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# Geospatial Analysis of Grapes Cultivation within Sensitive Geopolitical Areas: The Case of Al-Khader Village in Bethlehem, Palestine

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ABSTRACT

*Planting grape trees is very familiar in Palestine, particularly in the southern area of the West Bank, as this tree represents the second largest share of horticultural trees in Palestine after olive trees (PCBS, 2022). The total cultivated area of grapes trees in the West Bank and Gaza Strip is estimated to be 29.1 thousand dunums, i.e. 4.3% of the total area of horticultural trees in 2021. Hebron and Bethlehem Governorates south of West Bank represents the highest cultivated area planted with grapes. According to the Palestinian Ministry of Agriculture (MoA), the village of Al- Khader is the most productive area which cultivated with grapes tree in Bethlehem Governorate. This village is one of the most sensitive areas that is surrounded with Israeli colonies and military activities due to its location near Gush Etzion Israeli Settlement Bloc. The question of the real area of grapes cultivation within this village was a debate between the official organizations in Bethlehem Governorate for planning and economic purposes, as there is no scientific reference for this figure since they rely on estimations by questioning the farmers. The Applied Research Institute – Jerusalem (ARIJ) has accepted the implementation of this study to assist local organizations in the census of grapes trees in Al-Khader. After several focus group meetings and a week of fieldwork in a sensitive military area, the team was able to visit the whole targeted agricultural area. All the field data was combined with geospatial data and stored in a geo-database for the purpose of analysis and mapping. A previously developed landuse-landcover analysis for the targeted area shows that the total agricultural land in the village constitutes 12.63 thousand dunums which represents 61% of the total village area. The task analysis of the fieldwork results showed that the total planted land with grapes trees counts nearly 3,500 dunums which represents 27% of the total agricultural land of the village. Furthermore, the analysis showed that the total estimated grapes production of the village is nearly 2,500-3,000 tons from more than 250,000 grapes trees. The results of the study reveal the significance of geospatial technologies in fulfilling real world needs, which can help decision-makers to make evidence-based decisions and policies to develop the agricultural sector. Additionally, such studies can also contribute to the sustainable agricultural development and food security in Palestine and can contribute to the support of the resilience of Palestinian farmers on their lands.*

*Keywords: Geospatial; agricultural census; grapes trees; Palestine; colonization*

## INTRODUCTION

Planting grape trees is very familiar in Palestine, particularly in the southern area of the West Bank, as this tree represents the second largest share of horticultural trees in Palestine after olive trees (PCBS, 2022). The total cultivated area of grapes trees in the West Bank and Gaza Strip is estimated by 29.1 thousand dunums, i.e. 4.3% of the total area of horticultural trees in 2021. Hebron and Bethlehem Governorates south of West Bank represent the highest cultivated area planted with grapes by 43% and 31% of total cultivated grapes area in the West Bank respectively. Both governorates are also the highest producer of grapes in Palestine.

The agricultural census is a very significant mission for the planning and development of the agricultural sector. In Palestine, it takes its important from its connection to the Palestinian land that express the national Palestinian sovereignty. The Palestinian Central Bureau of Statistics – PCBS (2022) in cooperation with Ministry of Agriculture (MoA) have published the results of the agricultural census stating that this project is considered a key pillar for the sustainable agricultural development in Palestine and a significant achievement for the national identity in the face of the arbitrary measures of the Israeli occupation against the Palestinian agricultural sector. One of the main outcomes of this census is estimation of the total area of agricultural land in Palestine (West Bank and Gaza Strip) which counts to 1,096,321 dunums. Focusing on grapes cultivation, 'Table 1' shows the number of grapes tree horticulture along with the total cultivated area in Palestine by governorate.

TABLE 1. Number of Grapes Tree Horticulture in Palestine by Governorate, as on 01/10/2021.
Source: (PCBS, 2022)

| No. | Governorate | No. of Grapes Trees | Area (Dunum) |
|---|---|---|---|
| 1. | Jenin | 149,353 | 2,219 |
| 2. | Tubas | 175,298 | 1,058 |
| 3. | Tulkarm | 7,965 | 94 |
| 4. | Nablus | 108,838 | 1,000 |
| 5. | Qalqiliya | 3,698 | 61 |
| 6. | Salfit | 5,934 | 114 |
| 7. | Ramallah & Bireh | 36,607 | 668 |
| 8. | Jericho | 65,568 | 337 |
| 9. | Jerusalem | 23,786 | 648 |
| 10. | Bethlehem | 407,481 | 8,900 |
| 11. | Hebron | 723,742 | 12,425 |
| 12. | Gaza Strip | 75,088 | 1,594 |
| | Total | 1,783,358 | 29,118 |

The above table shows that the estimated total area of grapes cultivated land in Bethlehem Governorate is 8,900 dunums which is the second highest cultivated area planted with grapes compared to other governorates. The agricultural sector is an important driver in the Palestinian economy since it creates job opportunities in the local Palestinian market. As of 2010, this sector was employing 11.5% of the Palestinian labor force and the value of Palestinian agricultural production was $1,295 million.

Wheat and grapes are the most used elements for food commodities and food processing industry in the West Bank, which is considered one of the major contributors to the Palestinian economy. According to the statistics of 2012, the food processing sector absorbs 11,400 employees (ARIJ 2015). Thus, grape is one of the significant agricultural products for food security in Palestine. The fruit of grapes are used for the production of different types of food including (grape molasses, grape jam, malbann, raisins, and grape vinegar). Table 2 shows the total monthly estimated production of these products according to ARIJ (2015) study:

TABLE 2. Food production commodities from grapes. Source: (ARIJ, 2015)

| No. | Food | Production (ton/month) |
|---|---|---|
| 1. | Grape molasses | 1.95 |
| 2. | Malbann | 0.74 |
| 3. | Grape Jam | 0.28 |
| 4. | Grape Vinegar | 0.04 |
| 5. | Raisins | 0.33 |

Grape cultivation in Bethlehem is mostly famous in Al-Khader village to the west of the city which is considered as part of the culture of this village. However, the question of the real area of grapes cultivation within this village was a debate between the official organizations in Bethlehem Governorate for planning and economic purposes. The MoA estimation is that 2,000 dunums in Al-Khader are cultivated by grapes trees, whereas the Municipality of Al-Khader estimates the grapes cultivated area by 6,000 dunums. The Applied Research Institute – Jerusalem (ARIJ) is a well-known organization that integrates scientific research with modern technologies for agricultural sustainable and development projects. Within its social and community development responsibility, ARIJ has accepted the implementation of a study to assist local organizations in the census of grapes trees in the village.

Al-Khader is a Palestinian village in Bethlehem Governorate, it is located at 4 kilometers to the west of Bethlehem City. The village dates to 1700AD, and it is considered a historical village in the Holy Land that includes an old monastery in the old town and six mosques and many historical sites (Figure 1). Al-Khader is located at an altitude of 839m above sea level with a mean annual rainfall of 684mm. The average annual temperature is 16 C° (ARIJ 2010). According to the Palestinian Central Bureau of Statistics, the total population of Al-Khader in 2024 is estimated by 13,736 (PCBS 2024).


FIGURE 1. Al-Khader village west of Bethlehem.
*Source*: (ARIJ 2010)

ARIJ in cooperation with Al-Khader Municipality and MoA, and after several focus group meetings and interviews, have agreed to work on an agricultural census for grapes cultivation. A full plan of work has been developed and a team has been formed for the purpose of field work observation. The results of the study were very satisfying to all interested parties.

## PROBLEM STATEMENT

The utilization of geospatial technological methods in agricultural census is still limited in Palestine, most censuses have relied on sampling or questioning of farmers. According to the PCBS agricultural census report (PCBS, 2022), for the first time in the agricultural census, they have used computer Tablets including maps and applications for data collection and questionnaires filling. However, no geospatial data about agricultural areas locations were collected. In addition, no precise surveying for the whole agricultural land is available until now, because the ongoing project for land surveying and registration which was started in 2016 is focusing on inhabited areas and achieved around 35% of West Bank area so far (LWSC 2022). In the study area of Al-Khader village, there were discrepancies in the estimations of real cultivated areas with grape trees. Official organizations in Bethlehem governorate were looking for the actual areas and production of grapes in this village for planning and economic purposes. The Ministry of Agriculture (MoA) estimation is that two thousand dunums in Al-Khader is cultivated by grapes trees, whereas the Municipality of Al-Khader estimates the grapes cultivated area by six thousand dunums. Therefore, there is no accurate scientific reference for this figure, since all parties rely on estimations by questioning the farmers. The Applied Research Institute Jerusaem (ARIJ) including its professional units of agriculture and geoinformatics was able to fulfill the needed objectives of this study. The research on geospatial applications in agricultural census has received less attention from researchers in Palestine. So, this study will provide a suitable reference for researchers in this field.

## OBJECTIVES OF THE STUDY

This study aims to provide an empirical reference for the actual grape cultivated areas and the amount of grape production in Al-Khader village. Moreover, the study will highlight the importance of these agricultural products in food security and sustainability. To achieve this aim, the following three objectives will be fulfilled:

1. To analyze the agricultural areas in the study area in order to differentiate the grapes cultivated lands from other cultivated areas.
2. To provide accurate geospatial data about grapes farming through precise measurement of total grapes area and production.
3. To demonstrate the efficacy of geoinformatics techniques in agricultural census.

## SIGNIFICANCE OF THE SYUDY

The research takes its significance in general from the importance of Palestinian agriculture for food security, economic development, and sustainability. Due to the ongoing conflict and consecutive wars in Palestine, focusing on the utilization of new technologies in agricultural research and modern practices is considered an important issue for sustainable development. Very few research has been done in this field in Palestine, as most available geospatial information in Palestinian official organizations doesn't distinguish agricultural areas based on type of cultivation. Moreover, the grapes production is one of the main sources of income for the families of the village, and according to ARIJ (2015) estimations, the profit margin percentage for the farmers is 35.9%.

Therefore, this project was able to integrate different elements of geoinformation (landuse landcover classification, orthophoto interpretation, GPS field data collection, and spatial analysis). The provision of accurate geospatial data was very convincing for local authorities, as they are requesting empirical study that provides reliable information which supports planning and sustainable economic development.

It's worth mentioning that the agricultural sector is an important driver in the Palestinian economy referring to the job opportunities it creates in the local market and the value of the agricultural production. This sector was employing 11.5% of the Palestinian labor force, and the value of Palestinian agricultural production was $1,295 million (ARIJ 2015).

## LITRATURE REVIEW

The grapes cultivation began 6000 - 8000 years ago in the Near East (This, 2006). It has existed in Palestine since the Canaanite era (Broshi, 2001). Grapes are grown all over the whole world. China, France, United America, South Africa, Italy, Chile, Iran, Turkey, Spain and Argentina are top ten countries of grapes production in the world (see Figure 2). The FAO data of 2022 shows that China was the largest producer of grapes, accounting for 16.8% of global production. Italy came second at 11.3%, followed by France at 8.3%. Palestine is ranked at 62 on the world with 36,194 tons (FAO, 2022).

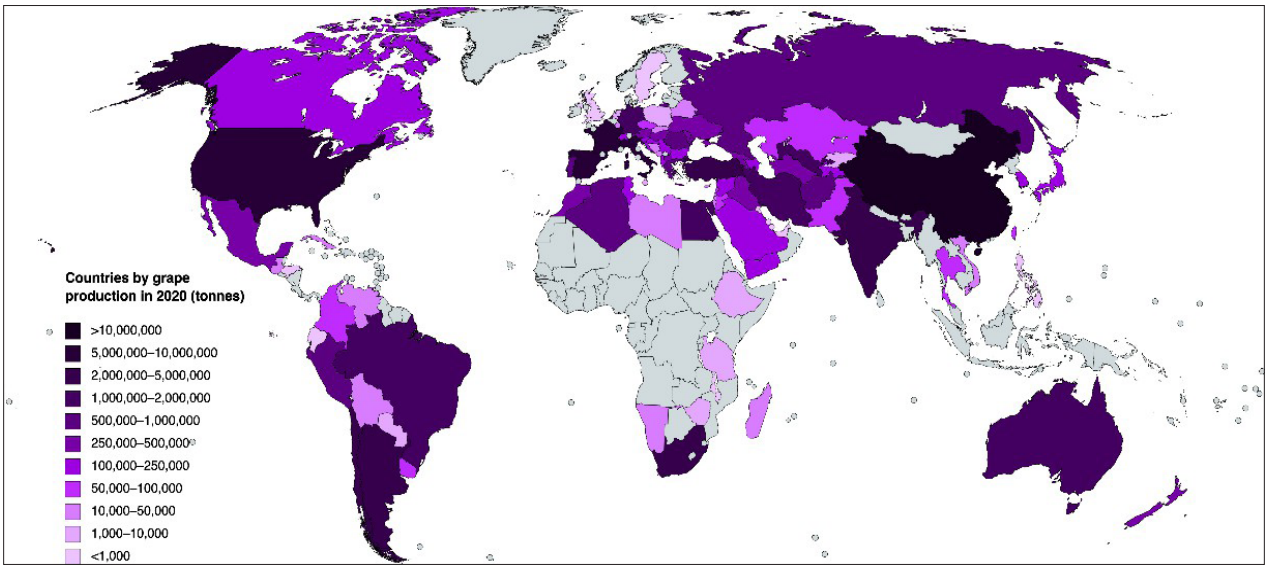



FIGURE 2. World Map of Grape Production.
*Source*: (FAOSTAT 2020).

The FAO estimates that 75,866 square kilometers of the world are dedicated to grapes. Approximately 71% of world grape production is used for wine, 27% as fresh fruit, and 2% as dried fruit (Khan et al. 2020). In Palestine, the researcher hasn't found official statistics about the usage of grapes production, however, and according to the MoA representative in Hebron Governorate, 80% of grape production is used for food, whereas 20% goes to the food manufacturing (Wafa 2022).

Grape production is crucial for food security due to its nutritional benefits, economic impact, contribution to sustainable agriculture, and adaptability to various climates. The Sustainable Development Goals (SDGs) place a strong emphasis on the elimination of food insecurity because it is one of the most urgent issues facing developing countries. Food insecurity is considered a global social problem that presents significant challenges to decision makers and local governments mandated to provide solutions. The four major aspects of food security consist of availability, accessibility, adequate use, and the stability of market supplies (FAO et al. 2019).

The integration of geospatial technologies of GIS and remote sensing has revolutionized the way we approach agricultural planning, census, and land cover analysis. This has enabled researchers, planners and policy makers to gain a comprehensive understanding of agricultural landscapes, crop patterns, and resource utilization (Sangirova et al. 2020) (Reddy et al. 2018).

One of the key benefits of geoinformatics in agricultural census is the ability to accurately map and monitor land use and land cover changes over time. By benefiting from GIS mapping, agricultural authorities can track the cultivable land, identify areas of land degradation, and plan for sustainable land use strategies. This information is crucial for forecasting crop production, managing food stocks, and informing policy decisions related to food security.

Moreover, the integration of remote sensing data and spatial analysis allows for the assessment of crop acreage, yield estimation, and precision agriculture (Reddy et al. 2018). Satellite imagery data collection can provide detailed insights into the state of crops, soil fertility, and irrigation patterns, enabling farmers to optimize their practices and improve productivity. Mathenge et al. (2023) argue that the agricultural sector should adapt to spatial recommendations that fully acknowledge the local diversity of the natural resource that largely determines production potentials under current low input agriculture.

Some geospatial research in the agricultural sector has been done in Palestine. Shadeed et al. (2022) has utilized the GIS in combination with multi-criterion decision analysis (MCDA) approach to develop land suitability maps that can help decision makers and planners in managing land-use for sustainable farming. The study has adopted the analytical hierarchy process (AHP) method that enables using many indicators with weighting for inputs. One of the main outputs of this analysis shows that 47% of the West Bank area is high to very high suitable for olive plantation. Such geospatial studies can help in improving the production of olive in Palestine.

Another agricultural study about olive trees in the West Bank has utilized the GIS to develop an agro-land suitability map for the best optimization in increasing production on the Faria fertile land in the north of West Bank. Different spatial weighted indicators have been used to predict the suitability analysis for the study area including land-use, accessibility, climate, water availability, and groundwater vulnerability. Results indicate that about 49% and 6% of the total area of Faria catchment are moderately and highly suitable for agricultural practices, respectively. The researchers emphasized that the geospatial techniques are very significant for sustainable agriculture in Palestine (Shadeed et al. 2017).

Other studies in Palestine have used remote sensing data to investigate their ability to develop accurate crop area estimation. Ghodieh (2019) has utilized remote sensing capabilities integrated with field survey, maps, and interviewing farmers to develop landuse landcover for north of West Bank. The resulted classification of this analysis had an accuracy of 81%.

As Palestine is a conflict occupied area, the daily Israeli measures and activities are negatively impacting the landcover and the agricultural sector. A study on Tulkarm city to the north of West Bank has examined the effect of political factors on the agricultural sector and found that the construction of the separation wall and the Oslo Accords classification of land into areas A, B and C had a major impact on the uncontrolled urban expansion at the expense of agricultural land, where 80% of the new urban areas within the study period occurred on agricultural land (Nassar et al. 2017). The Palestinian Ministry of Local Government (MolG) and the Municipal Development and Lending Fund (MDLF) in their development plans in cooperation with international donors usually prioritize communities that are subjected to political factors like those located in area C under the Israeli control, communities affected by the separation wall, or communities located near Israeli settlements. They consider such situations as vulnerable communities that need supporting the steadfastness of people living under unsafe circumstances (MDLF, 2022). East Jerusalem as an area with critical political situation is also considered a priority vulnerable area due to the human rights and geo-political conditions (Dhaher, 2017). Al-Khader village is considered a sensitive geo- political community in Bethlehem Governorate due to its location and due to the Israeli occupation measures and control. According to Harini et al. (2017), food and agriculture sectors can play a significant role in increasing the resilience of vulnerable populations to crises and help people recover. Consequently, this research is focusing on the importance of agricultural sector and grapes' cultivation for the resilience of the people of Al-Khader and for the sustainable agricultural development in the village.

It is worth mentioning that to the best of our knowledge, the researcher hasn't found any published

geospatial studies about grapes' cultivation in Al-Khader. Therefore, this study will contribute as a basis for researchers and policy makers for planning and development.

Moreover, the current statistics about grapes cultivation in the West Bank has different figures, as the MoA estimations of 2012 stating that 38,679 dunum of agricultural land has been utilized for the cultivation of grapes, whereas the last agricultural census of 2021 which was conducted by PCBS in cooperation with MoA state that 29,118 dunum has been cultivated with grapes. Therefore, there is a gap in the agricultural statistics of the MoA, which supports the necessity of adopting more scientific methodologies by integration with geospatial technology for conducting agricultural census which provides results with better accuracy.

Another example of census variation is that MoA and PCBS estimated the total area of agricultural land in Palestine with (1,854,000 dunum according to census of 2008, 1,207,061 dunum according to census of 2010, 1,096,321 dunum according to census of 2021) (ARIJ, 2015) and (PCBS, 2022).

However, the LULC GIS analysis conducted by ARIJ in 2010, indicated that the area of agricultural land in the West Bank was 2,150,800 dunum. The justification for this variation from the researcher's perspective is due to the difference in the methodologies between the two parties. ARIJ utilized the GIS- RS system to analyze the agricultural areas which is a comprehensive system that includes the whole agricultural areas as seen from the aerial photos and based on empirical evidence. On the other hand, the MoA-PCBS census methodology was based on "visiting and questioning the households that practiced agricultural activity" based on population census lists (PCBS, 2022). Consequently, there could be a possibility of lack of full data coverage, or it can be related to citizens estimations and accuracy.

## METHODOLOGY

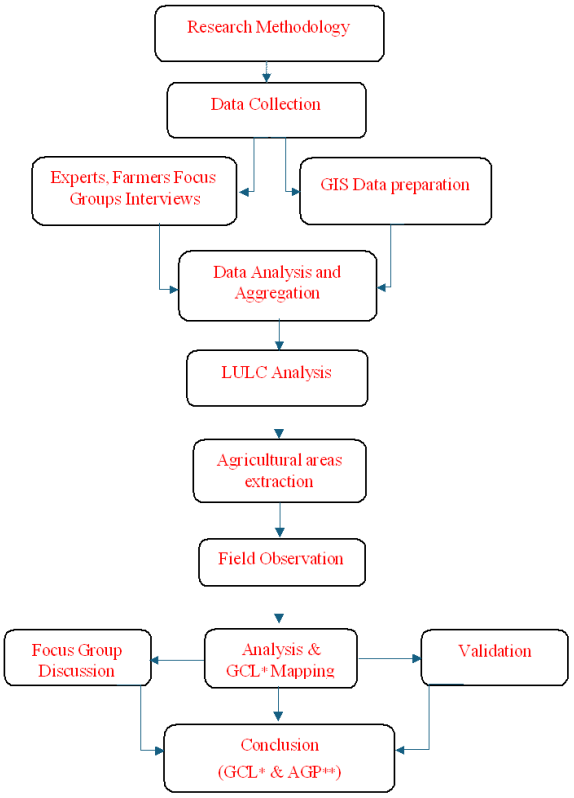
This study adopts mixed methods approach of quantitative and qualitative analysis, as it combines the geospatial analysis of grapes cultivation in the study area with the interviews of agricultural experts and farmers within focus group meetings. Data for this research was collected using orthophotos of 2010, 2016, and 2023 provided by Ministry of Local Government (MoLG) along with landuse landcover GIS analysis provided by ARIJ, in addition to field work observation and verification. Firstly, the study area was identified using primary and secondary data, then three focus group meetings were conducted with three-hours duration for each one to highlight the primary activities, data verification, and results' discussion. Another three interviews with agricultural experts from the study area including (The Deputy Mayor of Al- Khader Council as a farmer and a manager, The Head of Al-Khader Agricultural Cooperative Society, and an NGO's Agricultural Expert). GIS Data also was updated in the current year of 2024 based on the recent aerial photo of 2023. The boundary of the village which counts to 20,773 dunums (20.7 sqkm) was extracted by ARIJ Team from historical British maps of 1944 according to the Atlas of Palestine (Abu-Sitta, 2010).

The land-use landcover (LULC) GIS analysis was done based on the standard of CORINE Land Cover (CLC) classification provided by the European Environment Agency (ETCULS, 2019). The LULC was analyzed through GIS-RS Unit Team at ARIJ organization by direct manual orthophoto interpretation and screen digitizing with 0.5-meter resolution and using ArcGIS 10.2 software including spatial analysis tools. Then, the agricultural areas were extracted to distinguish them in the field based on types of cultivation. Comprehensive field work observation in a sensitive military area was done to cover the whole targeted agricultural land of the study area with the help of Al-Khader municipality team. The goal of the field observation is to extract and verify the grapes cultivated lands from other agricultural lands using colored-printed maps with aerial photos. All the field data was stored in a geo-database for the purpose of analysis and mapping then the final analysis was conducted in the office to achieve the desired objectives.

The study included conducting focus group interviews with agricultural experts and farmers to collect data about grapes cultivation, planting methods, and production estimations.

Researchers consider that classic photo interpretation is expensive, time consuming and subjective (Clementini et al. 2013). However, since the study area is relatively small for a village in Palestine, the classic interpretation supported by field observation will develop high accuracy results. Moreover, the study area includes many diverse cultivated lands which can have the same footprints that cannot be distinguished from satellite images, and the only detection method is field verification.

In conclusion, the choice between manual orthophoto interpretation and automatic land cover classification depends on the specific requirements of the project, including the size of the area to be analyzed, the complexity of the landscape, the availability of skilled personnel, budget constraints, and the desired accuracy and consistency. In many cases, a hybrid approach that combines both methods may provide the best results, leveraging the strengths of each to overcome their respective limitations (see Figure 3).




* GCL: Grapes Cultivated Land ** AGP: Annual Grapes Production

FIGURE 3. Flow chart of the overall technical methodology

Regarding data validation, the output mapping and figures were presented in a workshop in Al-Khader Municipality with the presence of all related stakeholders including Bethlehem Agricultural Directorate, Al-Khader Agricultural Cooperative Society and other agricultural experts. Moreover, the final GCL map was printed in colors with large size and was put on a wall inside the municipality for citizens feedback and participation. Also, for the GIS analysis assessment, a random sample of 200 points was selected to validate the results and classification. Then a confusion matrix was generated to calculate overall accuracy, producer's accuracy, and user's accuracy of classification. The confusion matrix is widely used for accuracy analysis in the field of remote sensing and land cover classification (Kramarczyk et al. 2025). Afterwards, the GIS results were revised by two experts from ARIJ organization. Finally, the total area of grapes cultivated lands measured to be within the average range of the debate between the MoA and Al-Khader Municipality.

## RESULTS AND ANALYSIS

Based on the explained approach, a land-use-landcover (LULC) for the targeted area was developed in cooperation with ARIJ GIS-RS Unit Team. The analysis shows that most of the land of Al-Khader village is agricultural land, where the total agricultural area constitutes 12.63 thousand dunums which represents 61% of the total village area including (heterogeneous, permanent crops, and arable land) as shown in (Table 3). Also, (Figure 4) shows the whole LULC classification mapping for the village which includes in addition to the previously mentioned classes (Palestinian built-up, Israeli settlements, open spaces, Israeli separation wall, forests, industrial commercial areas, and others).

TABLE 3. Agricultural land classification for Al-Khader village

| No. | Agricultural Lands | Area (dunums) | Perc% |
|---|---|---|---|
| 1. | Heterogeneous agricultural areas | 3,720.5 | 29.5% |
| 2. | Grapes Trees | 3,461.7 | 27.4% |
| 3. | Arable Lands | 2,765.7 | 21.9% |
| 4. | Permanent Crops | 2,677.1 | 21.2% |
| 5. | Greenhouses | 4.7 | 0.0% |
| | | 12,629.7 | 60.8% |

Moreover, the task analysis of the fieldwork observation which aimed to distinguish the grapes cultivated land from other cultivations showed that the total cultivated land with grapes trees counts nearly 3,500 dunums which represents 27% of the total agricultural land of the village, and 40% of the grapes cultivated areas in Bethlehem Governorate. 'Figure 5' shows a map of the Grapes Cultivated Land (GCL) which was developed and highlighted with green colors. The accuracy assessment of the results was measured using a confusion matrix for the grapes and non-grapes land on a sample of 200 points (Table 4), which indicated an overall accuracy (OA) of 90.5% using Equation (1). Moreover, grapes cultivated areas achieved a producer's accuracy (PA) of 90.8% using Equation (2), indicating limited omission error, while the user's accuracy (UA) was 93% using Equation (3).

$$OA = \left(\frac{1}{N}\right) \sum_{i=1}^{r} nii \quad (1)$$

$$PA = \left(\frac{nii}{n\,irow}\right) \quad (2)$$

$$UA = \left(\frac{nii}{n\,icol}\right) \quad (3)$$

where ($n_{ii}$) is the number of correctly classified lands, N is the total number of samples, r is the number of rows, and ($n_{icol}$) and ($n_{irow}$) are the column and row total, respectively.

TABLE 4. Confusion matrix accuracy assessment

| Reference \ Map | Grapes | Non-Grapes | Total |
|---|---|---|---|
| Grapes | 109 | 11 | 120 |
| Non-Grapes | 8 | 72 | 80 |
| Total | 117 | 83 | 200 |

Overall accuracy calculates the number of points classified accurately in the study area. Producer's accuracy represents the probability that a reference point class is correctly classified, indicating omission error, while user's accuracy expresses the probability that a point labeled as a given class on the map actually represents that class on the ground, indicating commission error.

The geospatial analysis also shows that 96% percent of agricultural grapes trees are located within Area C which is totally under Israeli military control according to Oslo Accords of 1995. The focus group discussion, including experts and farmers, had a significant participation in the detection of grapes cultivated lands. Furthermore, they agreed on estimating that each one dunum of land in Palestine can be planted with (70-80) trees of grapes, and each one dunum can produce nearly (750-1000) kilograms of grapes depending on the method of planting. Consequently, and according to this approach, the analysis showed that the total estimated Annual Grapes Production (AGP) of the village is nearly 2,500-3,000 tons extracted from more than 250,000 estimated trees of grapes.

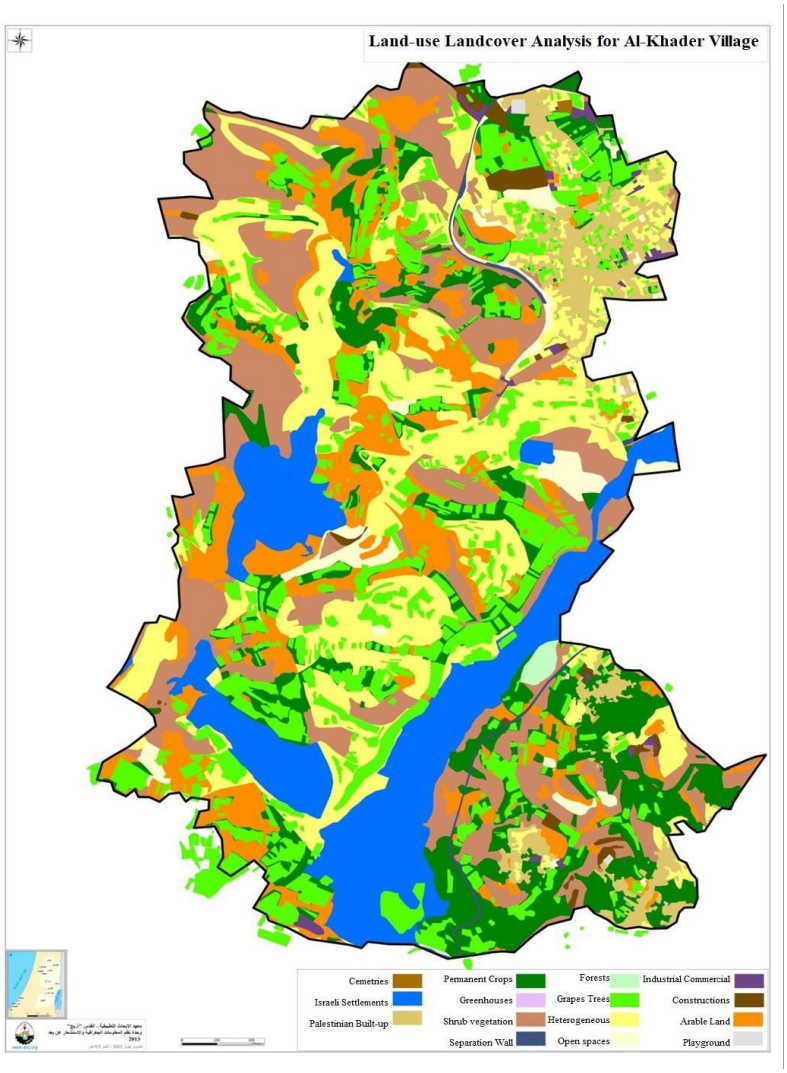



FIGURE 4. Land-use Landcover analysis for Al-Khader

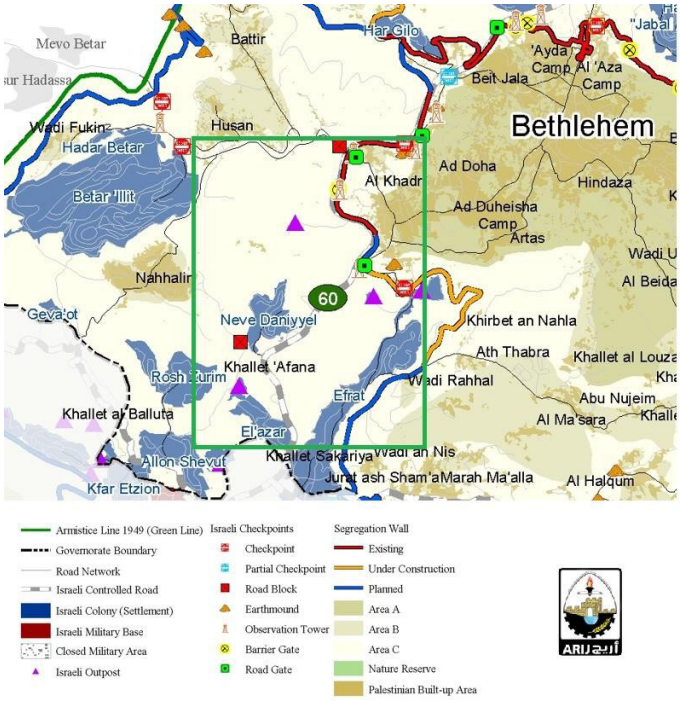



FIGURE 5. Grapes Cultivated Lands (GCL) in Al-Khader village

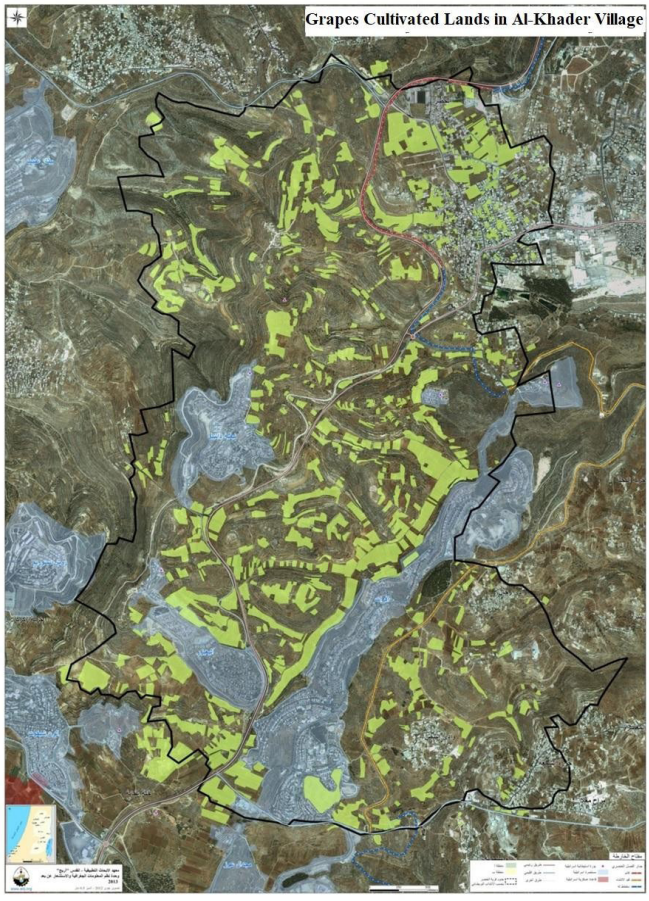



FIGURE 6. Geo-political map of Al-Khader village
*Source*: ARIJ, 2020.

## GEO-POLITICAL SITUATION OF AL-KHADER VILLAGE

The village of Al-Khader is located within a sensitive military area that includes and surrounded by ten Illegal Israeli settlements and outposts within the so called "Etzion Bloc", in addition to a system of Israeli military checkpoints and towers. For the land control in the village, 94% of Al-Khader land is classified as Area C which is considered Israeli controlled area according to Oslo Accords of 1995 and includes most agricultural area. Only 6% of the land is classified as Area A and B in which 90% of the population resides (ARIJ GIS, 2020).

In 2002, the Israeli government decided to start building the separation wall between the Palestinian communities and Israeli settlements, this wall has a destructive impact on all the Palestinian people.

For Al-Khader village, the Israeli wall has separated the urban area from the rest of agricultural area and besieged the village from three directions. According to ARIJ GIS, (2020), the Israeli separation wall which extends on the land of Al-Khader with 4.35 kilometers has isolated around 86% of the land of Al-Khader behind it as shown in (Figure 6).

Moreover, the land of Al-Khader village is also separated by the main Israeli controlled Road (No. 60), which connects the main cities of Jerusalem and Bethlehem with Hebron. As a result, the Israeli presence in the area is fragmenting the geographical unity of the village's land. It is worth mentioning that due to the Israeli control on the majority of the village land, they forbid the residents and farmers from building any construction like stores, cisterns or doing any maintenance for old existing construction within the area.

As a result, all these geo-political constraints have put Al-Khader village within a sensitive situation for the people and the land, which was reflected on the agricultural sector and the whole life in the area.

## URBAN SPRAWL ON THE AGRICULTURAL AREAS

Due to the explained geo-political situation in Al-Khader village, the urban growth is restricted within the area that is under the Palestinian control according to Oslo Accords which counts to 1202 dunums (6% of total village area). This situation has put the agricultural area located within area A and B under the target of Palestinian urban sprawl. The LULC and orthophoto comparison between 2010 and 2023 shows that the urban built-up area has increased by (200 dunums) within this period. Approximately, half of the expansion area was grape cultivated areas which were transformed to urban residential areas (see Figure 7). Most of the new urban areas are high-rise buildings for the purpose of housing and residential use. The current general pattern of the urban development in the village is vertical development due to the Israeli restrictions on building and the shortage of land availability permitted to building which is under Palestinian control.

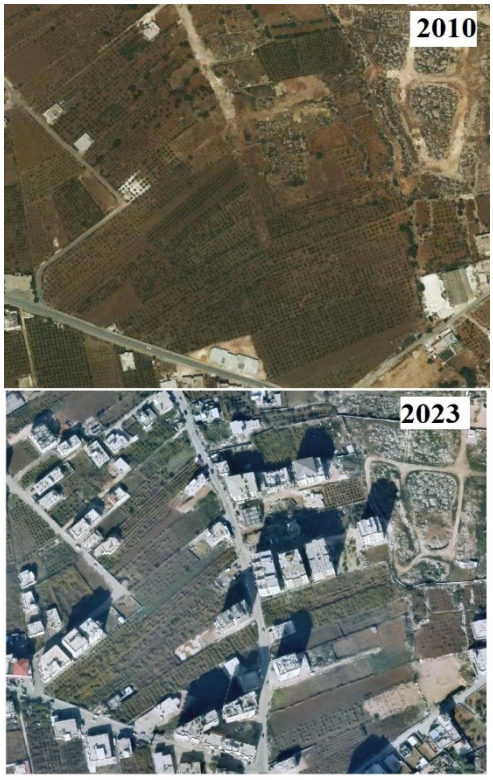



FIGURE 7. Urban Sprawl on grapes cultivated area in Al-Khader between 2010 and 2023. (GeoMoLG 2024).

## IMPACT OF THE OCTOBER 7TH WAR ON AL-KHADER AGRICULTURAL SECTOR

After the Israeli aggressive war on the Palestinian people, which is now focused on the Gaza Strip, very strict Israeli military measures have been imposed on the West Bank, including: daily invasions to Palestinian communities, restriction of movement, daily arresting, houses demolishing, settlers' violence, among many other measures.

For the case of Al-Khader village and focusing on the agricultural sector, the Israeli authorities with the extreme settlers have increased their attacks and punishment measures against Palestinian farmers. This has obstructed the daily work and movement of farmers and their accessibility to their lands, so, they are forced to use animals through dangerous dirty roads and mountains to reach their lands and collect the fruits

Official human rights organizations reported that since October, 7:

> "Israeli settlers have assaulted, tortured, and committed sexual violence against Palestinians, stolen their belongings and livestock, threatened to kill them if they did not leave permanently, and destroyed their homes and schools under the cover of the ongoing hostilities in Gaza" (HRW 2024).

Between 7 October 2023 and 15 July 2024, UN OCHA recorded 1,122 attacks by Israeli settlers against Palestinians in the West Bank, of which 105 led to Palestinian fatalities and injuries, 898 led to damage to Palestinian property, and 119 led to both casualties and property damage (OCHA, 2024)

For the economic activity in the village, the agricultural sector was absorbing 35% of the workforce, whereas 30% of the workforce was employed by the Israeli labor market. However, and after the outbreak of the ongoing war, most of the labors of the Israeli market were forbidden from reaching their work for nine months, and they moved to the local market, particularly the agricultural market. Furthermore, the Government employees' sector, which is estimated by 10% of labor force and suffering from the stopping of salaries has also moved to the farming. Accordingly, and with the current high unemployment rate which may exceed 50% (ILO, 2024), the agricultural sector is becoming the destination for most of the workforce.

However, the GIS spatial analysis on the LULC, and with the help of Al-Khader Agricultural Society, shows that 50% of the agricultural land is not accessible for the current year and since the start of this war due to the military prohibition. This represents the area which is located to the west of Road 60 and adjacent to sensitive settled areas. According to the Head of Al-Khader Agricultural Cooperative Society, the expected loss in grapes production for the current year due to the war circumstance and the Israeli restrictions is estimated to 70% and will not exceed 1,000 tons of grapes. Moreover, the cost of farming including soil tilling cost, fertilizers and medicines, and transportation cost has almost doubled this year (Wattan, 2024). Furthermore, another main challenge for the farmers is that prices are directly impacted by the competition from Israeli market products, which also reduces market returns and causes Palestinian local production to become overstocked. This competition lowers sales for regional agricultural output and has an impact on Palestinian farmers' profitability. So, all of these challenges will be negatively reflected on food security and the economic situation of the farmers and residents of the village.

## CONCLUSION

This research has discussed an important subject related to food security and sustainability in Bethlehem Governorate in Palestine. It focused on grapes' cultivation in a sensitive geo-political area of Al-Khader village west of Bethlehem, and the significance of the utilization of geospatial techniques in the census of agricultural land, and the estimation of grapes fruit production in the study area. The research has highlighted the significance of agricultural sector as a driver for the Palestinian economy since it was employing 11.5% of the Palestinian labor force, and the value of Palestinian agricultural production was $1,295 million. Focusing on grapes production, the research has discussed the food production commodities from grapes which are crucial for food security due to its nutritional benefits and economic impact.

The research idea has emerged to fill the gap of the absence of accurate empirical evidence for the statistics about grapes cultivated land in the study area. Therefore, the researcher has adopted a mixed approach that combine geospatial analysis of grapes cultivation with focus group interviews of agricultural experts and farmers, to collect data about grapes cultivation, planting methods, and production estimations.

The LULC analysis shows that most of the land of Al-Khader village is agricultural land, where the total agricultural area constitutes 12.63 thousand dunums which represents 61% of the total village area. The geospatial analysis of this research showed that the total Grapes Cultivated Land (GCL) counts nearly 3,500 dunums which represents 27% of the total agricultural land of the village, and 40% of the grapes cultivated areas in Bethlehem Governorate with an overall accuracy of 90.5%. Also, the results showed that 96% of agricultural grapes trees are located within Area C which is totally under Israeli military control according. For the total estimated production of grapes and according to the approach that was explained in the methodology, the analysis showed that the total estimated Annual Grapes Production (AGP) of the village is nearly 2,500-3,000 tons from more than 250,000 estimated trees of grapes.

Furthermore, the research has examined the urban sprawl on the agricultural area between 2010 and 2023 which shows that the urban built-up area has increased by 200 dunums within this period, where nearly half of this urbanization was on grapes cultivated land. Moreover, the research has shown that the current general pattern of the urban development in the village is vertical development due to the Israeli restrictions on building and the shortage of land availability permitted to building.

The research has also discussed the geo-political constraints on Al-Khader village, which have put it within a sensitive situation that was reflected on the agricultural sector and the whole life of the people. Part of this critical situation is the escalation of Israeli settlers' attack on Palestinian farmers after the ongoing war on Gaza Strip since of October 2023, in addition to the daily movement restrictions of farmers and their accessibility to their lands which have led to the prohibition of farmers to access around 50% of their agricultural land. Since the agricultural sector in Al-Khader was absorbing 35% of the workforce in the village, in addition to a large part of the 30% of the workforce which was employed by the Israeli labor market before the war, the current economy in the village is currently suffering. The agricultural experts estimate the loss in grapes production for the current year due to the war circumstance and the Israeli restrictions to 70% and will not exceed 1,000 tons of grapes.

The results of this research reveal the significance of geospatial technologies in fulfilling real world needs, which can help decision-makers to make evidence-based decisions and policies to develop the agricultural sector. Additionally, such studies can also contribute to the sustainable agricultural development and food security in Palestine and can contribute to the support of the resilience of Palestinian farmers on their lands.

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## DECLARATION OF COMPETING INTEREST

None.

## REFERENCES

Abu-Sitta, S. 2010. *Atlas of Palestine 1917-1966*. London: Palestine Land Society. https://www.plands.org/en/maps-atlases/atlases/the-atlas-of-palestine/pdfs/atlas-part-1.pdf

Applied Research Institute Jerusalem-ARIJ. 2010. *Al Khader Town Profile*. http://vprofile.arij.org/bethlehem/pdfs/VP/Al%20Khader_tp_en.pdf

Applied Research Institute Jerusalem-ARIJ. 2015. *Palestinian Agricultural Production and Marketing between Reality and Challenges*. https://www.arij.org/publications/food-market-assessments/booklets-leaflets-food-market-assessments/palestinian-agricultural-production-and-marketing-between-reality-and-challenges/

Basu, A. & Rhone, M. 2018. Dietary flavonoids and health benefits: Evidence from epidemiological studies. *International Journal of Environmental Research and Public Health* 15(10): 2192.

Broshi, M. 2001. *Bread, Wine, Walls and Scrolls*. London & New York: Continuum International Publishing Group.

Clementini, E. & Ippoliti, E. 2013. Automatic extraction of complex objects from land cover maps. https://doi.org/10.1007/978-3-319-00615-4_5

Dhaher, S. 2017. *The Impact of the Current Situation on the Human Rights of the Vulnerable Palestinian Groups in East Jerusalem*. Al-Quds University. Published by the Heinrich-Böll-Stiftung Palestine & Jordan Office. https://dspace.alquds.edu/items/dd25d385-b050-4055-8aa5-b19beb61bdb4

European Topic Centre on Urban, Land and Soil Systems (ETC/ULS). 2019. *Updated CLC Illustrated Nomenclature Guidelines*. Austria: European Environment Agency. https://land.copernicus.eu/content/corine-land-cover-nomenclature-guidelines/docs/pdf/CLC2018_Nomenclature_illustrated_guide_20190510.pdf

FAO. 2022. *FAOSTAT Value of Agricultural Production*. https://www.fao.org/faostat/en/#data

FAO, IFAD, UNICEF, WFP & WHO. 2019. *The State of Food Security and Nutrition in the World 2019: Safeguarding Against Economic Slowdowns and Downturns*. Rome: FAO.

Fraga, H., Malheiro, A. C., Moutinho-Pereira, J. & Santos, J. A. 2014. Climate factors driving wine production in the Portuguese Minho Region. *Agricultural and Forest Meteorology* 185: 26–36. https://doi.org/10.1016/j.agrformet.2013.11.003

Ghodieh, A. 2019. Crop area estimation for the Northern West Bank, Palestine using satellite remote sensing. *Journal of Human Sciences* 2019(2): 34. https://journal.uob.edu.bh/handle/123456789/4246

Harini, R. & Susilo, B. 2017. Food security assessment: A GIS-based mapping of food sufficiency in Kalimantan Utara, Indonesia. Dlm. *International Conference on Studies in Disaster Management, Civil and Architectural Engineering (SDMCAE-17)*, hlm. 18–19. https://www.dirpub.org/images/proceedings_pdf/DIR0417429.pdf

Human Rights Watch (HRW). 2024. *Israel Responsible for Rising Settler Violence*. https://www.hrw.org/news/2024/04/17/west-bank-israel-responsible-rising-settler-violence

International Labour Organization (ILO). 2024. *Palestinian Unemployment Rate Set to Soar to 57 Per Cent During First Quarter of 2024*. https://www.ilo.org/resource/news/palestinian-unemployment-rate-set-soar-57-cent-during-first-quarter-2024

Khan, N., Fahad, S., Naushad, M. & Faisal, S. 2020. *Grape Production Critical Review in the World*. https://doi.org/10.2139/ssrn.3595842

Kramarczyk, P. & Hejmanowska, B. 2025. AccuClass: A comprehensive tool for accuracy metrics evaluation in machine learning and remote sensing classification. *SoftwareX* 31: 102332. https://doi.org/10.1016/j.softx.2025.102332

Land and Water Settlement Commission. 2022. *The Progress of Land Settlement in the West Bank Governorates*. https://lwsc.ps/index.php

Mathenge, M., Sonneveld, B. G. J. S. & Broerse, J. E. W. 2023. Mapping the spatial dimension of food insecurity using GIS-based indicators: A case of Western Kenya. *Food Security* 15: 243–260. https://doi.org/10.1007/s12571-022-01308-6

Municipal Development and Lending Fund (MDLF). 2022. *Area C Development Program in the West Bank*. https://www.mdlf.org.ps/Document/Area%20c%20brochure.pdf

Nassar, M., Levy, R., Keough, N. & Nassar, N. N. 2017. Agricultural land use change and its drivers in the Palestinian landscape under political instability: The case of Tulkarm City. *Journal of Borderlands Studies* 34(3): 377–394. https://doi.org/10.1080/08865655.2017.1344561

Palestinian Central Bureau of Statistics (PCBS). 2022. *Press Release on the Preliminary Results of Agriculture Census, 2021*. https://www.pcbs.gov.ps/portals/_pcbs/PressRelease/Press_En_AgriCensus2021E.pdf

Palestinian Central Bureau of Statistics (PCBS). 2024. *Projected Mid-Year Population for Bethlehem Governorate by Locality 2017–2026*. https://www.pcbs.gov.ps/statisticsIndicatorsTables.aspx?lang=en&table_id=704

Reddy, G., Ramamurthy, O. & Singh, S. 2018. Integrated remote sensing, GIS, and GPS applications in agricultural land use planning. Dlm. *Geotechnologies and the Environment*. https://doi.org/10.1007/978-3-319-78711-4_24

Sangirova, U., Yunusov, I., Ahmedov, U., Namozov, J., Dustmurodov, G. & Khakimov, R. 2020. Features of GIS application in agriculture and logistics. *IOP Conference Series: Materials Science and Engineering* 918: 012140. https://iopscience.iop.org/article/10.1088/1757-899X/918/1/012140/meta

Shadeed, S., Abboushi, A. & Almasri, M. 2017. Developing a GIS-based agro-land suitability map for the Faria agricultural catchment, Palestine. *International Journal of Global Environmental Issues* 16(1–3): 190–204. https://doi.org/10.1504/IJGENVI.2017.083423

Shadeed, S., Alawna, S., Riksen, M. & Fleskens, L. 2022. Land suitability mapping for rainfed olive tree plantation in the West Bank, Palestine. *Desalination and Water Treatment* 268: 194–204. https://doi.org/10.5004/dwt.2022.28716

This, P., Lacombe, T. & Thomas, M. R. 2006. Historical origins and genetic diversity of wine grapes. *Trends in Genetics* 22: 511–519. https://doi.org/10.1016/j.tig.2006.07.008

United Nations Office for the Coordination of Humanitarian Affairs (OCHA). 2024. *Humanitarian Situation Update #192, West Bank*. https://www.ochaopt.org/content/humanitarian-situation-update-192-west-bank

Wafa News Agency. 2022. *Grapes Season in Hebron*. In Arabic language. https://www.wafa.ps/pages/details/55228

Wattan News Agency. 2024. *Suffering of Al-Khader Farmers During Grape Season*. https://www.wattan.net/ar/tv/438589.html