (3) shows the number and types of land cover classes that have been identified in the study area.

Table 3

Land Cover Classification Scheme in the West Bank

Number	Cover Land
1	Built-up area
2	Forest
3	Field crops
4	Ploughed land
5	Bad land1
6	Rocky land and quarries
7	Rocks and grass
8	Natural grass
9	Field crops1
10	Other trees
11	Olives-1
12	Palm trees
13	Water
14	Bad land2

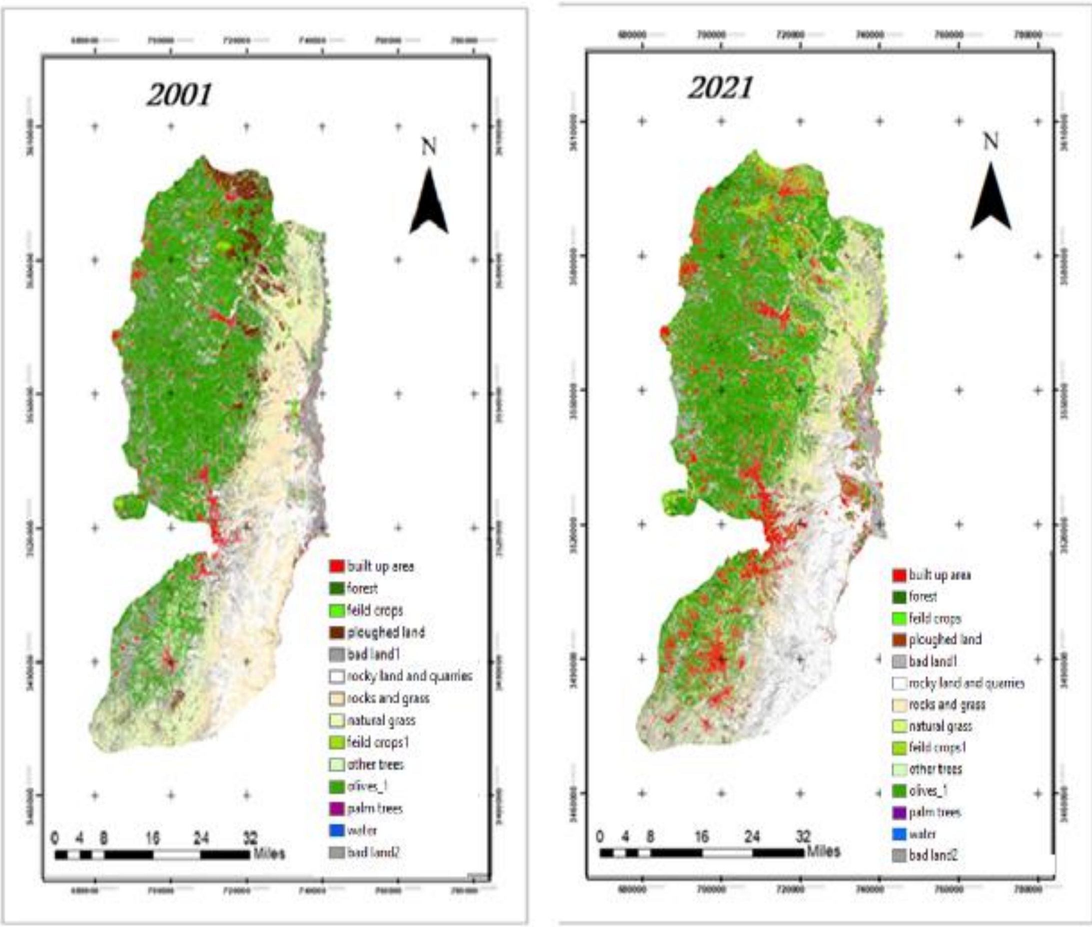
Satellite image classification

For the image classification, fourteen different land cover types were used. With the help of ArcMap 10.8, training areas were identified by drawing polygons over the representative areas for each land cover type. To each class, a different color was given to make the visual distinction easier. After defining all the training areas, the file with the land cover classes was saved and used to create a signature file.

After that, the Maximum Likelihood Classifier (MLC), which is a supervised classification method, was applied to the satellite image by using the signature file that was generated. In this way, the exact land cover classification over the whole study area was possible, which was based on the spectral characteristics of the training samples. The final classified image for the year 2001 is shown in Figure 10.

Figure 10

Classified satellite image of the West Bank in 2001 and 2021



Land Cover Class Areas

Tables 4 and 5 present the area (in square kilometers) of each land cover class in the region for the years 2001 and 2021, respectively. These tables show the spatial distribution and changes in land use and land cover over the period.

Table 4

Land Cover classes for the year 2001

Number	Land Cover	Area km²	% of the total area
1	Built-up area	132.215	2.3
2	Forest	199.485	3.5
3	Field crops	11.962	2.0
4	Plowed land	199.72	3.5
5	Bad land1	774.91	13.7
6	Rocky land and quarries	840.845	14.9
7	Rocks and grass	761.252	13.5
8	Natural grass	494.13	8.8
9	Field crops1	63.565	1.1
10	Other trees	54.398	1.0
11	Olives_1	1718.983	30.4
12	Palm trees	17.971	0.3
13	Water	0.172	0.0
14	Bad land2	375.832	6.7
Total		5645.44	100

Table 5

Land Cover classes for the year 2021

Number	Land Cover	Area km²	% of the total area
1	Built-up area	509.669	9.0
2	Forest	149.043	2.6
3	Field crops	125.218	2.2
4	Plowed land	11.952	0.2
5	Bad land1	1010.989	17.9
6	Rocky land and quarries	795.71	14.1
7	Rocks and grass	551.746	9.8
8	Natural grass	132.036	2.3
9	Field crops1	125.897	2.2
10	Other trees	320.036	5.7
11	Olives_1	1746.747	30.9
12	Palm trees	5.233	0.1
13	Water	0.131	0.000
14	Bad land2	161.041	2.9
Total		5645.44	100

Table 6

The change in land cover area between 2001 and 2021

Number	Land Cover	Area of 2001 (km²)	Area OF 2021 (km²)	Change (km²)	Change %
1	Built-up area	132.215	509.669	-377.454	285.49
2	Forest	199.485	149.043	50.442	-25.29
3	Field crops	11.962	125.218	-113.256	946.80
4	Plowed land	199.72	11.952	187.768	-94.016
5	Bad land1	774.91	1010.989	-236.079	30.47
6	Rocky land and quarries	840.845	795.71	45.135	-5.37
7	Rocks and grass	761.252	551.746	209.506	-27.52
8	Natural grass	494.13	132.036	362.094	-73.28
9	Field crops1	63.565	125.897	-62.332	98.06
10	Other trees	54.398	320.036	-265.638	488.32
11	Olives_1	1718.983	1746.747	-27.764	1.62
12	Palm trees	17.971	5.233	12.738	-70.88
13	Water	0.172	0.131	0.041	-23.84
14	Bad land2	375.832	161.041	214.79	-57.15

1. Agricultural area

1. Field Crops, Vegetables, and Plowed Land

According to Tables 4 and 5, a real emphasis on agricultural land use - the areas of field crops, vegetables, and plowed land - was a minor component of the total study area. In 2001, those three land types amounted to 2%, 1.1%, and 3.5% of the whole area, respectively. In 2021, the percentage of field crops reached 2.2%, that of vegetables - 2.2%, and plowed land decreased drastically to 0.2%.

The agricultural land plots could be traced mostly in the plains of Jenin, Tubas, Jericho, and other areas within the West Bank, but they were at different densities. Under normal circumstances, field crops require large areas of lands with gentle slopes since they are dependent on rainfall and the need for deep fertile soil. In turn, vegetable production, which is highly dependent on irrigation, requires a new set of environmental conditions that include a suitable slope and soil type as well as the availability of water resources.

A handful of issues have led to a limited scope of vegetable farming in the region. Among them are the decline in agricultural investment, the occurrence of negative environmental changes, loss of lands due to Israeli occupation, and being close to the separation wall, which besides imposing a lot of restrictions on farmers' access to their lands, makes it very difficult for them to reach their lands. Vegetables are very demanding in terms of care and irrigation, which makes them less attainable under such limitations as compared to field crops and olive trees, which require less intensive management.

Furthermore, it is worth emphasizing that plowed land is considered as one of the components of cultivated land, and the measured area of it varies significantly depending on the timing of the satellite imagery as farming is seasonal in nature.

Trees:

Trees made up 31.7% of the total area studied in 2001 and that figure went up to 36.7% in 2021. Of the tree categories, the olive trees had the widest area covered in comparison with fruit trees, citrus, almonds, and palm trees. Most of the governorates are covered with olive groves, which are also commonly mixed with other tree species like almond trees in the mountainous areas. On the other hand, palm trees are almost all in the Jordan Valley and Jericho in some farms that are specially designed for them. The classified satellite imagery revealed that there were some overlaps between different tree types as well as between tree cover and herbaceous or grassland areas.

Table 6 documents percentage changes and spatial expansion of agricultural land between 2001 and 2021. This covers field crops, plowed land, olive trees, palm trees, and other tree species, which together account for around 268.5 km² or 13% of the study area. The figures reflect the development of the areas in which field crops, olive trees, and other trees have been planted, while a decrease has been noted for palm trees and plowed land.

2. Natural Grasses and Rocks with Grass

Natural grasses directly covered only 8.8% of the area in 2001, which dropped to 2.3% in 2021. When including grasses growing among rocks, the total area of these two categories decreased from 22.3% in 2001 to 12.1% in 2021. This decrease has been mostly due to the urban expansion during the study period. However, natural grasses and rocky grasslands are still a considerable part of the land cover classes.

3. Forests

The forest cover in the West Bank was about 199.5 km^2 in 2001, which dropped to 149.0 km^2 in 2021. Their patches are scarce and, in general, are only found in a few places such as Umm al-Rihan and Arab al-Suwaytat in Jenin; Tubas and Ramallah are two other places.

4. Built-up Areas

During the period of urban expansion, built-up areas spread widely captured an area of 132.2 km^2 in 2001 and rising to 509.7 km^2 in 2021, thus explaining the rapid urbanization trend in the West Bank.

5. Rocky Lands and Quarries

Rocky lands and quarries made up 14.9% of the West Bank's total area in 2001, and it has only a slight decrease, to 14.1% in 2021. Such a high percentage is mainly due to the mountainous nature of the region. In the satellite images, the similar spectral characteristics of quarries and rocks led to the inclusion of quarries in this category.

6. Bad Lands

The area of bad lands (types 1 and 2), which was about 20.4% of the total area in 2001, has changed slightly and is now around 20.8% of the study area in 2021.

Summary of Non-Agricultural Land Cover Changes

The non-agricultural land cover types covering the same area as built-up areas, forests, bad lands (1 and 2), rocky lands and quarries, rocks and grasses, natural grasses, and water bodies have experienced a net loss of 268.5 km^2, or 7.5%, over the period from 2001 to 2021 as recorded in Table 6.

3.3 Classification Accuracy Assessment

The assessment of classification precision is an essential part of any remote sensing work. After the classification, the results obtained are verified by comparing them with ground truth data gotten from high-resolution aerial photos and Google Earth images. Several accuracy measures were taken to the task of evaluating the classification of the images of the West Bank:

1. Producer's Accuracy: This measure refers to the number of pixels correctly classified to a certain land cover type out of the total number of reference pixels of that land cover. The main function of this measure is to depict how the real land cover types are represented in the classification. It also indicates omission error (Raddad, 2017).
2. User's Accuracy: It shows the portion of pixels that belong to each land cover class that are also correctly classified by the classifier in each class compared to the total number of pixels that the classifier assigned to that class. In other words, it is the trustfulness of the classification reviewed by the user's eyes. Also, it stands for a commission error (Raddad, 2017).
3. Overall Accuracy: Overall accuracy is the ratio of correctly classified pixels across all land cover classes to the total number of pixels analyzed. It is derived from the error matrix by dividing the sum of the diagonal elements (correct classifications) by the total number of pixels in the matrix (Ghodieh , 2000)

Error Matrix

The error matrix, or confusion matrix, shows the agreement between classified pixels and reference (ground truth) data. It presents the number of correctly and incorrectly classified pixels for each land cover type in a table (Raddad, 2017). Table 7 presents the error matrix for the 2001 classified image.

Table 7

Error matrix for the year 2001

	BUA	Forest	FC	PL	BL1	RLAQ	RAG	NG	FC1	OT	Oli	PT	W	BL2	TOTAL	UA%
BUA	27	0	0	0	2	0	0	0	0	0	0	0	0	1	30	90
Forest	0	28	0	0	1	0	0	0	1	0	0	0	0	0	30	94
FC	0	0	29	0	0	0	0	0	1	0	0	0	0	0	30	97
PL	0	0	0	26	0	0	0	0	4	0	0	0	0	0	30	87
BL1	0	0	0	0	25	1	4	0	0	0	0	0	0	0	30	84
RLAQ	0	0	0	0	1	29	0	0	0	0	0	0	0	0	30	97
RAG	0	0	0	0	0	1	27	2	0	0	0	0	0	0	30	90
NG	0	0	0	0	2	0	1	27	0	0	0	0	0	0	30	90
FC1	0	0	2	0	0	0	0	0	28	0	0	0	0	0	30	94
OT	0	0	0	0	0	0	0	0	1	27	2	0	0	0	30	90
Oli	0	0	0	0	0	1	0	0	0	1	28	0	0	0	30	94
PT	0	0	0	0	0	1	0	0	0	0	1	28	0	0	30	94
W	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	100
BL2	0	0	0	0	7	0	0	0	0	0	0	0	0	23	30	77
TOTAL	27	28	31	26	38	33	32	29	35	28	31	28	10	24	400	
PA%	100	100	94	100	66	88	84	93	80	96	90	100	100	96		

Table 8

Error matrix for the year 2021

	BUA	Forest	FC	PL	BL1	RLAQ	RAG	NG	FC1	OT	Oli	PT	W	BL2	TOTAL	UA%
BUA	26	0	1	0	2	0	0	0	0	1	0	0	0	0	30	87
Forest	0	29	0	0	0	0	0	0	1	0	0	0	0	0	30	97
FC	0	0	30	0	0	0	0	0	0	0	0	0	0	0	30	100
PL	0	0	0	30	0	0	0	0	0	0	0	0	0	0	30	100
BL1	0	0	1	0	28	1	0	0	0	0	0	0	0	0	30	94
RLAQ	0	0	0	0	0	30	0	0	0	0	0	0	0	0	30	100
RAG	0	0	1	0	0	0	28	1	0	0	0	0	0	0	30	94
NG	0	0	0	0	1	0	0	29	0	0	0	0	0	0	30	97
FC1	0	0	0	0	0	0	0	0	30	0	0	0	0	0	30	100
OT	1	0	5	1	0	0	0	0	1	21	1	0	0	0	30	70
Oli	0	1	0	0	0	0	0	0	0	0	29	0	0	0	30	97
PT	0	0	0	0	0	0	0	0	0	0	0	30	0	0	30	100
W	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	100
BL2	1	0	0	0	3	0	0	0	0	0	0	0	0	26	30	87
TOTAL	28	30	38	31	34	31	28	30	32	22	30	30	10	26	400	
PA%	93	97	79	97	82	97	100	97	94	95	97	100	100	100		

The previous abbreviations in tables 7 and 8 mean the following:

BUA = Built-up area

FC = field crops

PL = ploughed land

BL1 = bad land1

RLAQ = rocky land and quarries

RAG = rocks and grass

NG = Natural grass

FC1 = field crops1

OT = other trees

OLI = olives_1

PT = palm trees

W = water

BL2 = bad land2

UA% = User Accuracy

PA% = Producer Accuracy

TS = Total Sample

TCS = Total Corrected Sample

Statistical Accuracy Assessment: Kappa Coefficient

Among the primary statistical methods for evaluating the accuracy of classified images is the Kappa Coefficient. This measures the agreement between two classifications, considering all elements of the error matrix and correcting for chance agreement (Raddad, 2017).

$$Kappa\ Coefficient = \left((TS * TCS) - \sum(\ Column\ Total * Row\ Total) \setminus TS^2 - \sum(Column\ Total - Row\ Total)\right) * 100$$

Percent Correct (Overall Accuracy)

Percent correct, or overall accuracy, is calculated as the ratio of correctly classified cells (diagonal elements in the error matrix) to the total number of samples used for accuracy assessment.

Accuracy Assessment Procedure

This study employed the error matrix to estimate classification accuracy for satellite images from 2001 and 2021. A total of 30 sample cells were chosen for each land cover class, except for the water class since it had only 10 samples because of its limited area in the West Bank. This resulted in a total of 400 samples for all classes.

- Each column in the error matrix represents the reference (true) land cover category.
- Each row represents the classified land cover category.
- The diagonal cells represent the correctly classified samples.

Results for 2001

- Sum of correctly classified samples:
  27+28+29+26+25+29+27+27+28+27+28+28+10+23=362
- Overall Accuracy:
  362/400= 90.5%
- Kappa Coefficient = 83.13%

Results for 2021:

- Sum of correctly classified samples:
  26+29+30+30+28+30+28+29+30+21+29+30+10+26=376
- Overall Accuracy:
  376/400 = 94%
- Kappa Coefficient = 86.66%

Summary

The classification accuracy was 90.5% for the 2001 image and improved to 94% for the 2021 image, showing a high classification reliability. The Kappa coefficients were also 83.13% in 2001 and 86.66% in 2021, showing strong agreement.

Challenges of Conducting Supervised Classification in the West Bank:

The process of supervised classification in the West Bank is hindered by a variety of challenges: technical, field, political, and analytical. From a technical standpoint, the similarity of the spectral reflections often leads to situations where confusions between rocky areas, quarries, stone buildings, cultivated land, and barren surfaces are made, as well as between rocky and vegetated areas. Another drawback is the limited number of cloud-free satellite images; thus, for both 2001 and 2021, only one suitable image from June was available. Changes in vegetation throughout the year also cause the classifications in just one period to be not representative of the whole year. Besides that, the 30-meter spatial resolution of the images is not enough to separate small-scale agricultural patterns within the villages.

From a field point of view, it is challenging to get to Area C, which is still under Israeli control, and collect ground data. Politically, rapid settlement expansion and frequent land-use changes make it impossible to keep data updated without doing it constantly. In general, these factors determine the classification accuracy. Precision is also affected by the number of training samples; the larger the sample size, the higher the classification accuracy will be. Field verification, instead of only relying on aerial images, is a must if we want to have high-resolution and reliable land-cover mapping in the West Bank.

Chapter Four

Changes in Vegetation and Agricultural Cover and the Factors Affecting Them

4.1 Land use and land cover

Land cover maps from satellite images look for changes at the pixel level by checking each pixel separately over time. This very detailed comparison yields a lot of valuable information about the changes in land cover. Mapping land cover is necessary because it gives the basic data of the Earth's surface features and their spatial distribution (Kumar, et al., 2022).

Table 9

Vegetation cover, agricultural area, and urban mass in the West Bank for the years 2001 and 2021

vegetation cover	Area (km²) in 2001	%	Area (km²) in 2021	%
Built-up area	132.215	2.3	509.669	9
Forest	199.485	3.5	149.043	2.6
Field crops	11.962	2	125.218	2.2
Plowed land	199.72	3.5	11.952	0.2
Field crops1	63.565	1.1	125.897	2.2
Other trees	54.398	1	320.036	5.7
Olives	1718.983	30.4	1746.747	30.9
Palm trees	17.971	0.3	5.233	0.1
Natural grass	494.13	8.8	132.036	2.3

Table 9 shows increased urban mass and an increase in vegetation cover, with the exception of the forests. The significant growth in urban areas over the 20 year period is due to its population growth.

4.2 Analysis of Land Use, Land Cover, and Vegetation Cover in the Study Area

The classification of agricultural lands in the study area is shown in Figure 11 and Table 10. The total land area of high agricultural land was nearly 532.20 km², medium-value agricultural land had an area of about 1,540.36 km², and low-value agricultural land made up an area of approximately 3,524.11 km². The forested area was about 55.43 km². It can be said that the greatest part of the high-value agricultural land was mainly in the regions of Jenin, Tubas, and Jericho.

Table 10

Agricultural Land Classification Areas in the West Bank

Agriculture Land Classification	Area (Km²)
Land of High Agricultural Value	532.1996
Land of Medium Agricultural Value	1540.359
Land of Low Agricultural Value	3524.109
Forest	55.43036

The land cover classification map presents the various land cover types of the West Bank that span 35 different categories such as natural grasslands, forests, agricultural land with natural vegetation, and other land cover classes, as can be seen in Figure 12. Table 11 gives a comprehensive description of all the land covers along with their areas.

The agricultural land classification map was merged with the land cover classification map using the overlay function, and the data were combined through the frequency command, thus resulting in the creation of Tables 12, 13, 14, and 15. These tables demonstrate the area of each land cover type based on the agricultural land classification derived from geological data.

As an example, the forest area shows a mixture of different land covers quality-wise, although the total area of the land is small. The classification explains the composition of built-up areas, natural grasslands, agricultural lands, and other categories, with forests making up the major part at about 54.39 km² (Table 12).

The high-value agricultural lands table brings out the diversity and the extent of vegetation cover with agricultural land with natural vegetation covering approximately 12.53 km². It is a place where the areas of arable land, both irrigated and non-irrigated, are detailed with a view to showing the potential for reclamation and cultivation. Moreover, segments of lands classified as rocks and grass may be reclaimed for expanding agricultural areas in the study region besides natural grasslands.

In medium-value agricultural lands, the area covered by olive trees is the largest extent of about 606.16 km². On the other hand, agricultural land with natural vegetation covers roughly 469.49 km², which is more than the area in high-value lands. It most probably explains that the total area of medium-value agricultural lands is bigger than that of high-value lands as shown in Table 14. Both irrigated and non-irrigated lands within this group can be used for different agricultural purposes such as field crops and fruit tree cultivation. Besides this, the natural grass covering, rocks, and weed-covered lands can be reclaimed depending on the type of soil and its suitability.

In the case of low-value agricultural lands, the main covers are natural grass and rocks, with the areas of about 1,327.63 km² and 1,139.80 km², respectively. Anyway, the agricultural land in this group is close to 207.97 km² which shows the possibility of reclamation dependent on the characteristics of the soil and the availability of rain.

4.3 Summary of Results from Supervised Classification Analysis Using Remote Sensing and Official Data

The land cover classification map presents the various land cover types of the West Bank that span 35 different categories such as natural grasslands, forests, agricultural land with natural vegetation, and other land cover classes, as can be seen in Figure 12. Table 11 gives a comprehensive description of all the land covers along with their areas.

The agricultural land classification map was merged with the land cover classification map using the overlay function, and the data were combined through the frequency command, thus resulting in the creation of Tables 12, 13, 14, and 15. These tables demonstrate the area of each land cover type based on the agricultural land classification derived from geological data.

As an example, the forest area shows a mixture of different land covers quality-wise, although the total area of the land is small. The classification explains the composition of built-up areas, natural grasslands, agricultural lands, and other categories, with forests making up the major part at about 54.39 km² (Table 12).

The high-value agricultural lands table brings out the diversity and the extent of vegetation cover with agricultural land with natural vegetation covering approximately 12.53 km². It is a place where the areas of arable land, both irrigated and non-irrigated, are detailed with a view to showing the potential for reclamation and cultivation. Moreover, segments of lands classified as rocks and grass may be reclaimed for expanding agricultural areas in the study region besides natural grasslands.

In medium-value agricultural lands, the area covered by olive trees is the largest extent of about 606.16 km². On the other hand, agricultural land with natural vegetation covers roughly 469.49 km², which is more than area in high-value lands. It most probably explains that the total area of medium-value agricultural lands is bigger than that of high-value lands, as shown in Table 14. Both irrigated and non-irrigated lands within this group can be used for different agricultural purposes such as field crops and fruit tree cultivation. Besides this, the natural grass covering, rocks, and weed-covered lands can be reclaimed depending on the type of soil and its suitability.

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Reasons for Differences Between Remote Sensing and Official Data. Remote sensing (RS) identifies different land covers by using the spectral signature of a satellite image taken at a certain time. On the basis of pixel reflectance, it changes these different factors: cultivated land, plowed land, bare soil, and vegetation cover.

Official data, on the other hand, is more concentrated on land use, giving functional categories as classification of the land such as irrigated vs. non-irrigated agricultural land, or agricultural land with natural vegetation, regardless of the current spectral appearance.

As an instance:

The RS classification identified 263.07 km² as agriculture and plowed land. While official data cited 690.15 km², since geomatics not only records the current state of the land but also considers the areas that are designated for agriculture even if they are not currently cultivated or visible in the satellite image.

In the same way, RS might label a piece of arable land that has not been cultivated for some time as "bad land" based on the color of the spectra, while official data use the land-use concept to differentiate.

Additional Observations:

The RS classification figured out that barren land accounted for 1,172.03 km². On the other hand, official data, which can combine different categories such as "bad land" and natural grasses, has the area of similar land covers with rocks and grass equal to 1,515.75 km². Also, the changes can be found in the areas of forest and tree cover (olive trees, vineyards, citrus, etc.) as a result of the application of different criteria for classification.

Land Use and Cultivation Dependent on External Factors:

Except for the differences in the classification, there are still a lot of external factors that influence land reclamation and agricultural practices. Among them is the Israeli occupation that restricts access to and the management of a large number of the West Bank lands, especially Area C, thus making the farmers' ability to cultivate and take care of their lands in an effective way very limited.

4.4 Obstacles Imposed by the Israeli Occupation Affecting Vegetation Cover in the West Bank

Indications are that Israeli occupation has been the main factor in the West Bank which led to most of the changes in land use policy by decreasing the area's vegetation cover through various repressive and exploitative practices. These comprise plotting for illegal settlements on confiscated lands and constructing the bypass roads, mostly resulting from closing roads to secure 'security' reasons. In addition, farmers in Palestine are continually losing their lands hence less crop diversity, soil depletion, and a slower gradual revival of vegetation health (Abdallah & Swaileh, 2011).

The construction of the separation wall has been one of the most harmful issues which the Israeli occupation has resorted to; this wall meanders along the 1967 border. In essence, the barrier has created new enclaves of farmlands and nature reserves while at the same time Israel is allowed to dominate the main water sources in the area (Abdallah & Swaileh, 2011).

The administrative arrangements after 1967 leading to the division of the West Bank into Areas A, B, and C have also contributed to complicating the issue. The segregation can be better understood from Figure (13), which demonstrates the separation frontier and how it keeps widening every year thus creating an environment for more settlements and settlers (Al-Akhras & Amr, 2023).

Currently, the Israeli government has the authority to use almost 2,380 km² of Palestinian land, which is equivalent to 42% of the West Bank, and 68.7% of Area C. The latter alone is 61% of the West Bank's total surface, under Israeli civil and military control, while Area A (17.6%) and Area B (18.4%) have a different degree of Palestinian administration and security jurisdictions (Al-Akhras & Amr, 2023).

Among such categorizations, land under the Israeli administration can be used for colonial projects and expansion without any limitation. It can be opened up for setting new settlements, given to settlers for farming, or converted into state land or nature reserves, without the least bit of consideration for the rights of Palestinians. Just in the year 2022, Israel detained 26,000 dunums of Palestinian agricultural land under various kinds of legal pretexts. The situation escalated when it was found that 120,000 dunums of agricultural land are in the hands of settlers and since 1967, the Israeli government has converted almost 31% of Palestinian territory into “state land” that is reserved for the use of the government (Al-Akhras & Amr, 2023).

These processes have greatly contributed to the environment in the area suffering over a long time. The West Bank experienced a substantial loss of forest and other vegetated areas, which had been going since 2001, up to 2023 when vegetation was left with only 21 hectares, which is general shrinkage of the vegetation cover. The deterioration of the local environment occurred despite the calls made by various nations, among them the UN Security Council Resolution 2334 (2016), which updated the resolution that states that Israeli settlements on occupied territory are illegal (Al-Sharif, 2024).

4.5 Israeli Occupation Control of Palestinian Water Resources

The area under study suffers from scarce water supply, among other reasons, as the Israeli occupation has total control over the Palestinian water resources. Since 1967, the occupation authorities have been limiting wells that are drilled, as well as the construction of water distribution networks all over the West Bank. These limitations have sharply cut down Palestinian development and access to water sources that are safe and reliable.

As a result of the Israeli occupation, the Palestinians are being deprived of around 80% of their groundwater resources, hence, their right to fair and sovereign utilization of Palestinian water is being violated (ARIJ, 2015). This has had a significant effect on agriculture, the supply of drinking water, and the natural environment, especially in the rural areas and villages that rely on groundwater for irrigation.

Since 1967, the Israeli occupation has imposed draconian restrictions on the Palestinians' access to land and natural resources. More than half (55%) of the West Bank has been turned into areas closed for military purposes or restricted zones, so Palestinians are not allowed to use these lands (ARIJ, 2015). In terms of water, Palestinians are only allowed to have access to 15% of the total water resources available in the West Bank. These limitations have made it difficult to develop agriculture and to have access to drinking water, particularly in the villages and remote areas.

The occupation forces are lengthening their illegal settlements to grab more and more Palestinian lands, mainly fertile agricultural land, thus exacerbating the crisis of water and land resources (ARIJ, 2015)). In an interview with Shabab FM Radio in 2024, Dr. Ahmed Ghodieh spoke about the water crisis in the West Bank and emphasized that clean water is a basic human right. He said that with a growing population in the study area, the demand for water had gone up drastically, no matter if the water was used for drinking, agriculture, or industry.Groundwater, which amounts to 30% of total yearly precipitation, is still the main source of drinking water in the West Bank.

Dr. Ghodieh explained that though WHO recommends an average per capita water supply of 100 liters per day, the Palestinians only get 30-60 liters each day due to the restrictions imposed by the occupation. On the other hand, an average Israeli consumes 353 liters daily, and Israeli settlers in the West Bank use 200 liters. These inequalities have led to the worsening of the water crisis.

After the establishment of the Palestinian Authority in 1996, Israel dams have been constructed by the occupation in the valleys that feed the Gaza Strip, thus prohibiting the flow of water to the Palestinian areas. Moreover, the Apartheid Wall built in 2002 has resulted in the closure of several wells leading to the loss of water from the underground of about 10 million cubic meters annually, while another 90 million cubic meters may be lost as a result of drilling limitations beyond the wall.

In addition to rivers and lakes, the sources of fresh water have also been decreasing due to increased salt content, as well as the denial of permissions for drilling. Many wells are allowed a maximum of 140 meters in depth, which is not sufficient for the sustainable extraction of water. Dr. Ghodieh drew attention to the significant increase of salinity in the Jordan River coming from 600 ppm in 1925 to 5,000 ppm today and the chloride concentration in the Jericho area, which soared from 24 mg/L to 1,365 mg/L.

Contrary to the Oslo Accords, where Palestinians were to be allotted a water quantity of 235 million cubic meters, of which 80 million cubic meters were to come from the Eastern Aquifer Basin, Palestinians have only been allowed by Israel to utilize 130 million cubic meters, far from the agreed volume. Currently, the per capita share is just about 30 liters a day for the poorest communities in the West Bank, which is far less than the international minimum standards.

Moreover, the water infrastructure in the West Bank is in a poor condition. 38% of the drinking water is lost due to leakage and bad servicing. Besides, Israel is exploiting water resources in the West Bank and selling water to the Palestinian municipalities through companies like Mekorot, while at the same time, it is forbidding the Palestinians from drilling new wells, building reservoirs, or putting up environmentally friendly water infrastructure.

For instance, in the Jordan Valley alone, Israeli settlers possess 40 water wells from where they extract an annual volume of water that is estimated at 44 million cubic meters, thus they make the water distribution deficient more than it was before.

Dr. Ghodieh mainly emphasized the necessity of the adoption of modern methods in solving water problems. The most crucial are:

Put only the necessary amount of water can drip irrigation, and for example, the installation of drippers.

Without overloading the water system with pollutants reinforced by water treatment plants, resist wastewater reuse for irrigation.

Make water network resources more efficient through the constant repairs of pipelines and by experts.

In addition, locally, it is still feasible to think about new, especially artesian, household well drillings.

Critical emphasis should be laid upon the spreading of drip irrigation methods which have been proven to be conducive to water saving and agricultural productivity in times of scarcity.

4.6 Solutions for Water Conservation and Enhancing Agricultural Production

Water scarcity is still one of the most serious problems that endangers the future of agricultural production in the West Bank. The limited water access, which has been worsened by political restrictions and Israeli control over the water sources that are shared, has made it very difficult to both the extension and the maintenance of the irrigated agricultural lands. The competition for water between the domestic, industrial, and agricultural sectors is the main reason for the worsening of this problem.

As per (ARIJ, 2015), Palestinians are entitled to only 125 million cubic meters of water yearly for all kinds of uses. Out of that amount, 93 MCM is reserved for agricultural irrigation, which only covers 6% of the cultivated land area of the West Bank. It is clear to see that Israel, on the other hand, is controlling 1,252 MCM of water per year, which enables her to irrigate about 62% of her agricultural land. Apart from that, the Israeli occupation is also allowed to take an extra 80 MCM per year from the Palestinian water sources. This stolen volume is equivalent to 26.8% of the water used on Palestinian agricultural land, which is mainly located in illegal Israeli settlements in the West Bank (ARIJ, 2015).

Such a drastic shortage has made Palestinian farmers to use revolutionary agricultural and irrigation methods with the intention of saving water. One of the methods is the change of surface irrigation which is 55% water-use efficiency to drip irrigation and achieves 84% efficiency (ARIJ, 2015).

Drip Irrigation Systems

Drip irrigation is a water-saving system that supplies water right to the plant's root zone by means of small holes called drippers or emitters. The latter let out water very gradually, either non-stop or at scheduled times (daily or every other day). Such a precise method keeps the soil close to the roots wet while it is dry from the sun in other places, thus water is saved, and plants become fertile (Abeid-Allah, 2017).

Different types of drip irrigation systems are currently implemented in the West Bank (Abeid-Allah, 2017):

- Surface Drip Irrigation: The tubes are located on the soil surface and are capable of producing between 4 and 24 liters per hour. Good for different kinds of vegetable and fruit crops.
- Subsurface Drip Irrigation: Tubes are buried at various depths depending on the soil and crop requirements. Generally, it is used for trees and helps the trees to be more durable and also cuts off the manure waste to half or less.
- Bubbler System: It is a device for the mature trees that have been formerly irrigated by the flooding method, and now this system provides larger volumes, up to 300 liters per hour, while improving control and efficiency.
- Microjet System: This is a widely spaced family of the tree-perfect-farm-system, which irrigates a broader area and consumes between 30 and 100 liters per hour.

Advantages of Drip Irrigation:

By the use of drip irrigation throughout the Palestinian agriculture, various kinds of benefits and advantages can be gained such as:

- Efficient Water and Fertilizer Use: Farmers can manage water and nutrient delivery accurately and in this way the water friendly farmers lose 30–35% of water, which is avoided.

- Improved Crop Yields: The vegetables' airway is going to be adjusted through the proper moisture control and the vegetable yields can be increased by 60% while the fruit yields by 50%.
- Salinity Management: Continually applied little amounts of water prevents salt deposits in the root zone; Besides, salty water can be used without any difficulties if the leaves are not wetted.
- Labor and Energy Savings: A drip system consumes less energy, thus, less labor is required. Operating water pressure is low, unlike sprinkler systems that require very high water pressure.
- Disease and Weed Control: The method of drip irrigation minimizes the soil that is going to be watered, hence, weed growing and soil-borne diseases infestations decrease.
- Decrease Drainage and Runoff: Precisely watering the plants implies less water can be wasted due to runoff and soil erosion.

4.7 The Normalized Difference Vegetation Index NDVI

The Normalized Difference Vegetation Index (NDVI) is the primary remote sensing parameter that can be retrieved from satellite images for deforestation or any other types of environmental changes. These changes include desertification, soil erosion, and wildfires. NDVI in this research is used to study the dynamics of vegetative cover in the West Bank from the year 2001 to 2021 (Raddad, 2017). The NDVI is derived from reflectance values of red (R) and near-infrared (NIR) spectral bands, employing the feature of lower reflectance of red light and higher reflectance of NIR by healthy vegetation. This spectral behavior makes it possible to separate vegetated areas from non-vegetated ones with high accuracy (Ghodieh, 2023). The formula employed is:

NDVI = (NIR − Red) / (NIR + Red)

For Landsat satellites, the calculation is as follows:

- Landsat 7: NDVI = (Band 4 – Band 3) / (Band 4 + Band 3)
- Landsat 8: NDVI = (Band 5 – Band 4) / (Band 5 + Band 4) (Baroud, 2019)

The NDVI values range from -1 to +1, explained as follows:

- 1 to 0.0: Water bodies
- 0.1 to 0.1: Barren land, rocks, sand, or snow
- 0.2 to 0.5: Grasslands, shrubs, or senescing crops
- 0.6 to 1.0: Dense vegetation and tropical forests (Baroud, 2019)

If a plant is healthy, it reflects most NIR and also absorbs red light. On the other hand, a diseased plant shows more red and absorbs more NIR. This makes NDVI a powerful indicator of vegetation health.

In the study area, the NDVI analysis reveals the following:

- In 2001, NDVI values ranged from -0.40 to 0.50**.**
- In 2021, NDVI values ranged from -0.36 to 0.54**.**

The positive NDVI value changed from 0.50 to 0.54, thus slightly increasing the vegetation density. The change is important considering the situation of land and water constraints. The range of NDVI values is shown in Figures (15) and (17) and explained in detail in Tables (16) and (17). In both years, the areas covered with vegetation were mainly the north and the west of the West Bank, while the east remained sparsely vegetated as a result of its dryness. The northwest was the area with the most dense vegetation cover.

Vegetation Cover Area

2001: The total vegetation cover area was approximately 405 km²**,** including:

- Fairly dense vegetation: 397 km²
- Dense vegetation: 8 km²
- Remaining land (urban, rocky, aquatic, quarries, and natural): 5,238 km²

2021: The vegetation cover increased to 794.52 km²**,** including:

- Fairly dense vegetation: 788.25 km²
- Dense vegetation: 6.27 km²
- Remaining land types: 4,850.43 km²

The positive NDVI value widened from 0.50 to 0.54, thus slightly increasing the vegetation density. The change is very significant if one considers the conditions of land and water that are limiting. The range of NDVI values is presented in Figures (15) and

(17) and elaborated in detail in Tables (16) and (17). In both years, the areas covered with vegetation were mainly the north and the west of the West Bank, while the east was still sparsely vegetated due to its dryness. The northwest was the area with the highest vegetation density cover.

Challenges and Obstacles Affecting Vegetation and Agricultural Cover in the Study Area:

The Israeli occupation is one of the biggest problems that the study area has been facing for a long time. It is well known that the whole of Area C is still under the absolute control of Israel, so the access to and the use of large tracts of agricultural land are limited. The confiscation of land is being extended further, and the supply of water is decreasing because Israel controls the main water sources. Moreover, the crossing from one part of the West Bank to another is limited due to the presence of external roadblocks and security checkpoints. There are many places, especially those that are in the mountains or far from the center, which are hard to reach because of the army's restrictions.

The researcher had difficulty obtaining the latest yearly data from the geological survey and other official institutions like the Ministry of Local Government, the Ministry of Agriculture, and the Meteorological Department. The personal visit to these institutions was made more difficult by the existence of the military checkpoints and the limited movement between different areas of administration.

Chapter Five

Results and Recommendations

5.1 Results

These research results clearly show how essential Geographic Information Systems (GIS) and remote sensing (RS) are to the vegetation monitoring and highly accurate land cover mapping of the West Bank.

The supervised classification accuracy in 2001 was 90.5%, and this accuracy has been improved further up to 94% in 2021, which confirms that the instruments used are reliable and robust for land cover interpretation over time. These high accuracy levels with good κ coefficients show that minor spatial and temporal variations in land cover are well captured by GIS and remote sensing.

On their own, GIS and remote sensing are two powerful and complementary methods: remote sensing can provide up-to-date, high-resolution images of large and diverse landscapes, while GIS allows detailed spatial analysis, integration with auxiliary datasets, and production of thematic maps in the most comprehensive way. This integrated approach gives researchers and decision-makers the ability to identify, monitor, and quantify changes, land cover classes, and environmental trends with a level of efficiency and reliability far beyond that of traditional methods.

Besides that, the utilization of these technologies bears tremendous practical benefits. It is very easy to see how it drastically reduces the time, labor, and money that are necessary for the difficult job of data collection and analysis in areas where steep terrain, rocky ground, or low accessibility would make ground-based surveys impossible or very difficult.

Being the source of ongoing monitoring and long-term comparisons, such as the 2001–2021 datasets investigated here, GIS and remote sensing are not just offering accurate current images of land cover but also revealing essential trends, such as the continuous decrease of vegetation cover and the increase in bare land. These insights are priceless in guiding sustainable land management strategies, informing policy decisions, and facilitating the prioritization of conservation and reclamation efforts in the West Bank's unique and politically sensitive landscape.

Results Related to Satellite Image Classification of the West Bank:

The analysis classified the satellite images into 14 land cover categories, constituting the main land types in the West Bank, and led to a very accurate mapping result. Accuracy of classification changed depending on the sample area and spectral differences between land cover classes. In particular, rocky lands and quarry areas were always identified with high precision both in 2001 and 2021 because of their distinctive spectral signatures. Vegetation cover represented 50.6% of the area in 2001 and dropped slightly to 46.2% in 2021, while non-vegetated land, such as built-up areas, rocky lands, quarries, badlands, and areas that are either sparsely vegetated or water-covered, increased from 49.4% to 53.8% during the same period.

The accuracy of these results was confirmed by supervised classification methods, which were validated against geological data and land cover assessments in ArcMap 10.8. The analysis also recognized the impact of the Israeli occupation, which continues to dominate the scene, including the confiscation of 26,000 dunums of agricultural land in 2022 alone, thus significantly affecting land use patterns and the distribution of vegetation. NDVI analysis showed a slight recovery of vegetation density, with the highest values increasing from 0.50 in 2001 to 0.54 in 2021, and the lowest values improving from -0.40 to -0.36 over the same period.

5.2 Recommendations

Based on the findings, some recommendations have been drafted to help in the West Bank to propagate the sustainable land and vegetation management practices. Firstly, digital mapping and remote sensing should be deeply embedded in the working processes of universities, research institutions, ministries, municipalities, and planning bodies and should be accompanied by a bank data system to facilitate the next research and spatial planning. The local and central authorities should use GIS not only to produce but also to maintain up-to-date and detailed maps and interlink these for efficient planning. Government entities and decision-makers are invited to implement these proposals to conserve the green cover, polish the soil, and improve the topographic features and at the same time encourage further research.

The measures should include reclaiming of lands that are barren and full of rocks and afforestation in these areas not only to prevent further confiscation but also to conserve fertile agricultural lands by the urban spread through the check of the issuing of building permits and by the adoption of the cultivation through the targeted incentives. It is also very important to enlarge the agricultural lands and to increase the crops variety. The focus should be on soil reclamation and local products through modern agricultural methods with the aim of food self-sufficiency and the possible exporting of the surplus. The Ministry of Agriculture and agricultural specialists should organize hands-on workshops and provide farmers with up-to-date knowledge concerning water-saving irrigation techniques, the implementation of organic fertilizers, and the use of environmentally-friendly methods of agriculture. Additionally, the development of water resources can be supported through the building of dams for rainwater collection, and the introduction of desalination technologies to the saline groundwater can assure the future irrigation needs.

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Appendices

Appedix A

Tables

Table 11

The land cover classification area in the West Bank

Land Cove	Area (Km²)
Water Bodies	0.612053
Non-Irrigated Complex Cultivation	213.0714
Agriculture Land with Natural Vegetation	592.1734
Non-Irrigated Arable Land	251.1911
Olive Groves	751.5867
Pannana Plantation	0.338471
Palm Groves	5.714734
Forest	59.15769
Others	2.451679
Vineyards	81.98565
Refugee Camps	6.839348
Citrus Plantations	11.02255
Dump Site	0.041114
Mineral Extraction Sites	15.85534
Green Urban Areas	1.4666
Transitional Woodland	25.91706
Sport & Leisure Facilities	2.564863
Drip Irrigated Arable	89.28559
Military Camps	8.177274
Natural Grass Land	1489.991
Open spaces with little or no vegetation	1278.91
Fruit Trees	3.0411
Discontinuous Urban Fabric	436.2736
Continuous Urban Fabric	12.0886
Sea and Ocean	180.3138
Beaches & dunes	19.98798

Bare Rock	17.8719
Drip Irrigated Vineyards	17.22806
Irrigated Complex Cultivation Practices	96.4001
Salt Marshes	7.094152
Colonies	108.4436
Salinas	0.782355
Construction Sites	8.26221
Halophytes	39.85764
Industrial or Commercial Unit	3.65753

Table 12

The land cover area according to the agricultural land classification (forest).

Land Cove classification	Agricultural land classification	Area (Km²)
Continuous Urban Fabric (built-up area)	Forest	0.0153
0ther trees	Forest	0.0002
Olive trees	Forest	0.0371
Colonies	Forest	0.0529
Irrigated arable land	Forest	0.0065
Agriculture Land with Natural Vegetation	Forest	0.16
Rocks and Grass	Forest	0.2084
Natural Grass Land	Forest	0.4614
Forest	Forest	54.3901

Table 13

Shows the land cover area according to the agricultural land classification (Land of High Agricultural Value).

Land Cove classification	Agriculture land classification	Area (Km^2)
Rocky land	Land of High Agricultural Value	0.0415
Water Bodies	Land of High Agricultural Value	0.0005
Other trees	Land of High Agricultural Value	33
Continuous Urban Fabric (built-up area)	Land of High Agricultural Value	11.694
Forest	Land of High Agricultural Value	0.1404
Transitional Woodland	Land of High Agricultural Value	0.2647
Others (bad land)	Land of High Agricultural Value	0.569
Colonies	Land of High Agricultural Value	4.025
Palm trees	Land of High Agricultural Value	5.0917
Agriculture Land with Natural Vegetation	Land of High Agricultural Value	12.5339
Irrigated arable land	Land of High Agricultural Value	141.8766
Non-Irrigated Arable Land	Land of High Agricultural Value	261.55
Halophytes	Land of High Agricultural Value	1.0793
Olive trees	Land of High Agricultural Value	14.555
Rocks and grass	Land of High Agricultural Value	16.7219
Natural Grass Land	Land of High Agricultural Value	16.9883

Table 14

The land cover area according to the agricultural land classification (Land of Medium Agricultural Value).

Land Cove classification	Agricultural land classification	Area (Km^2)
Discontinuous Urban Fabric (built-up area)	Land of Medium Agricultural Value	71.1929
Non-Irrigated Arable Land	Land of Medium Agricultural Value	43.6954
Agriculture Land with Natural Vegetation	Land of Medium Agricultural Value	469.49
Irrigated arable land	Land of Medium Agricultural Value	15.2531
Halophytes	Land of Medium Agricultural Value	3.3629
Rocks and grass	Land of Medium Agricultural Value	120.6902
Natural Grass Land	Land of Medium Agricultural Value	143.7258
Olive trees	Land of Medium Agricultural Value	606.1638
Rocky land	Land of Medium Agricultural Value	0.536
Palm trees	Land of Medium Agricultural Value	0.1673
Forest	Land of Medium Agricultural Value	0.2215
Other trees	Land of Medium Agricultural Value	38.353
Others (bad land)	Land of Medium Agricultural Value	1.45
Colonies	Land of Medium Agricultural Value	45.6273
Transitional Woodland	Land of Medium Agricultural Value	19.7860

Table 15

The land cover area according to the agricultural land classification (Land of Low Agricultural Value).

Land Cove classification	Agricultural land classification	Area (Km²)
Other trees	Land of Low Agricultural Value	25.3068
Palm trees	Land of Low Agricultural Value	0.4557
Water Bodies	Land of Low Agricultural Value	0.637
Agriculture Land with Natural Vegetation	Land of Low Agricultural Value	207.97
Irrigated arable land	Land of Low Agricultural Value	28.4987
Non-Irrigated Arable Land	Land of Low Agricultural Value	60.2501
Halophytes	Land of Low Agricultural Value	35.2209
Others (bad land)	Land of Low Agricultural Value	24.9221
Forest	Land of Low Agricultural Value	4.2831
Transitional Woodland	Land of Low Agricultural Value	5.8546
Construction Sites (built-up area)	Land of Low Agricultural Value	391.3174
Rocky land	Land of Low Agricultural Value	33.152
Colonies	Land of Low Agricultural Value	107.3922
Olive trees	Land of Low Agricultural Value	130.6331
Rocks and grass	Land of Low Agricultural Value	1139.7973
Natural Grass Land	Land of Low Agricultural Value	1327.6330

Sources: The researcher worked on ArcMap 10.8 and data from Geomolg.

Table 16

NDVI value and NDVI classification for the West Bank in 2001.

NDVI Value	NDVI Classification
-0.41 - -0.23	Water
-0.23 – 0.05	Rocks and sand
0.05 – 0.13	Rocks, urban, and natural grass
0.13 – 0.31	Fairly dense vegetation
0.31 – 0.5	Density vegetation

Table 17

NDVI value and NDVI classification for the West Bank in 2021.

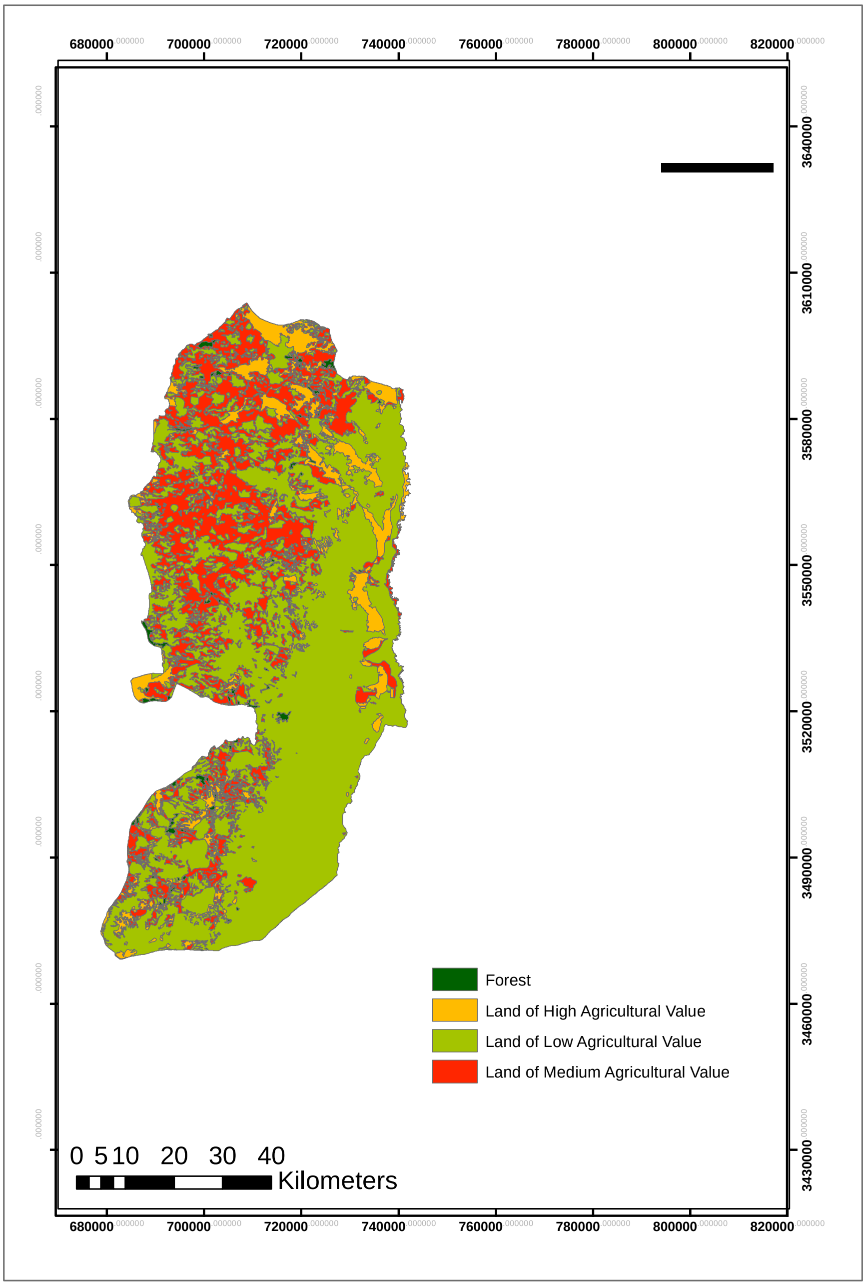
NDVI Value	NDVI Classification
-0.40 - - 0.211	Water
-0.211 - - 0.0215	Rocks and sand
0.0215 – 0.168	Rocks and urban, and natural grass
0.168 – 0.357	Fairly dense vegetation
0.357 – 0.546	Density vegetation

Appendix B

Figures

Figure 11

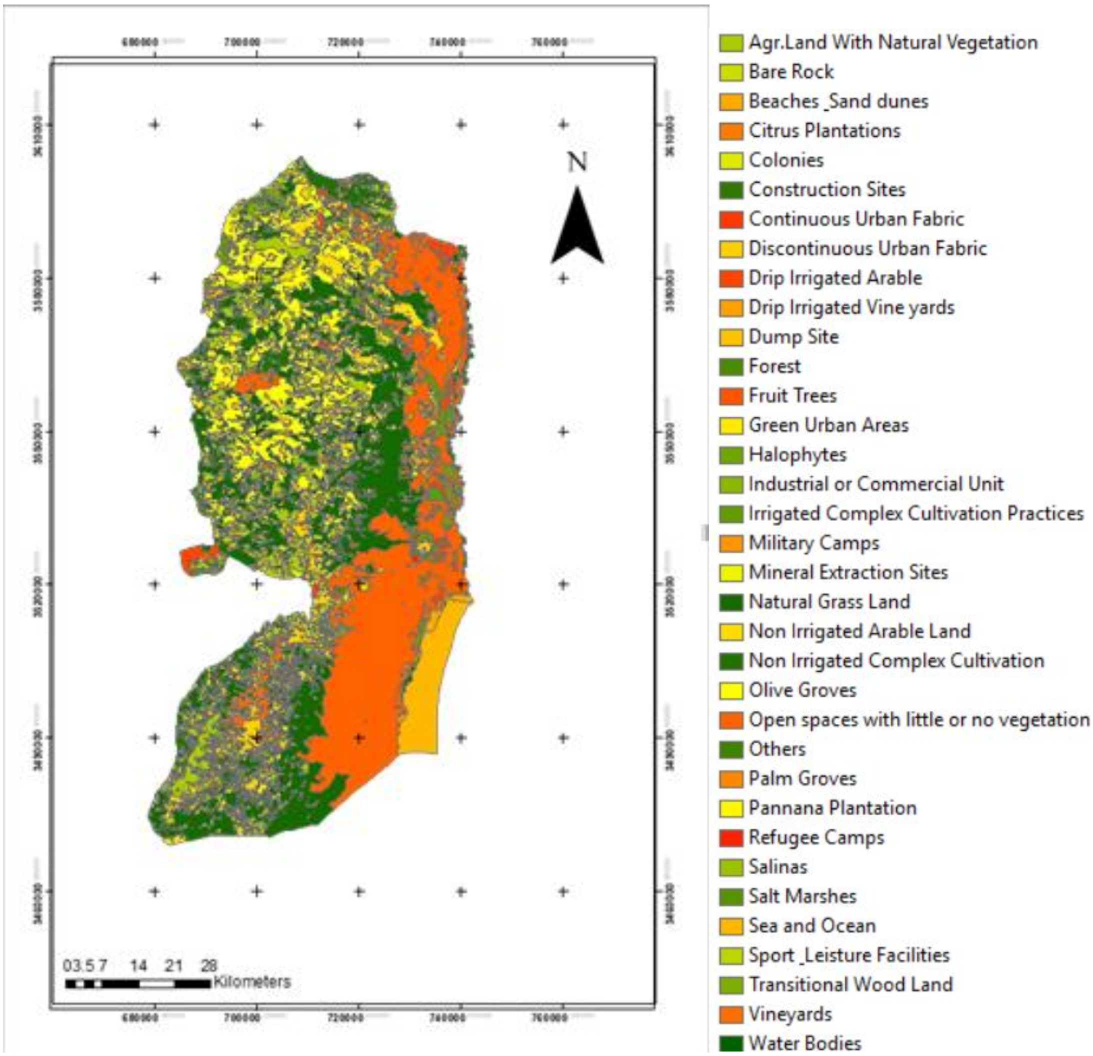
Land Cover Classification of the West Bank.



Sources: https://geomolg.ps/L5/index.html?viewer=A3.V1.

Figure 12

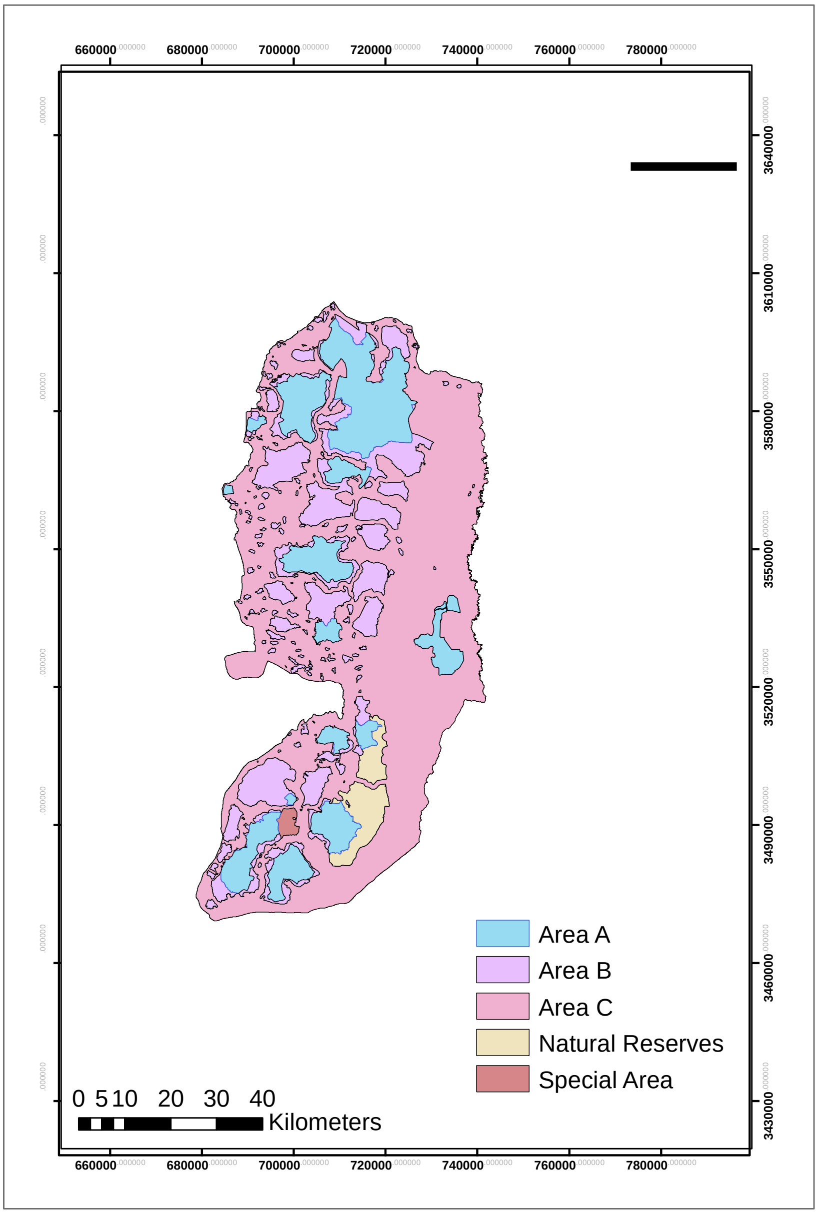
Land Cover Classification of the West Bank.



Sources: https://geomolg.ps/L5/index.html?viewer=A3.V1.

Figure 13

Areas A_B_C in the West Bank. Based on the Oslo Interim Agreement in 1993



Sources: https://geomolg.ps/L5/index.html?viewer=A3.V1.

Figure 14

NDVI for the Year 2001

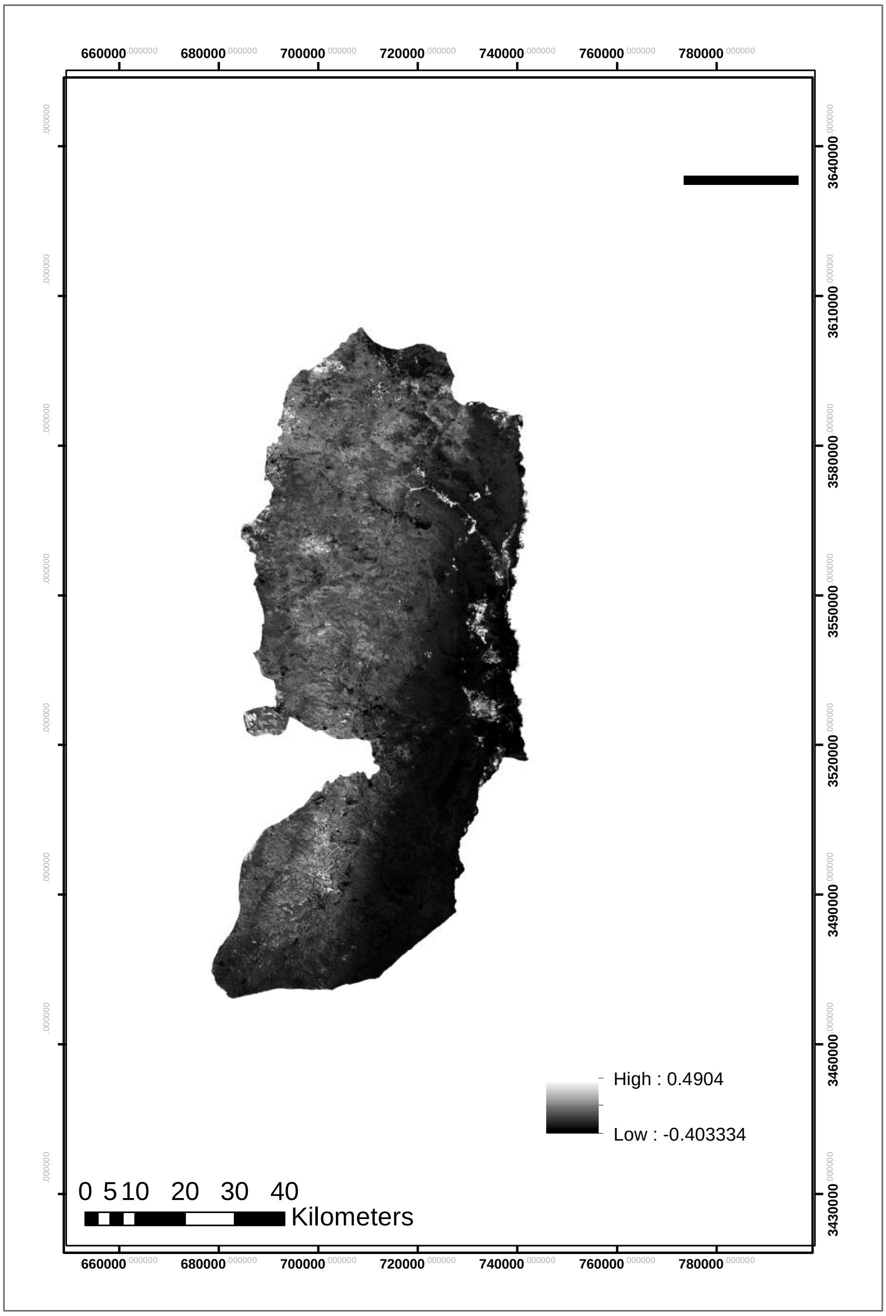


Figure 15

NDVI Classification for the Year 2001

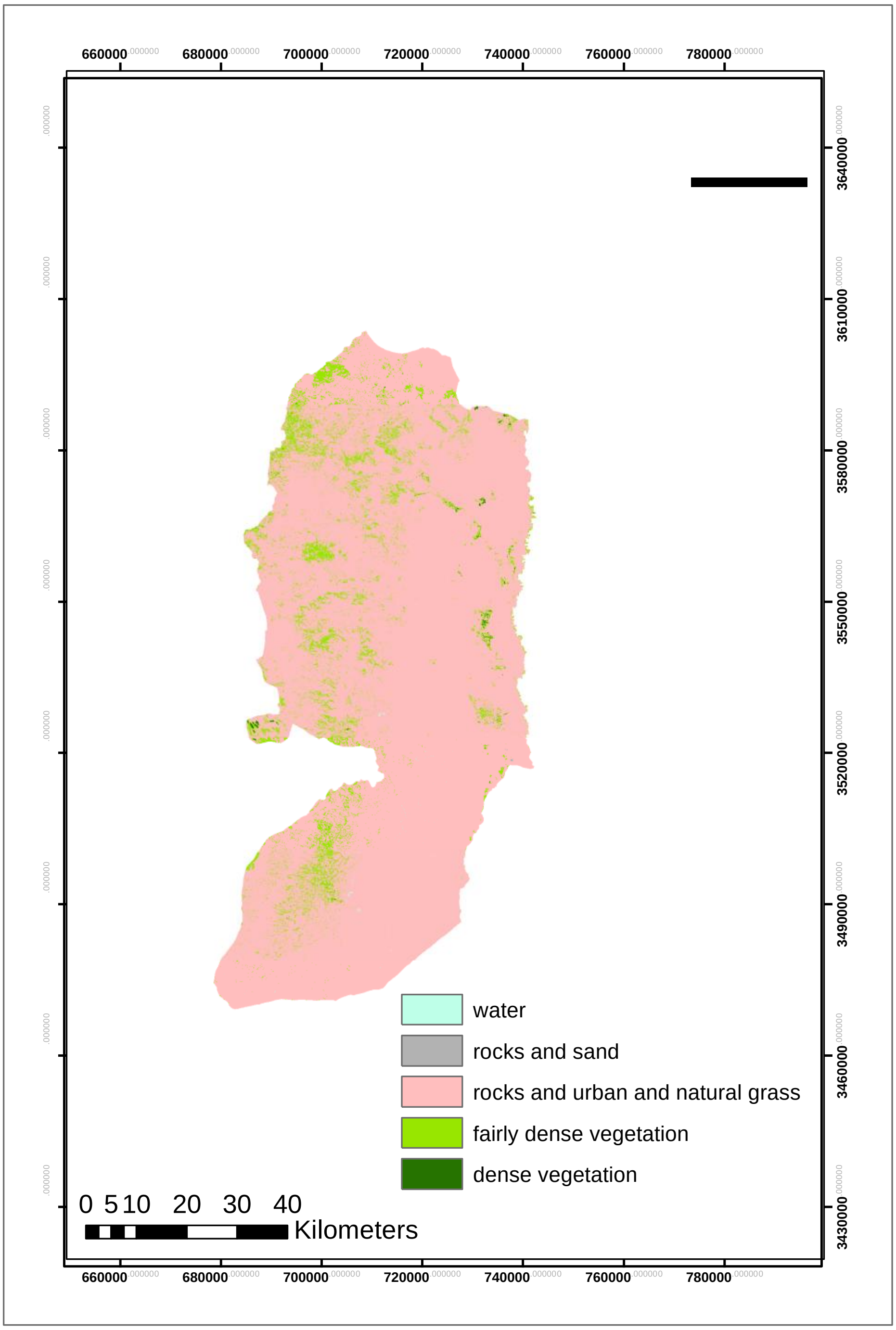


Figure 16

NDVI for the Year 2021

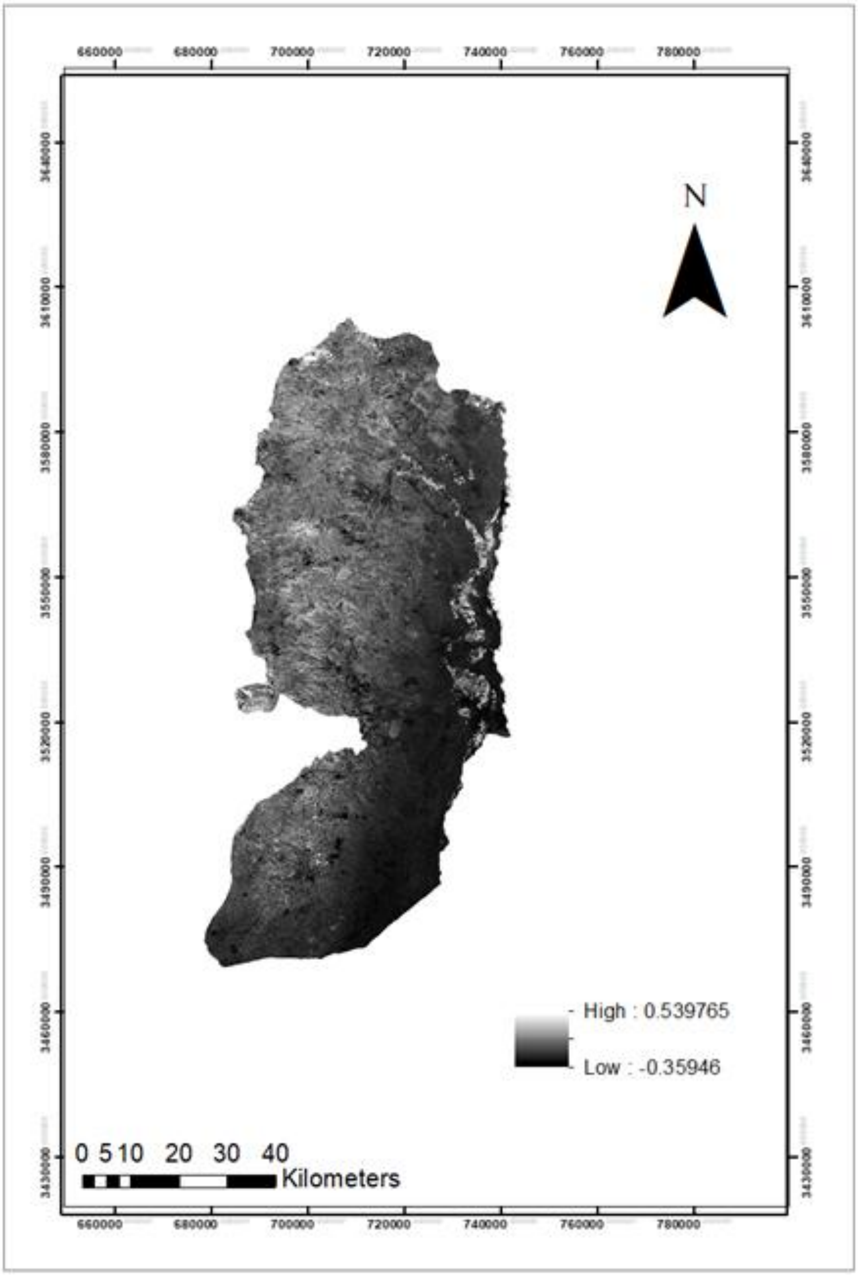
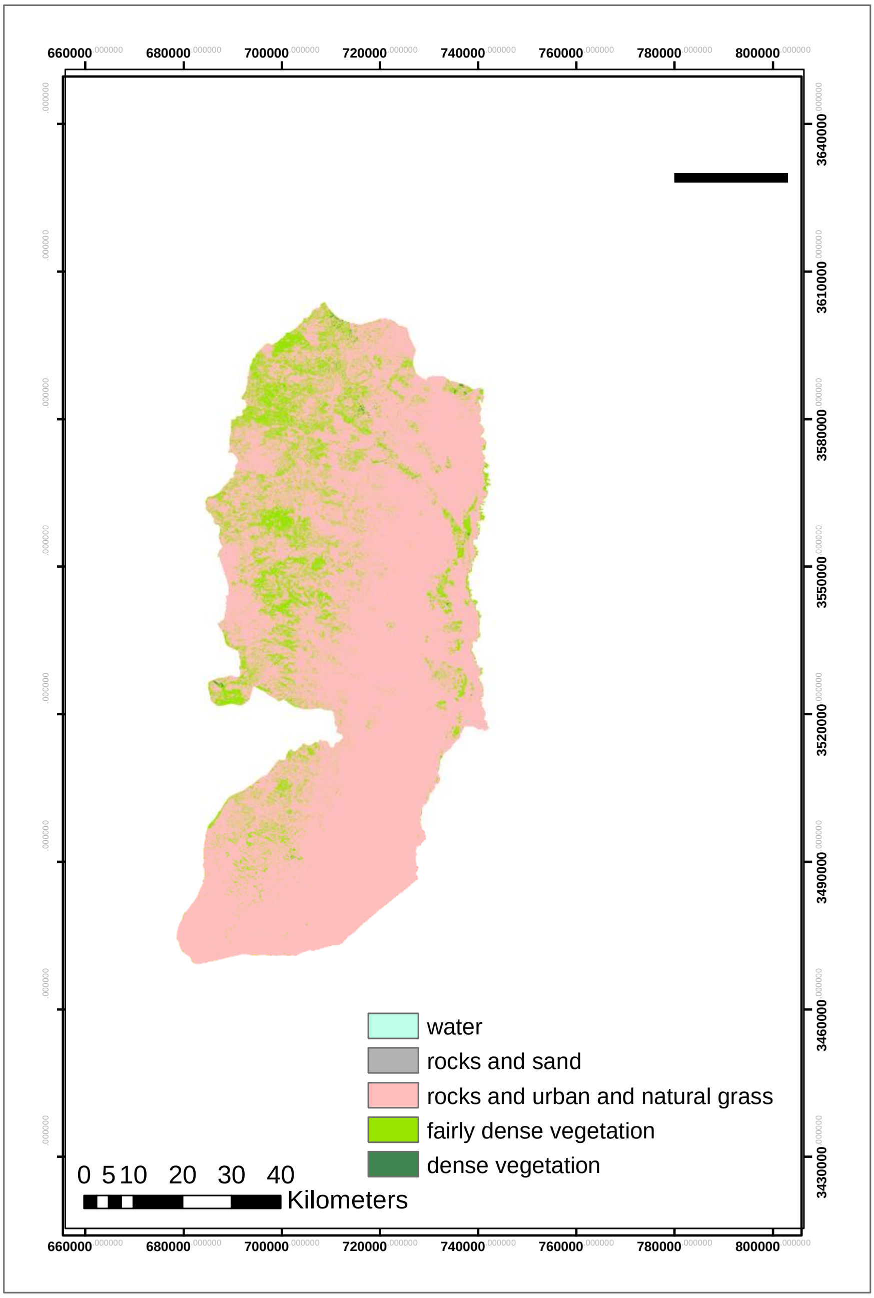


Figure 17

NDVI Classification for the Year 2021



جامعة النجاح الوطنية

كلية الدراسات العليا

مراقبة الغطاء الزراعي والنباتي في الضفة الغربية، فلسطين باستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية

اعداد

مها جميل عبد الكريم مسامح

اشراف

د. احمد رأفت غضية

قُدِّمت هذه الأطروحة استكمالاً لمتطلبات درجة الماجستير في الجيوماتكس من كلية الدراسات العليا بجامعة النجاح الوطنية في نابلس، فلسطين

2025

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الملخص

تُعد دراسة الغطاء الأرضي واستخداماته في الضفة الغربية باستخدام نظم المعلومات الجغرافية والاستشعار عن بُعد أمرًا بالغ الأهمية لرصد التغيرات المكانية مع مرور الوقت، لا سيما في ظل القيود التي يفرضها الاحتلال الإسرائيلي. تستخدم هذه الدراسة صور الأقمار الصناعية لعامي 2001 و2021 لتقييم تغيرات الغطاء الأرضي، مع التركيز على الغطاء النباتي والمناطق الزراعية. وتهدف إلى توفير رؤى قيّمة للوزارات والمتخصصين.

تنقسم منطقة الدراسة إلى ثلاث مناطق رئيسية: المرتفعات الجبلية، وغور الأردن، والسهل الساحلي. وقد تم تحليل صور الأقمار الصناعية من لاندسات 7 (ETM+) ولاندسات 8 (OLI)، المؤرخة في 25 يونيو 2001 و24 يونيو 2021. وتم تحديد أربع عشرة فئة من فئات الغطاء الأرضي لتمثيل منطقة الدراسة، مع دمج التضاريس الصخرية والمحاجر نظرًا لخصائصها الطيفية المتشابهة. حقق التصنيف المُشرف باستخدام طريقة الاحتمالية القصوى (Maximum Likelihood Classifier) دقة عالية بلغت 90.5% لعام 2001 و94% لعام 2021. وبلغت معاملات كابا 83.13% و86.66%، مما يؤكد موثوقية التصنيف القوية.

ولم تُظهر النتائج أي زيادة ملحوظة في الأراضي الزراعية بين عامي 2001 و2021. ومع ذلك، تشير بيانات وزارة الحكم المحلي إلى إمكانية استصلاح بعض الأراضي وزراعتها بناءً على التصنيفات الزراعية. وبلغ متوسط مؤشر الغطاء النباتي الموحد (NDVI) لعام 2021 0.11، وهو مماثل لقيم عام 2001. وتُبرز هذه النتائج أهمية الرصد المستمر للغطاء النباتي واستخداماته في الضفة الغربية للحفاظ على الغطاء النباتي، واستصلاح التربة، وحماية الأراضي الزراعية من التعديات الإسرائيلية.

الكلمات المفتاحية: الضفة الغربية، فلسطين، نظم المعلومات الجغرافية، الاستشعار عن بعد، استخدام الأراضي/الغطاء الأرضي، الغطاء النباتي، NDVI.